LIFE15 ENV/GR/000338

Final Report

Covering the project activities from 01/07/2016 to 31/12/2019

Reporting Date

31/03/2020

LIFE PROJECT NAME or Acronym

LIFEPOSITIVEMgOFGD

Data Project

Project location:	Kentriki Makedonia (Ellas)
Project start date:	01/07/2016
Project end date:	31/12/2019 **Extension date:**
Total budget:	€ 2.333.817,00
EU contribution:	€ 1.129.690,00
(%) of eligible costs:	60

Data Beneficiary

Name Beneficiary:	ELLINIKI LEFKOLITHI ANONYMOS METALLEFTIKI VIOMIHANIKI NAFTILIAKI KAI EMPORIKI ETERIA (Grecian Magnesite Mining Industrial Shipping and Commercial Company Societe Anonyme)
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1 Table of contents

2 List of keywords and abbreviations

APM	Administrative Project Manager
BAT	Best Available Technique
BREF	Best Reference
Capex	Capital expenditure
CCM	Caustic-Calcined Magnesia
CLM	Cement-Lime-Magnesia
DBM	Dead-Burned Magnesia
DCM	Dissemination and Communication Manager
DG ENV/C.4	Environment Directorate-General
EASME	Executive Agency for SMEs
EIP	European Innovation Partnership
EIPPCB	European Integration Pollution Prevention Control Bureau
ELV	Emission Limit Value
ESP	Electrostatic Precipitator
EU	European Union
EUROMINES	European Association of Mining Industries, Metal Ores & Industrial Minerals
FGD	Flue Gas Desulfurization
GA	Grant Agreement
GCT	Gas conditioning tower
GM	Grecian Magnesite
GMEA	Greek Mining Enterprise Association
HFO	Heavy Fuel Oil
IED	Industrial Emissions Directive
KoM	Kick off meeting
M	Month
Max/min	maximum/minimum
NEEMO	Monitoring life projects and communicating about the Life Programme
pc / pcs	piece / pieces
pH	(chemistry) a measure of acidity/alkalinity of a solution
PMC	Project Management Committee
PTM	Project Technical Manager
r	velocity ratio
RK3	Rotary Kiln No. 3
SEV	Hellenic Federation of Enterprises
T or Temp	Temperature
TWG	Technical Working Group

Units:

%	percentage, mass
Am^3/h	actual cubic meters per hour, also as [m^3/h]
bar	pressure in Bar
g/m^3	grams per cubic meter
Kg/h	kilograms per hour
Kg/m^3	kilograms per cubic meter

Km^2	square kilometres
KW	kilowatt
KWh/kg	Kilowatt-hours per kilogram
l/h	litres per hour
m	meters
m/s	meters per second
m^2	square meters
m^3	actual cubic meters
m^3/year	cubic meters per year
mg/Nm^3	mg per Normal cubic meters
min	minutes
mm	millimetres
Nm^3	Normal cubic meters (cubic meters expressed in standard conditions)
Nm^3/h	Normal cubic meters (cubic meters expressed in standard conditions) per hour
^oC	degrees Celsius
Pa	Pascal
ppm	parts per million
rpm	rotations per minute
tpa	tonnes per annum (year)

Molecular formulas:

$CaCO_3$	calcium carbonate
$Ca(OH)_2$	calcium hydroxide or hydrated lime
CO	carbon monoxide
CO_2	carbon dioxide
H_2O	water
HCl	hydrogen chloride
HF	hydrogen fluoride
H_2S	hydrogen sulfide
MgO	magnesium oxide
$MgSO_3$	magnesium sulfite
$MgSO_4$	magnesium sulfate
O_2	oxygen
NOx	nitrogen oxides
NO	nitrogen monoxide
NO_2	nitrogen dioxide
NOx	nitrogen oxides
S	sulfur
SO_2	sulfur dioxide
SO_3	sulfur trioxide
SOx	sulfur oxides

Other:

B TANMA	a GM DBM grade
TANMA	a GM DBM grade
SM88	a GM DBM grade
VM80	a GM CCM grade

Symbols:

′′	inches
Ø	diameter

3 Executive summary (maximum 2 pages)

The **main objective** of this project is to **demonstrate that a new dry desulfurization technology based on Magnesium Oxide (MgO) reagents is a positive Net Environmental Impact** solution for magnesium oxide industries, especially in those areas **with limited water availability** where wet technologies cannot be applied.

The **specific objectives** of LIFEPOSITIVEMgOFGD are the following:

- To test and demonstrate that a **SOx emission reduction of at least 60%** based on sulphur balance and an **ELV of 1.500 mg/Nm3** is achievable.
- To use an MgO sorbent of which at least 75% will be consisting of processed old mining waste of Grecian Magnesite, instead of sodium or calcium-based sorbents (hazardous substances)
- To upgrade at least **90% of the generated waste**. This by-product will be characterized and evaluated to be used in fertilizer and construction applications
- To consume **at least 40% less energy consumption** than wet desulfurization technologies
- To consume **at least 80% less water** than wet desulfurization technologies.
- To intervene to include the description of the technology and its results in the CLM BREF during its next revision through the CLM Technical Working Group set up by the European IPPC Bureau (EIPPCB).
- To replicate the results to the Magnesia sector and transfer them to other relevant **European energy-intensive industries**.
- To demonstrate the economic feasibility and analyze the advantages and **environmental and socio-economic benefits** of the new technology.

All the **Deliverables** of the project have been submitted **(40 Deliverables) and 18 Milestones** have been overcome**.**

Regarding the Project Progress and achievements, a **significant progress** of the project **implementation** during the first part of the project (July 2016-September 2017) was achieved. Work was focused on **the pilot plant final design** with external support as planned. Another important milestone is that the **installation permit was** officially issued. The Environmental Permit had been previously issued by the relevant Authorities. A **significant** progress was made on the project implementation during its second part (October 2017-April 2019). Furthermore, a strong effort was carried in the development of the **replication and transferability strategy** to achieve a major impact of the project. **Environmental and economic feasibility** of the new technology was analysed, and the Final Workshop was successfully organised.

First, bidding procedures were followed for basic and detailed pilot plant design, monitoring equipment and CFD study. The tasks were awarded to the most suitable contenders and were carried out with the support of Grecian Magnesite's engineering team. After that, an **open tender** procedure for the procurement of the **pilot plant equipment** was **launched and completed.**

The installation of the **first full scale pilot of a new dry desulfurization technology** designed to use magnesium oxide was completed at the **end of February 2018**, started to operate from mid-March 2018 and will continue operating until **after the project's duration**. Therefore, milestone B.2.1 Initial operation of prototype (Month 21) has been successfully completed within schedule.

However, it should be noted that strong efforts were made to deal with several technical problems, linked directly with Action B2.2 **Validation and determination of operating conditions** (as explained in detail in Section 6.1). All technical problems were solved, and the pilot plant operates in a stable fashion treating the flue gases generated in a magnesite calcination rotatory kiln.

Finally, a strong effort has been carried out to solve the arising problem of the **low performance of conventional MgO** (compared to $Ca(OH)_2$ and Na_2CO_3), which makes the achievement of the ELV (1.500 mg SO_2/Nm^3) possible only when the initial SO_2 concentration does not exceed 3.000 mg/Nm^3, by suitable kiln fuel mix manipulation.

As a proof of concept, several trials were made with a natural, very high specific surface area MgO, not available in GM's portfolio or the in the European market. Trial results indicated that with such a grade, emissions of 1.200 mg/Nm^3 and 70% abatement are possible. **Thus, from purely technical point of view, MgO can be an effective sorbent provided it has suitable properties (i.e. very high specific surface area, e.g. 130 m^2/g).** Such a grade has significantly lower specific consumption (kg MgO/kg SO_2 removed) compared to conventional MgO but still higher than the consumption of market benchmark sorbents such as high-performance calcium hydroxide. **During the end of the project, efforts were made to produce such a grade onsite in GM, but they failed.**

Concerning by-product valorization, characterization and evaluation of the generated by-product was carried out to be used as an eco-cement component for construction applications and as fertilizer. Valorisation tests have been conducted for Sorel cement bonded panels which positive results. Various by-product samples have been collected and are being characterized. In order to test the by-product, contact with a major European panel producer was established. On the other hand the fertilizer application study showed that the by-product cannot be used a fertilizer, but could possibly be suitable as a raw material for fertiliser production, an avenue to be exploited in the After-LIFE period.

In conclusion, considering the different alternatives, and after a comprehensive techno-economic study was conducted, the **most sustainable solution, technically and economically**, for pilot plant operation has been defined as a **combined use of a conventional MgO sorbent (CCM) and an appropriate fuel mix which provides lower SO_2 emissions at the rotary kiln level at sensible costs**. In this case, (which is also the after-LIFE scenario) plant input SOx concentration is ≈ 3.000 mg/Nm^3 and the emissions lower than the ELV of 1.500 mg/Nm^3 using a high MgO/SO_2 ratio (>20) and an abatement of 51%. Sustainability relies heavily on several assumptions, the most important of which is the degree of commercial exploitation/valorization of the by-product. The current rate is 15% while the After-LIFE target is 90%. In all scenarios, this does not generate net profits but can minimize operating costs at sustainable levels (Find more information in Section 6.1 and Deliverable B3.4 Environmental and Techno-economic analysis). Sustainability, as defined in the techno-economic study, is reached at around 70% valorisation. Until then, GM is willing to cover the associated extra costs by its own funds.

Main project achievements

1. Design and Construction of the pilot plant

The construction of the main plant was conducted by Scheuch GmbH Austria (who won the open bid procedure) and subcontractors for secondary constructions, overseen by GM. The scale of the pilot plant is impressive, since it is designed to be fed with all the flue gases coming from one of GM Magnesite's kilns in the calcination department of the plant in Yerakini.

2. Production of MgO Sorbent

The sorbent required for the pilot plant is produced on-site. The raw material for its production comes from exploiting old mine stockpiles and not from the mine deposit itself, in this way having savings in depleting natural resources. **80% of the MgO sorbent** used comes from the utilization of old mining waste. More than **20.000 tonnes per year waste** are utilized.

3. Optimisation and Validation
The pilot plant is fully automated, monitored and operated centrally from a control room and treats **84.000 m³** (actual) of flue gases every hour. SOx emissions are reduced by 51%, achieving a value of **less than 1.500 mg** of equivalent SO_2 per normal m^3, which is the current BAT Emission Limit Value. The pilot plant consumes **96 % less water** and **24% less energy** than an equivalent FGD plant based on wet desulfurization technology as compared to 80% and 40% originally assumed at the proposal stage.

4. ***By-product and its valorization***
The pilot plant's by-product is a fine powder and mixture of magnesium oxide (which did not react with the flue gases) and the desulfurization by-products, mainly sulphite and sulphate salts. These characteristics make the by-product suitable as raw material for magnesium cements in construction products and possibly as raw material for fertilizer production. At the current rate, more than **12.000 tonnes of by-product** are generated by the pilot plant yearly. At the project's end, **15%** of the freshly generated by-product is being valorized. In the After-LIFE period, the target rate is **90%**. By-product valorisation will be carried out according to a specific plan which includes in-house valorisation, and identified end-users.

5. BAT candidate
Main result of the project is a **new dry FGD technology** which uses a reagent based on the processing of old mining waste and which generates a residue with high added value. In the After-LIFE period of the project GM will work to have the technology included in the next update of the CLM BREF (Deliverable B.3.8 Reference Document for the use of MgO as desulfurization agent- BAT candidate), in order to be replicated among other industries with similar environmental problems exhibiting similar benefits as those outlined above.

6. ***Replicability and transferability***
LIFEPOSITIVEMgOFGD technology has high operating costs, and it is sustainable under very specific conditions, which restrict its R&T potential. Concerning Replicability, **another MgO producer have expressed interest in the technology** but would only be willing to replicate it if a solution is found to increase performance and reduced sorbent consumption. **GM will focus on in-site replication to another rotary kiln**. For the same reason, as well as due to the low ELVs applied in other sectors, no transferability is possible either.

Regarding **dissemination activities**, project's web page was completed (www.betterlife-withmgo.eu) and **updated regularly**. Furthermore, the communication plan has been implemented and the notice boards have been carried out. GM has participated in the Air+Health Brussels KoM, in two Environmental science and technology conferences (one national and one international) and in three Greek LIFE Task Force workshops. DG ENV/C.4 and EIPPCB have been informed about the project. Preliminary meetings with several stakeholders have been held. The organization of the 2 important Workshops should be highlighted: (1) Breakfast for the Air Quality" Workshop and (2) Workshop "Green Satellite Event" with a highly successful turnout of more than 100 participants in total. Moreover, the close cooperation with LIFE Greek Task Force has been reinforced. **Final Event** of the project took place successfully with more than **50 participants**. This was conducted on December 17th, 2019 at the Centre for Research and Technology (CERTH) in Thessaloniki to present the final results, mainly attended by students, researchers and academia. This was followed by an organized pilot plant visit, which included a detailed tour of the installation, the control room and the rotary kiln. The first, second, third (including the presence of the Project´s Officer) and fourth NEEMO visits were also carried out. See final promotional Project video: https://www.youtube.com/watch?v=PX0G-0jCEZQ&t=20s

Some deviations and problems occurred within the project's duration but were relatively minor and were followed by appropriate corrective actions.

4 Introduction (maximum 2 pages)

Description of background, problems and objectives

Environmental problem/issue addressed

SO_2/SO_3 emissions are closely related to the burning of solid or liquid fuels for heating, transport and industrial purposes, especially those fuels that have high concentrations of S (coal, coke, heavy fuel oil). While natural gas in the EU has gained widespread application, a large part of the industrial sector still uses high S fuels for cost and availability reasons, especially those activities where fuel consumption constitutes a significant part of the production costs (e.g., lime, cement and magnesia industries). The emissions related to the MgO industry are mainly dust, NOx, SO_2, CO, and CO_2.

The main technique referenced for **SOx emissions abatement is Flue Gas Desulfurization** (FGD). FGD techniques adapted to the needs of the European industry which are in alignment with European environmental policies and legislation are very important for Europe's added value and future development.

The **magnesia sector is a recent inclusion to the Cement and Lime (CL) BREF**, and magnesia production has been identified as a polluting industry regulated by the IED and the CLM BREF concerning pollution control. Sulfur oxides are generated during the magnesia production, i.e. during the calcination and sintering process of Magnesite, mainly from the fuel combustion to generate the high required amount of thermal energy. However, the performance and optimization of the SO_2 abatement techniques given as references in the CLM BREF have not yet proved their applicability to the magnesia sector.

Outline the hypothesis to be demonstrated / verified by the project

Industry can reduce its sulfur oxide emissions, by one or by a combination of the following measures:

- **Fuel switching**: change from high-sulphur solid (e.g. coal) and liquid (e.g. heavy fuel oil) fuels to low-sulphur fuels (such as natural gas) for power and heat production purposes within the energy, industry and domestic sectors
- **Improvements in energy efficiency**: such improvements can bring about decreases in the demand for energy, which will reduc associated emissions.
- **Abatement equipment**: flue gas desulphurization (FGD) equipment installation based on a variety of techniques.

Currently, the most used FGD technology used involves **wet (i.e. water) scrubbing** using various alkaline SOx neutralization reagents, the most popular being calcium carbonate. Despite its high SOx reduction efficiency, this technology has **disadvantages related to cross media effects and an extremely high consumption of water**. Water consumption as well as water and soil pollution directly or indirectly related to wet scrubbing cannot be underestimated. The environmental performance of a technology is not judged only by the reduced emissions efficiency but also from the total environmental balance, taking into account the resources consumption (energy, water, raw materials etc.), the transfer of pollutants to other media and the generation of new waste. Especially in the more arid regions of Europe (i.e. Greece, Italy and Spain), increased water consumption is either not possible or related with a significant reduction in existing water reserves that are more valuable elsewhere (i.e., irrigation and potable water).

- A **full scale pilot installation** allows determining the technical specifications and operating parameters at this scale for optimum performance of the technology. Ultimately, the results and the detailed collection of data for the application of this new technology should be included in the CLM BREF for the BAT definition and could be implemented by target industries and in effect promoting the sustainability of magnesia production which is critical raw material for Europe.

Description of the technical / methodological solution

The project concerns the development and validation of a **full-scale dry Flue Gas Desulfurization** (FGD) **pilot plant** that will **use MgO** as the main sorbent. This pilot plant treats the combustion gases that are generated in a magnesite calcination rotary kill located in GM facilities (Greece) with an actual volumetric flow of **84.000 m^3/h** (or 40.000 Nm^3 at a reference temperature of 0 ^oC) an area with a scarce water deposits. There, in this demonstrative pilot plant the use of MgO **was tested at this scale for the first time**.

Expected results obtained and environmental benefits

Environmental benefits

Results concern the successful operation of the pilot plant and the achievement of the required desulfurization **using MgO** substantially originating from old mining waste raw materials while exhibiting energy and water consumption significantly lower than those of wet desulfurization processes, **achieving a value of less than 1.500 mg of equivalent SO_2 per normal m^3** (i.e. **1.455 mg/Nm^3**) which is the current BAT Emission Limit Value.

Concerning the environmental benefits per se, the Yerakini-Polygyros area will be the first to benefit from the project: drastically lower SO_2 emissions mean cleaner air for the benefit of the local population. For the greater **Chalkidiki area (2.918 km^2)**, there will be drastic reduction of risk of acid rain and related nuisances. The respective areas of adopting plants around Europe will also enjoy similar environmental benefits.

Apart from the direct benefits above, the technology has a positive net environmental impact because of the **very little amount of water used**, **the absence of water effluents** thus avoiding cross media effects (e.g. pollution of soil and water bodies) and the high-added value by-product that can provide revenue if used as raw material for construction applications.

Obtained results

- The pilot plant treats **84.000 m^3** of flue gases every hour.
- SOx emissions are reduced by **51%**, achieving a value of **less than 1.500 mg of equivalent SO_2 per normal m^3**, which is the current BAT Emission Limit Value.
- **520 tons of equivalent SO_2 are prevented** to escape in the atmosphere every year.
- 80% of the MgO sorbent used comes from the utilization of old mining waste. More than **20.000 tons per year waste are utilized**.
- The pilot plant consumes **96 % less water and 24% less energy** than an equivalent FGD plant based on wet desulfurization technology.
- At the current rate, more than **12.000 tons of by-product are generated** by the pilot plant yearly. At the project's end, 15% of this is valorized.

Various alternatives with technical and economic impact were examined in the course of the optimisation of the pilot Flue Gas Desulphurisation (FGD) unit. The best option as defined in terms of the techno-economic analysis, the Replicability and Transferability strategy, the CLM BREF review, and the environmental and socio-economic impact are the following:

Sorbent

GM grade based on old stockpiles by as high as 80%, is the grade of choice. This significantly lower than a very high specific surface area MgO available from an external source which cannot be sustainably available in the European market for the foreseeable future. This grade cannot be replicated by GM: a laboratory and a production trial were carried out in an effort to examine whether the MgO grade of choice could be further improved in terms of reactivity. Laboratory calcination, in a bench scale lab furnace, showed that activity increase is possible in principle. However, these laboratory conditions cannot easily be upscaled to an industrial size kiln. Indeed, a conventional rotary kiln fails to produce such a grade and a special kiln is required. Performance improvement (with the current production equipment available) will have to go back into a research phase (ideally with academic support), the possibility of which will be looked into in the After-LIFE period.

Fuel mix

The baseline fuel mix scenario is unfavourable due to the high initial SOx concentration. The technically sensible concentration of 3.000 mg/Nm^3 can be accomplished by specific fuel mix adjustments that have to consider both sulfur content and economics. The various scenarios possible are analysed in detail in Deliverable B.3.4.

Valorisation degree

The operation of the pilot plant **relies on the commercial exploitation/valorization of the by-product at a high degree**. In no scenario can valorisation generate net profits but can minimize operating costs at sustainable levels.

In summary, sustainability requires the fulfilment of the following criteria:

- Availability and pricing of certain fuel types
- By-product valorization of with **at least a 70% rate**, at relatively high added value applications (own consumption and customer applications)

Expected longer term results

The expected long-term results can be summarized as follows:

- To **continue operate** within the pilot plant after the project's end, because its role to desulfurise the flue gases of one of the calcination department kilns is essential to meet legislation requirements and efforts will be made to replicate the technology to one more kiln on the same site.
- To **upgrade 90% of by-product** generated by the pilot plant yearly:
  - Currently, **15% of the by-product generated is valorised** by mixing it with a current commercial MgO grade for Sorel cement applications.
  - To finalise the **agreement to supply the by-product for panel** manufacture and the continuation of valorisation efforts, will generate revenue and increase the long-term sustainability of the project: +26%
  - **Increase own consumption** +26%
  - **Sell to other panel manufacturers or fertilisers producers** (i.e. as raw material in their processes for the production of fertilisers): 23%
- **Further performance and operation optimization efforts**. These will concentrate on increasing the performance of the MgO sorbent. Any improvement in this area will directly reduce sorbent consumption and by-product generation, lowering operation costs. Thoughts

and ideas exist but their testing would require significant time and resources which go beyond this project.

- To **replicate** the technology within the same site.
- Continue with **dissemination** activities
- Update the EIPPCB on the project's results and follow up the BREF revision process.
- To intervene to include the **proposed technology as BAT for the next CLM BREF** review that is to commence by **April 2021** through the CLM Technical Working Group set up by the European IPPC Bureau (EIPPCB). GM plans to secure participation in the Technical Working Group (TWG) overseeing the review process, through Euromines, the European Association of Mining Industries and thus push for the adoption of the technology. This process is expected to conclude by the end of 2022. The BAT candidate reference document has already been prepared and will be submitted to the TWG as soon as the body forms. Then:
    - Network with EUROMINES and the Greek Ministry of Environment and Energy to attain membership status to the TWG
    - Send EIPPCB the BREF template filled for the proposed FGD technology when the TWG call opens.

LIFEPOSITIVEMgOFGD technology has high operating costs, is sustainable under very specific conditions and as such has a restricted R&T potential. All possibilities for **replication** have been examined. Only one European MgO producer have expressed interest in the technology but would only be willing to replicate if a solution is found to increase performance and reduce sorbent consumption. For the same reason, as well as due to the low ELVs in other sectors, no **transferability** is possible either.
Note that, currently, at 15% valorization, the corresponding operating costs are significantly higher than the cost associated with the benchmark (i.e. the operating cost when using the market benchmark calcium hydroxide grade). At **70% valorization rate**, **net operation costs** are in the order of **0,8 M€** and start to be considered sustainable. **The ultimate target is to reach 90% in the short term, allowing for a reduced cost of around 0,4 M€**. However, if the sustainability requirements are not met, in order to ensure plant operation, the company will examine the possibility to fall back to an FGD $Ca(OH)_2$ grade (benchmark or otherwise) purchased locally or from abroad, after the required plant modifications. Note that the cost of by-product disposal associated with calcium hydroxide use is not high enough to counter-balance the increased operation costs associated with the high MgO consumption required.

5 Administrative part (maximum 1 page)

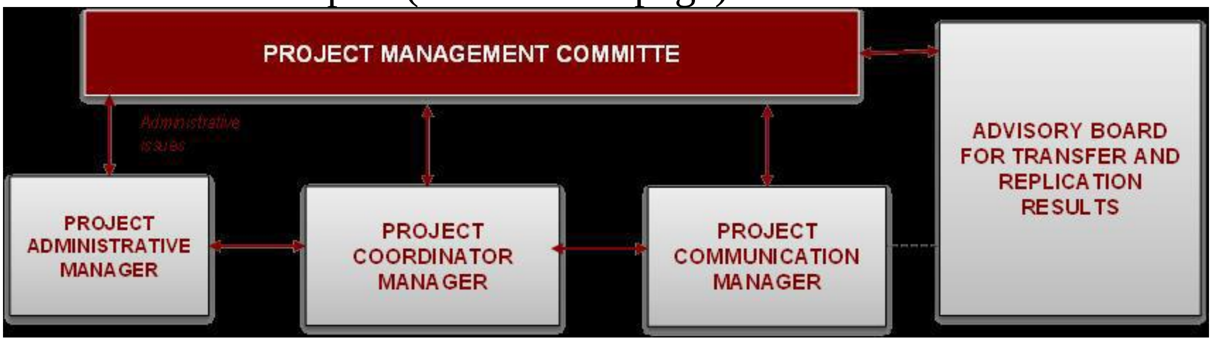

FIGURE 1: Project Management Structure

The project's Management structure includes a management body-the **Project Management Committee** as depicted in figure 1.

Members of the PMC basically are:

- R&D Center Manager **- Project coordinator**
- Maintenance & Engineering Department Manager – **Project Technical Manager**
- Development Manager– **Communication and Dissemination Manager**
- **Senior Research Engineer**
- **Production Manager**
- **Electrical Engineering Department Manager**
- **Mobile Equipment Manager - Engineering Department**

For **Strategic decisions** of the project the following Directive Staff of GM will also participate:

- **General Manager of Mines and Works**
- **Environmental Manager**

They oversee the progress of the project and provide the corporate vision for the decisions taken and prioritize key actions of the project requiring high internal resources.

Advisory Board for transferability and replication of results

An Advisory Board has been formed in order to provide advice and help maximize the projects replicability and transferability. So far, all board members have been informed about the project and its progress. The project coordinator has met with and is in regular contact with all board members. These contacts will continue for the remaining of the project. The entities of the main board members are the following:

- Greek Mining Enterprises Association
- Hellenic Federation of Enterprises
- EUROMINES European Association
- TIMAB Magnesia France
- Magnesitas Navarras (MAGNA)
- Magnesitas de Rubian
- Greek Lime Association

Management Progress - Action E.1 Overall project management

Action E.1 Overall project management

Foreseen start date	01/07/16	Actual start date	01/07/16
Foreseen end date	31/12/19	Actual end date	31/01/19
Deliverables		Foreseen due date:	Completed
E.1.1.1 Minutes of the Kick off Meeting		31/07/16	18/07/16
E.1.1.2 Minutes of the 1st Progress Meeting		30/06/17	13/07/17
E.1.1.3 First Progress Report		30/06/17	cancelled
E.1.1.4 Minutes of the Mid-Term Meeting		31/10/17	29/09/17
E.1.1.5 Midterm Report (Moved earlier)		31/10/17	31/10/17
E.1.1.6 Second Progress report		31/03/19	25/04/19
E.1.1.7 Minutes of the 2nd Progress Meeting		31/03/19	22/01/19
E.1.1.8 Minutes of the Final Meeting		31/12/19	31/12/19
E.1.1.9 Final Report		31/03/20	30/04/20
E.1.1.10 Independent Audit Report to be submitted with final report		31/03/20	30/04/20
E.1.2.1 After-LIFE Plan		31/12/19	31/12/19
Milestones		Foreseen due date:	Achieved on:
E.1.1.1 Kick off meeting		31/07/16	18/07/16

E.1.1.2 Positive Mid-term Report (Updated)	31/10/17	
E.1.1.3 Positive Mid-term Report	31/03/18 Rescheduled 31/10/17	27/10/17
E.1.1.4 Positive Progress of Project	31/12/18	25/04/19
E.1.1.5 Positive Final Technical and Financial Report	31/03/20	30/04/20
E.1.2.1 After-Life Plan Strategy defined	31/12/19	31/12/19

Meetings held during the course of the project:

Kick-off meeting was successfully held on **18/07/16**.

On **07/09/16** a meeting was held with the topic of **economic management** of the project

On **11/10/16** the **LIFE15 Kick-off meeting ENV Air and Health** a meeting was held at EASME/ Brussels.

On **19/10/16** an internal administrative meeting was held.

The **1st Meeting of the Steering Committee** was held on **21.12.16**

A t**wo-day Internal Audit Meeting (1st) was held on 16-17/01/17**

The **first NEEMO visit took place on 03.02.17**

The **Project Steering Committee** convened on **21.03.17**

The **Mid-Term Meeting** was held on **29.09.17**.

Mid-Term report was successfully accepted on 8/12/17

NEEMO's **2nd monitoring visit** was conducted successfully on 14/03/18

NEEMO's and EASME's **3rd monitoring visit** conducted successfully on 18-19/09/18

The GM team has been communicating closely during this period and several management meetings have been carried out to discuss project issues/problems during the project management.

Progress report was successfully accepted on

The **2nd Progress Report Meeting** was held **22/01/19** in the Yerakini facilities

2nd Progress Report preparation meeting was held **13/03/19**

NEEMO's **4th monitoring visit** carried out successfully on 18/10/19

The **Final Report Meeting** was held on 08/11/19 in the Yerakini facilities related to the Final results of the project and Final Report preparation. **E.1.2.1 After-LIFE Plan** has been submitted successfully and uploaded in the Website.

Achieved **progress indicators:**
- 2 Committee meetings
- 10 Project Management meetings

6 Technical part (maximum 25 pages)

6.1 Progress per action

ACTIONS B (TECHNICAL)

Action B.1 Flow sheet and Implementation of the demonstrative installation

Foreseen start date	01/07/16	Actual start date	01/07/16
Foreseen end date	31/12/17	Actual end date	09/03/18
Deliverables		Foreseen due date:	Completed
B.1.1 Pilot plant Design Specifications (Month 3)		30/09/16	08/09/16
B.1.2 Pilot plant Final Design (Month 6)		31/12/16	29/12/16
B.1.3 Process flow diagrams (Month 18)		31/12/17	28/02/18
B.1.4 Mass and energy balances (Month 18)		31/12/17	09/03/18
Milestones		Foreseen due date:	Achieved on:
B.1.1 Design of dry desulfurization plant (Month 6)		31/12/16	29/12/16
B.1.2 Construction and Implementation of the demonstrative installation (Month 18)		31/12/17	28/02/18

The Sub-action B1.1 Design of the desulfurization installation has been completed (07/16-12/16) and **Sub-action B1.2 Implementation of the demonstrative desulfurization installations** (01/17-12/17) has been carried out.

The design specification study has been completed. GM performed crucial design specification measurements (e.g. range of volumetric flow rates, moisture content, temperature and SO2 concentration) to establish the baseline situation and the required sizing of the installation (Deliverable B 1.1).

The desulfurization process designer was provided with detailed flue gas flow data (SO_2 concentrations, volumetric flows, temperatures, moisture, dust load) of Kiln No. 3 and desulfurization reagent efficiency and consumptions in the form of different scenarios which the latter used as design inputs for the desulfurization unit under study. Moreover, the designer was provided with the required degree of desulfurization, a process description for the pilot plant including the main units and a list of the actual required deliverables. The need for different scenarios reflected the large variations in operating conditions (and hence, flue gas characteristics) of rotary kiln No.3 which are due to the different magnesium oxide grades that are being produced from one shift to the next.

In Deliverable B1.1 a series of characteristic flue gas flow data measurements is presented, and 4 different case scenarios are compared. Between these scenarios, the variability of conditions is reflected. Secondly, desulfurization reagent (MgO) injection rates are calculated based on the expected efficiency of the reagent. These estimates are based on preliminary tests conducted by GM. Finally, the process and engineering study specifications are given. This means that a flow sheet of the process a list of the main equipment is constructed, i.e. the outline of what GM wants the pilot unit to do.

GM required **external assistance engineering services** for the basic design of the pilot unit design. GM awarded these services to **Scheuch GmbH** after a bidding procedure. GM also required external assistance for the computational fluid dynamics (CFD) study (see p.52 of GA and Table F3). GM awarded these services to the **Department of Mechanical Engineering of the Polytechnic School of AUT** after a bidding procedure.

The cooperation between GM, Scheuch and AUT was successful and the **pilot plant final design** (including the design of infrastructure and peripheral equipment) was completed according to schedule (Deliverable B.1.2), using the data contained in Deliverable B.1.1 as input. As a result, the mass balances, flowsheet, the flue gas output, the general layout of the installation and main equipment specifications (e.g. types, construction materials, material flows, sizing, energy requirements) were produced. The CFD study helped to maximize dispersion of the magnesium oxide sorbent and the stability of the injection system.

The main characteristic of the pilot plant is the use of MgO as reagent which differentiates its design compared to standard reagents such as hydrated lime. The processing of flue gases in the plant can be divided into the following main sections:

- Receiving flue gas from the existing RK3 chimney.
- Conditioning of the flue gases in a gas conditioning tower. The objective is to cool down the gases and increase the humidity with the use of spray water, in order to optimize conditions for reagent reaction. The temperature of the flue gases should be reduced to 160°C just above the acid dew point (145°C). This will assist the reaction with the additive. The cooling is performed by the addition and mixing of water into the flow of gases. Water is introduced through an array of high pressure nozzles at the top of the conditioning device.
- Dosing and mixing of the dry powder magnesium oxide in a specially designed mixing reactor/duct/injector lance arrangement.
- Gas dedusting and recirculation of reagent through a special bag filter designed to maximize residence time of reagent.
- The spent reagent is recycled to the Mixing Reactor by the Recirculation Mixer. The required amount of collected dust is metered by a dosing screw conveyor and is introduced back to the Mixing Reactor. The rest is fed by a pneumatic conveying system to a silo for further handling.

GM received offers for **monitoring equipment** after a bidding procedure. Due to the nature of the process and magnesia's novel entry in IED (e.g. equipment companies have no prior experience in the sector), monitoring equipment had to be carefully specified and selected. The task was completed with SICK being awarded the contract.

Related environmental and installation permits were issued according to Greek and EU legislation.

After pilot plant final design had been completed, GM conducted an **open tender procedure** for the procurement of the equipment. Publication of the call and all relevant documentation was made on the following web sites (4):
http://www.euromines.org/news/latest-news-open-tender
http://www.dimoprasion.gr/?p=90187
http://betterlife-withmgo.eu/en/open-tender
http://grecianmagnesite.com/news/call-submission-expression-interest-equipment-and-engineering-service-procurement

GM received expression of interest from **6 bidders**, 3 of which were pre-selected according to the evaluation criteria set out in the call. Then, GM prepared and provided the detailed technical file to the selected bidders and received their quotations.

Finally, the **evaluation committee convened on 17/05/17 and made the final selection**. **Scheuch GmbH** was selected.

Pre-selection Meeting Summary (held on 6/4/17):
Overall, six technical companies expressed their interest for the Open Tender. Two companies were disqualified from the evaluation & pre-selection procedure since they did not submit all required application documents.
The remaining companies were evaluated and scored based on seven basic selection criteria, namely (i) reference list, (ii) bidder's self-sufficiency, (iii) size & market position, (iv) service back-up and spare parts availability, (v) previous successful collaboration with GRECIAN MAGNESITE, (vi) financial viability, and (vii) quality certification.
Based on the relevant evaluation meeting results, three companies were pre-selected.

Final selection Meeting Summary (held on 17/5/17):
Three technical companies had been qualified to the final selection stage of the Open Tender. The final date for the submission of the technical & financial bids from the abovementioned companies was set for 8 May 2017. Based on the evaluation meeting results, SCHEUCH GmbH ranked first.

The final ranking of the candidate companies was based on several basic evaluation & selection criteria. A formal announcement was made the signing of the contract. GM signed a contract with Scheuch GmbH for the construction of the pilot plant.

The Equipment´s deliveries from concluded in November 2017.
The major pilot plant construction works were finished in January 2018 with the following tasks having been carried out:

- Reactor pipe and GCT support structures
- GCT erection
- Recirculation filter assembly
- GCT and Reactor Pipe assembly, erection and insulation
- Recirculation filter assembly erection and its insulation
- Crude gas duct supporting structure
- Assembly of electrical equipment
- Construction and assembly of equipment of pneumatic transportation

At the beginning of February 2018, the remaining secondary tasks were completed:

- Installation and calibration of flue gas analysers.
- Delivery and connection of the water descaling unit.

The **Construction of the pilot plant finished on 15/02/18**. Afterwards, the **Commissioning** of the plant started on **19/02/18** and finished **28/02/18**. The initial set of Operation trials started. All progress indicators have been successfully achieved. Deliverables B1.3 and B1.4 have been submitted and the important milestone B.1.2 Construction and Implementation of the demonstrative installation (Month 18) has been successfully achieved with a small delay as mentioned above.

The process **flow diagram and mass energy balances** (Deliverables B.1.3 and B.1.4) were delivered after the initial set of operation trials. Note that the Deliverable B.1.4 Mass Balances attached to the current report, is an updated version taking into account the completion of Task B2.

Achieved **progress indicators**:
- 1 Demonstration Plant Design
- 1 Process Flow Diagram
- 1 Mass Energy Balance

Action B.2 Validation and determination of operating conditions

Foreseen start date	01/01/18	Actual start date	28/02/18
Foreseen end date	31/03/19	Actual end date	30/04/19
Deliverables		**Foreseen due date:**	**Completed**
B.2.1 Report with the methodology indication the operating conditions and optimization parameters (Month 30)		31/12/18	28/02/19 Update (30/12/19)
B.2.2 Report on validation of the technology and evaluation of achieved results (Month 33)		31/03/18	30/03/19 Update (30/12/19)
Milestones		**Foreseen due date:**	**Achieved on:**
B.2.1 Initial operation of prototype (Month 21)		31/03/18	16/03/18
B.2.2 Validated desulfurization plant working in optimum conditions (Month 33)		31/03/19	30/03/19

This Action started at the end of February 2018. Despite the specific provisions in the design of the installation, GM still needed time to define the correct working conditions for the minimization of technical problems that had to be dealt with. A strong effort was made to operate and optimize this first full-scale pilot plant.

Systematic efforts for the optimization of the FGD pilot plant were carried out. Optimization work was conducted through several trials lasting from a few hours to a few days in which one or more process parameters were manipulated to achieve the lowest possible SO_2 emissions at the exit of the pilot plant.

The following **Technical problems** and strategies to overcome them has been carried out. These problems are related to the MgO behavior and the required operating conditions to increase its performance. Some problems worth of note are:

MgO dust escaping ESP reacts more intensively than expected with flue gas humidity at the GCT operating temperatures. Agglomerate built-up in the GCT. Solution:

- Revised operating method for the water injectors. Constant compressed air flow at maximum value (used to create fine water droplets), instead of being proportional to the water injection rate.
- Higher water pump pressures.

Erratic operation of pneumatic transportation line for final by-product and reagent recirculation. Solution:

- Addition of second rotary air sluice
- Change of conveying line size (larger diameter).
- Installation of a ventilation line
- Change of feeding shoe with a venturi injector (jet feeder). Different operating principle.

Problematic control of sorbent dosing rate. Solution:

- Installation of load cells under the sorbent silo. Loss in weight system
- Installation of HENSE flowmeters on the fresh sorbent line and the recirculated sorbent line.

Several issues were addressed to increase FGD performance, such as better recirculation flow control, lower GCT temp, increase magnesium oxide efficiency and/or use alternative MgO grades.

For the trial purposes, **four different CCM grades** were used (two produced by GM and two outsourced) as well as a calcium hydroxide FGD benchmark grade for reference/comparison purposes.

GM made a strong effort to look for alternatives and achieve higher desulfurization rates at least in terms of proof-of-concept. Towards this end, GM outsourced two very high surface area grades which were subsequently tested in the pilot plant.

To summarise the optimisation and validation trials (Deliverables B.2.1 and B.2.2), the main and most important parameters were found to be the **CCM sorbent quality (or grade), the mass flow rate with which it is injected in the system and the production settings of the rotary kiln**. Concerning the last parameter, it was found that the initial SO_2 emissions (i.e. the input concentration of the pilot plant) can be controlled by manipulating the fuel mix used in the rotary kiln. Recirculation rate has only a limited impact on the performance of the CCM grades, an effect that was shown to be strong in the case of calcium hydroxide usage. Concerning the water injection flow rate in the GCT, it is decisive in controlling the tower's exit temperature and partly responsible for the flue gas moisture levels (these are also related to the fuel originating water). The flue gas temperature was not found to correlate with FGD performance, at least within the allowed temperature range of the system (145-180 ^oC).

Concerning the performance of the grades, it was found that conventional reactive MgO grades (35-50 m^2/g) exhibit high specific consumptions and are in principle able to achieve the BAT AEL of 1.500 mg/Nm^3 at the expense of very high injection rates and kiln fuel mix manipulation. Sustainable rates achieve emissions of 1.900-2.000 mg/Nm^3 with **45-50% FGD efficiency** for the basecase fuel mix less than the project's targets. On the other hand, trials conducted with the very high surface area grades, show that CCMs with very high specific surface area (i.e. $\geq$ 130 m^2/g) can be significantly more performing, i.e. achieving the BAT AEL much easier at injection flow rates of < 900 kg/h. Even emissions of 1.200 mg/Nm^3 and **70% FGD efficiency** were shown to be possible. By comparison, the industrial standard for dry desulfurisation, a European calcium hydroxide grace, achieves the same AEL at a rate < 500 kg/h, provided adequate recirculation control. Unfortunately, the high surface area grades are not an availeble product in Europe. GM investigated the possibility to produce in-house a grade with similar properties using their own raw materials (being old tailings or otherwise), however not successful results were obtained. Such a product requires use of specialized production equipment (e.g. installation of a specialised kiln).

To achieve the ELV of 1.500 mg/Nm^3 with conventional CCM grades, the input SO_2 is adjusted to around 3.000 mg/Nm^3 by suitable fuel mix manipulation in the rotary kiln. All the details concerning the candidate scenarios and the aforementioned fuel mix choice are provided in a separate techno-economic analysis.

The operation of the pilot plant will continue to operate after the project's end, because its role to desulfurise the flue gases of one of the calcination department kilns is essential to meet legislation requirements and efforts will be made to replicate the technology to one more kiln on the same site.

Note that in the environmental permit of the Yerakini plant, the ELV of 1.500 mg/Nm^3 related to dry FGD is already approved and applicable and the justification for *using* dry FGD is provided in the environmental impact study submitted. This means that in their decision, the authorities have already considered the arid conditions in the Yerakini area, the cross-media effects arising from wet-FGD as well as economic benefits of using alternative fuels.

Perspectives for continuing the action after the end of the project (Action B2):

1) Continue the operation of the pilot plant
2) Increase the valorized volumes of the generated by-product (from 15% to 90%)
3) Perform further performance and operation optimization efforts: Efforts will be made to examine ways to further increase the performance of the pilot plant. These will concentrate on increasing the performance of the MgO sorbent by: (1) Addition of synergistic additives (e.g. substances that act as oxidation catalysts) and (2) Blending with other alkaline substances.

Achieved **progress indicators**:

- Number of individual tests 10 (short term) + 2 (long term)
- Flue Gas monitoring = continuously during the tests and use of half-hour averages
- 1 installation and process operation protocol

Action B.3 Characterization and valorization of the generated waste residue

Foreseen start date	01/07/16	Actual start date	01/07/16
Foreseen end date	31/12/19	Actual end date	31/12/19
Deliverables		**Foreseen due date:**	**Completed**
B.3.1 Report for the production of granulated by products (Month 36)		30/6/2019	18/07/19
B.3.2 Report on Fertilizer application tests (Month 42)		31/12/2019	31/12/19
B.3.3 Magnesium cement test report (Month 42)		31/12/2019	31/12/19
B.3.4 Environmental and Techno-economic analysis (Month 42)		31/12/2019	31/12/19
B.3.5 Replicability and transferability strategy draft Plan (Month 24)		30/6/18	06/09/18
B.3.6 Replicability and transferability strategy (including market analysis and exploitation plan) (Month 42)		31/12/2019	31/12/19
B.3.7 Synergies with EU Policies and Analysis (Raw material substitution and savings)		31/12/19	31/12/19
B.3.8 Reference Document for the use of MgO as desulfurization agent		31/12/19	31/12/19
Milestones		**Foreseen due date:**	**Achieved on:**
B.3.1 Characterization of by-product completed (Month 42)		31/12/2019	31/12/19
B.3.2 Environmental and techno-economic feasibility study completed (Month 42)		31/12/2019	31/12/19
B.3.3Replication and transferability strategy developed at the end of the project (Month 42)		31/12/2019	31/12/19

The action mainly started after the installation of the FGD installation and the collection of the first waste residue samples. However, the project foresaw activity throughout 2016 (see p.87 Table C3 of GA) which involved **preparatory work** (i.e. collection and characterization of current waste residues -i.e. current filter dust- to serve as reference and help determination of indicators).

Concerning **Sub-action B3.1 Characterization of the residue**, by-product samples were collected and analyzed in the laboratory. Collection and characterization of prior waste residues (i.e. existing ESP filter dust) was also conducted. This sampling and characterisation was a continuous effort; samples were mainly characterized using the following techniques: X-RF (chemical analysis), X-RD (identification of crystalline phases), TG/DTA (quantification of phases), BET specific surface area (related to porosity and reactivity), reaction times (neutralisation rates) and insoluble content (related to impurity content). Residue characterisation did not have a dedicated deliverable, but all relevant characterisation results can be found in **Deliverable B3.1** Report for the production of granulated by-products and especially in **B3.2** Report on Fertiliser application tests.

Concerning **Sub-action B3.2 Valorisation of the residue**, application studies were completed. A complete application testing scheme was realised which consists of a) laboratory and on-site granulation and upgrading trials, b) magnesium cement formulation tests and d) fertilizer application tests.

Granulation trials were conducted because most practical fertiliser application require spherical granules instead of powder products. The trials were successful in producing stable granules with adequate mechanical strength, however the industrial pan granulator available produced much larger granules (5-10 mm) than the application standard (2-5 mm). Smaller granules (1-3 mm) were produced using a laboratory granulator. Upgrading of the by-product was also conducted in the laboratory by adding sulfuric acid or magnesium sulphate to increase its useful SO_3 content.

Figure 1: Industrial granulation

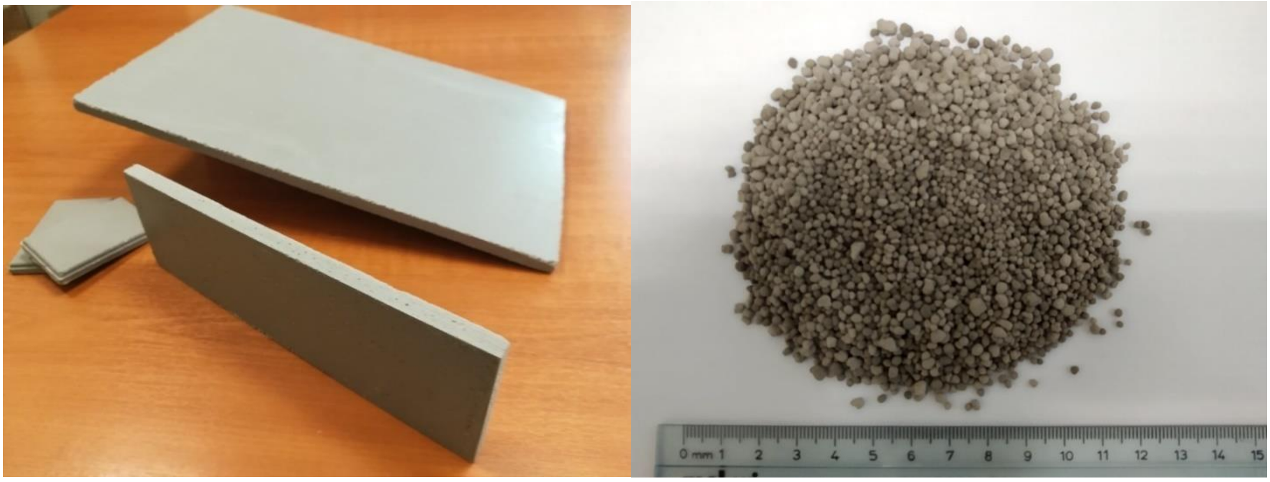

Figure 2: Laboratory magnesium oxide panels and granulated product

Magnesium cement formulation tests were found very promising and included: a) Sorel cement formulation trials, b) production of laboratory panel specimens, c) measurement of mechanical properties (**B3.3** Magnesium Cement Test Report). It was found that the GM grade FGD by-product is suitable for Sorel cement (MOC and MOS) applications and has similar or better performance than a marketable GM grade and can be used for the production of panels and abrasives and/or mixed with the aforementioned GM grade with potential cost benefits. Moreover, the by-product has earned an initial approvement by a major European panel producer) **for the production of magnesium oxide panels**. On the other hand, by-products of very high specific surface area MgOs are unsuitable for the above applications due to their very high reactivity.

For the **fertilizer application**, detailed characterisation work was conducted. This concerned general physico-chemical properties as well as more specific tests (i.e. fertiliser product specification tests) related to the application of fertilisers for powder and granulated by-product samples (laboratory and industrially produced, including upgraded samples). Moreover, the current European and Local legislation was also outlined. **(B3.2** Report on Fertilizer application tests). It was found that all samples exhibited lower MgO and SO_3 contents than the required specifications. Another possibility would be for the FGD by-product to be sold *as raw material* for the production of fertilisers, an avenue which will be pursued in the After-LIFE period of the project.

A comprehensive techno-economic analysis of FGD pilot plant operation was conducted in order to assess the sustainability of proposed operation scenarios, largely based on the appropriate fuel mix used at the rotary kiln level (**B.3.4** Environmental and Techno-economic analysis), taking into account the low performance of MgO and its high consumption rates. A **sustainable solution, technically and economically**, is the combined use of a conventional, GM produced MgO sorbent (CCM) and a **fuel mix** which provides lower SO_2 emissions at the rotary kiln level. This sustainability relies heavily on the commercial exploitation/valorization of the by-product. This does not generate net profits but can minimize operating costs at sustainable levels. In particular, the **sustainability requires the fulfilment of the following criteria**:

- Availability of appropriate fuels
- Some fuel pricing assumptions
- By-product valorization of with at least a 70% rate, at relatively high added value applications (own consumption and customer applications)

At **70% valorization rate**, **net operation costs** start to be considered sustainable and are estimated to be in the order of **0,8 M€**, which is the reference cost chosen in the study. This is equal to the operating cost of the plant if it utilized a **market benchmark FGD grade calcium hydroxide**. **The target is to reach 90% in the short term, allowing for a reduced cost of around 0,4 M€**. GM will work towards high valorization rates in the 3 year After LIFE period. However, if the sustainability requirements are not met, in order to ensure plant operation, the company will examine the possibility to fall back to an FGD $Ca(OH)_2$ grade purchased locally or from abroad, after the required plant modifications.

Concerning **Sub-action B3.3 Replicability and transferability Strategy**, GM has made significant efforts in communicating with stakeholders, organising dedicated workshops, analysing the market and putting forth initially a draft R&T strategy and with the conclusion of the project a revised R&T planning, including relevant actions for replication and policy. The revised strategy is analysed in detail in Deliverable **B.3.6** Replicability and transferability strategy (Exploitation Plan and Market Analysis). This deliverable takes into account the actual project results, achievements and shortcomings. **It is concluded that due the high operating costs of the technology and its conditional sustainability the R&T potential is restricted.** Concerning Replicability, GM will focus on **in-site replication to another rotary kiln** and will only push for another replication within the sector if a solution is found to increase performance and reduced sorbent consumption. On the other hand, **by-product valorisation will be realised according to a specific plan which includes in-house valorisation, and three identified end-users from the construction and fertiliser sectors.** Specific preparation and planning is made in order to obtain BAT candidate status during the next CLM BREF review. Note that **the technique does not offer a reduced BAT AEL.** However, if the technology is accepted as BAT, it could serve as an operation example and a basis for further development within the sector or elsewhere in the future. The **BAT template** for the proposed technology has already been prepared (Deliverable **B.3.8** Reference Document for the use of MgO as desulfurization agent) and will be submitted to the BREF review **Technical Working Group** (TWG) once the procedure commences (estimated April 2021). Under moderate estimations, this process is expected to conclude by the end of 2022.

In the following, the most important activities associated with this sub-action, are provided in chronological order:

Initially, t**arget stakeholders for Replication and Transferability** were identified:
- Magnesium Sector or Sectorial Association
- Other Sectors that could use the same technology or Association
- Fertilizers Sectors (by-products)
- Construction Sector (by-products)
- Authorities (BREF)

and the **Advisory Board for R&T** was formed consisting of:
- Greek Mining Enterprises Association
- Hellenic Federation of Enterprises
- EUROMINES European Association
- TIMAB Magnesia France
- Magnesitas Navarras (MAGNA)
- Magnesitas de Rubian
- Greek Lime Association

Concerning **policy/CLM BREF**, DG Env/C.4 Industrial Emissions was contacted on and informed on the project and helped establish a contact point directly with the EIPPCB. The EIPPCB made clear that it was still too early for the next BREF revision and indicated that any new information will be collected through the TWG process, **which will start no sooner than 2021**. The Bureau was glad to accept progress reports through e-mail.

Several early meetings with stakeholders were held (find relevant material in Annex V for these meetings in the submitted Midterm Report):
- Meeting with CaO Hellas on 26/04/17, the biggest producer of lime in Greece, to discuss the FGD issues in the lime and magnesia sector and eventual collaboration within the LIFEPOSITIVEMgOFGD framework has been carried out
- Meeting with Magnesitas Navarras, Magnesitas de Rubian, TIMAB Fertilizers on 31/5/2017 to discuss transferabillity within the MgO Sector, the SOx emissions problem and the role of by-products in the fertilizer sector.
- Meeting with MAGES, the Spanish Association of Magnesia Producers on 24/5/17 as a first approach for dissemination and transferability within the MgO and Cement Sector.
- Meeting with the Hellenic Federation of Enterprises (SEV) during its Board Meeting in November 2016 to disseminate the project and inform Board Members.
- Meeting with Greek Mining Enterprises Association (GMEA) during its Board Meeting in March 2017. As a first approach for transferability within Greece and inform Board Members.

After the EIPPCB’s reluctance in participating in Workshops with the Advisory Board, equivalent alternatives were developed in the draft strategy to maximize R&T for the technology and the by-product end-use (Deliverable **B3.5** Transferability & Replicability Strategy Draft Plan). This mainly involved:
- Initial R&T survey with the distribution of the questionnaire
- Market survey
- Prioritization of end-users - Characteristics required by industries to use the proposed solution
- Individual meetings and plant demonstrations with end-users (technology and by-product)

- Synergies with the project results dissemination

Alternatives to replace workshops with the EIPPCB
- Submission of the BREF template
- Networking with Euromines and Greek authorities to support GM's nomination in the TWG for the CLM BREF revision.
- One dedicated R&T workshop and/or organization of a special R&T session/workshops during the next two dissemination workshops (if necessary)

The LIFE Project was presented to other MgO producers at a dedicated roundtable discussion during the Magforum 2018 (Magnesium Minerals and Markets Conference) that was held in Hamburg, 17-19/6/2018.

1st R&T Workshop
Project coordinator presented the project in the Magnesia Producers Assembly at EUROMINES in Brussels on 19/03/19. It is possible to find Agenda and Participants list, Presentation and Minutes of this Assembly in the Deliverable D.1.1.6_Dossier of the communication activities and impact achieved to be submitted with the Progress Report (Action D) and in ANNEX I: Relevant documentation of Stakeholders meetings of the submitted Progress Report.
Due to main Stakeholders that could potentially replicate the technology were there GM take profit of this situation for a specific Meeting Session at the end of this Assembly carried out to discuss replication and transfer potential (**Action B3**) with the following participants:
- GM
- Euromines
- RHI
- TernaMag
- MAGNA

2nd R&T Workshop
A successful 2nd workshop took place during the "Green week satellite Event Organization'' on 28/3/19. The GM team had prepared a session to discuss the replication and transferability of the project. An extensive discussion took place with the interested participants/stakeholders and the Advisory panel. The discussion was divided between a group meeting with the Advisory panel (GMEA, IGME, SEV) and several individual meetings with stakeholders. The following participants were involved:

- GM
- GMEA
- SEV
- CAO HELLAS: Lime producers
- Greek Lime Federation
- ΑΓΕΤ: Cement producer)
- IGME
- ΔΕΗ: Public power corporation
- TernaMag: Magnesia producer
- TITAN: Cement producer

Conclusions drawn were:
- The cement industry faces some issues with SOx emissions because of the relatively low emission limits in their activity associated with the wastes co-incineration. The MgO is an

undesirable component in cement and for that reason they prefer lime reagents when the desulfurization agent and by-products are mixed with the raw mill, since both CaO and $CaSO_4$ are present in the cement. Nevertheless, they are interested in the project in case that low SOx emission limits will be achievable by the technology.

- Lime industry's BAT-AELs (<400 mg/Nm^3) are in most cases achieved by natural FGD (i.e. by the CaO dust generated in the kiln). Therefore possibilities for transferability to them are limited.
- The power generation plants in Greece are using lignite with significant amounts of S. therefore the SOx emissions are an issue in their activity. The applicability of the technology in their plants is limited for the following reasons:
    - The SOx emission limits in the LCP (Large Combustion Plants) are < 200 mg/Nm^3 which is far below the performance of the MgO dry FGD.
    - Because of the large volumes of Flues Gas (> 1.000.000 Nm^3/h) the applicable technology is the wet FGD.
    - In specific cases, where dry FGD can be used, the most performant $Ca(OH)_2$ reagent is used.
- The main conclusion and advice from the Advisory Panel are:
    - Focus on lower SOx emitters for R&T. However, there are few IPPC installations with SOx emissions in Greece. A market survey is necessary.

Moreover, project's results were presented and discussed during the **European magnesia sector** (EUROMINES magnesia group) on its **Assembly** (5/11/2019: Brno, Czech Republic). GM updated the participants on the latest developments, progress and results regarding the LIFEPOSITIVEMgOFGD Project.

<u>Conclusions drawn were:</u>
Conventional reactive CCM has limited performance. exhibits Moreover, the use of a very high specific surface area MgO cannot be considered a sustainable solution at this point. The other alternative to achieve BAT ELVs, i.e. using the proposed MgO grade (GM's product) under the condition to have low initial SOx (< 3.000 mg/Nm3) depends on the fuel mix which is used in each production plant.

The Final Event of the project This was conducted on 17/12/2019 at the Centre for Research and Technology (CERTH) in Thessaloniki to present the final results, mainly attended by students, researchers and academia. There was no R&T session, but the event was followed by an organized pilot plant visit, which included a detailed tour of the installation, the control room and the rotary kiln.

<u>Sub-action B3.4 Contribution and Synergies with Strategies of other Union Policies</u>
Apart from policies related to industrial emissions, such as the IED, which is the main focus of the project, there are also synergies with other policies such as the **Circular Economy Action Plan**, **Clean Air Policy** and **Raw Materials Policy**. The utilization of mining waste to produce the sorbent used and the utilization of the by-product, are recycle/reuse activities which broaden the policy scope of the project. In Deliverable **D.3.7** Synergies with EU Policies and Analysis (Raw material substitution and savings), submitted with the current report, the policy synergies are analysed and the relevant environmental benefits quantified, including raw material and CO_2 emission savings.

The LIFEPOSITIVEMgOFGD project has been included in the JRC - Air Quality Measures Catalogue: http://fairmode.jrc.ec.europa.eu/measure-catalogue/ linked with the **Clean Air Policy initiative.**

European Circular Economy Stakeholder Platform Contribution: GM will submit information in the Good Practice section of the website https://circulareconomy.europa.eu/ platform/en/good-practices early in the After-LIFE period.

Perspectives for continuing the action after the end of the project (Action B3):

1) **Valorisation of by-product**: According to the After-LIFE Plan and the techno-economic study conducted, the target is that within 3 years, this percentage will increase to 90%:
   - On site utilization or recycling: 41%
   - Finalize the agreement to supply the by-product for panel manufacture: 26%
   - Sell to other panel manufacturers or other applications (e.g. as raw material for the production of fertilisers): 23%
2) **Replicate the technology within the same site**: Efforts will also be made to replicate the technology to one more kiln on the same site within the next two years. Similarities in operation between the two kilns make replication possible with minor adjustments.
3) **CLM-BREF update:** The most significant task for the After-LIFE period is for the IPPC Bureau to consider the proposed technology as BAT for the next CLM BREF review that is to commence by April 2021. Specific actions include:
   - Update EIPPCB on the project's results by e-mail
   - Network with EUROMINES and the Greek Ministry of Environment and Energy to attain membership status to the TWG
   - Send EIPPCB the BREF template filled for the FGD technology we propose when the TWG call opens.

The initiation of the next CLM BREF review process (see Figure 1) is expected to take place on April 2021 (8 years after the previous revision). To this end the project team decided to plan the policy contribution, in terms of BREF revisions, in the 3-year after-life duration of the project (i.e. 31/12/2022). Three different case scenarios (best, moderate and worst-case scenarios) have been elaborated based on the different BREF scope expansions as shown Table 1. In the best and moderate scenarios, the 1st Draft, including BAT Conclusions, will have been completed by 31/12/2022, whereas in the worst-case scenario the 1st Draft version will have been published by 31/12/2022 without BAT conclusions. In any case GM shall participate in the BREF revision process (as in previous revision) as member of the TWG either as representative of EUROMINES (European Association of Mining Industries, Metal Ores & Industrial Minerals) and/or the Greek Ministry of Environment and Energy focusing in addressing major issues such as those concerning with the improvements of existing techniques and processes with respect to the protection of the environment and/or economic aspects.

Considering the above, the project team performed the necessary actions during the lifetime of the project in order to be fully prepared for the upcoming review. Taking into consideration the provisions of Decision 2012/119/EU a "*10-heading structure*" has been developed providing information on the developed technique in order to be evaluated and considered in the determination of BAT. The aim is to include as much information as needed in order to be assessed in terms of (a) its qualifications to be considered as a BAT within the sector concerned and (b) its applicability within the sector. Information on the developed technique includes elements such as description, technical description, achieved environmental benefits, environmental performance and operational data, cross-media effects, technical considerations relevant to applicability, economics, driving force for implementation, example plants (Deliverable **B.3.8** Reference Document for the use of MgO as desulphurisation agent)

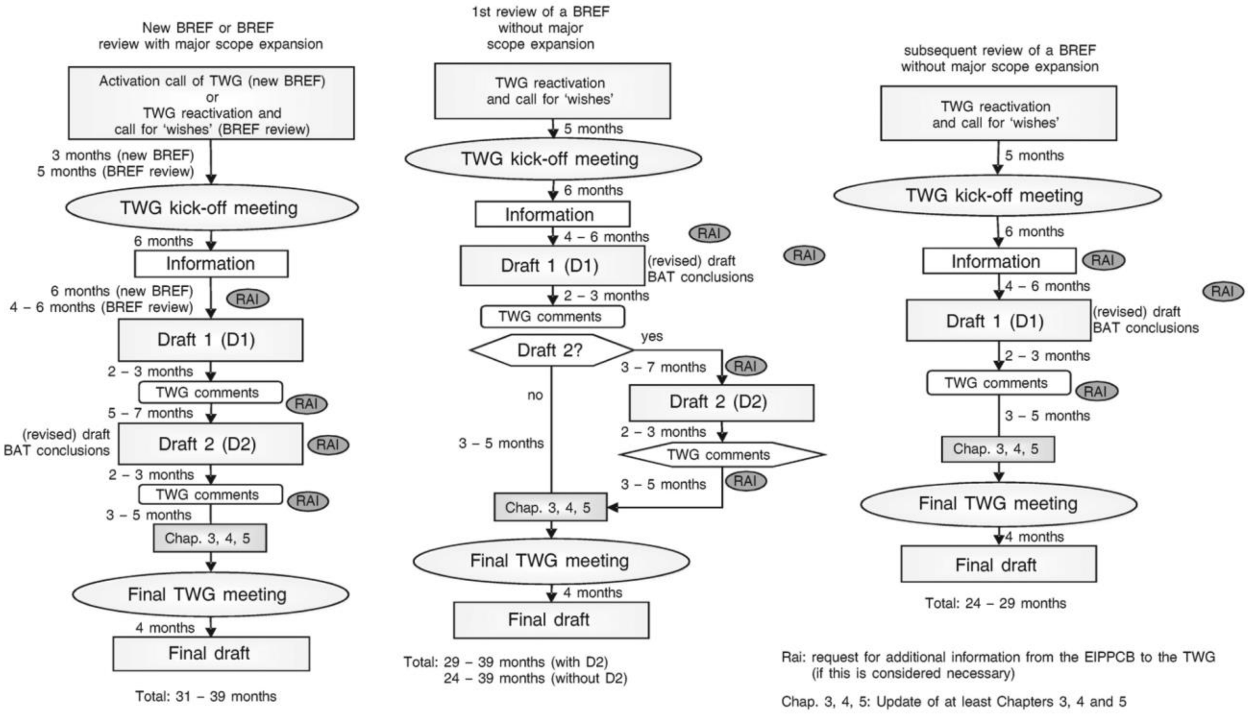

Figure 3: Typical workflow for the drawing-up and review of BREFs (Decision 2012/119/EU)

Table 1: Timeline Scenarios for next CLM BREF revision

Best case scenario (subsequent review of BREF without major scope expansion)			**Moderate case scenario (subsequent review of BREF without major scope expansion)**			**Worst case scenario (review of BREF with major scope expansion)**		
Date	Aggregated months	Activity		Aggregated months	Activity		Aggregated months	Activity
Apr-21	0	TWG reactivation and call for wishes	Apr-21	0	TWG reactivation and call for wishes	Apr-21	0	TWG reactivation and call for wishes
Sep-21	5	TWG K.O. meeting	Sep-21	5	TWG K.O. meeting	Sep-21	5	TWG K.O. meeting
Mar-22	11	Information	Mar-22	11	Information	Mar-22	11	Information
Jul-22	15	**Draft 1 (BAT Concl.)**	Sep-22	17	**Draft 1 (BAT Concl.)**	Sep-22	17	**Draft 1 (BAT Concl.)**
Sep-22	17	TWG comments	Dec-22	20	TWG comments	Dec-22	20	TWG comments
Dec-22	20	Final TWG meeting	May-23	25	Final TWG meeting	Jul -23	27	Draft 2 (Bat Conc.)
Apr-23	24	Final draft	Sep-23	29	Final draft	Oct-23	30	TWG comments
						Mar-24	35	Final TWG meeting
						Jul-24	39	Final draft

Achieved **progress indicators**:

- 1 Installation and process operation protocol
- Production of optimized by-product
- Successful granulation powder
- Magnesium cement formulation
- Application test report
- 14 companies interested in results
- 1 by-product approval
- 3 Workshops carried out

ACTIONS C (MONITORING)

Action C.1 Monitoring of the impact of project actions

Foreseen start date	01/07/16	Actual start date	01/07/16
Foreseen end date	31/12/19	Actual end date	31/12/19
Deliverables		**Foreseen due date:**	**Completed**
C.1.1 Monitoring Report: Indicators Report at initial of the project (Month 6)		31/12/16	21/12/16
C.1.2 Indicators in 1st Progress Report		30/06/17	cancelled
C.1.3 Indicators Report to be submitted with Mid-Term Report		31/10/17	4/10/17
C.1.4 Indicators Report to be submitted with 2nd. Progress Report (Month 33)		31/3/2019	26/04/19
C.1.5 Indicators Report at final report.		31/12/19	31/12/19
Milestones		**Foreseen due date:**	**Achieved on:**
C.1.1 Initial Indicators collected. Establishment of the baseline (Month 6)		31/12/16	21/12/16
C.1.2 Intermediate indicators collected (Month 18)		31/12/18	31/12/18
C.1.3 Final indicators collected and quantification of environmental and project impact.		31/12/19	31/12/19

Sub-action C1.1 Analysis of initial indicators was completed according to schedule.

Deliverable **C1.1** updates/modifies the impact indicators related to Actions B.1, B.2 and B.3 considered at the proposal stage - and introduces additional ones when necessary - without changing the project objectives. The update is due to necessary adjustments/changes after the plant design and more careful revision of the state-of-the-art and public literature. It gives values for reference, state-of-play at the beginning of the project and state-of-play at the end of the project.

Sub-action C1.2 Determination of impact through tracking indicators was in progress during whole project duration.
Deliverable **C1.3** reports on the values of the impact indicators related to Actions B.1, B.2 and B.3 and was submitted within the Mid-Term Report. The key impact indicators had to do with:

- Water Consumption
- Waste Management
- Energy consumption
- Circular economy practices
- MgO by-product used
- Chemicals substitution
- SO_2 emissions
- Area potentially affected
- Human population affected
- Total Area affected

Relevant issue during this period was the Introduction of LIFE+ Indicators in the new KPI tool in January 2018. The latest indicator update can be seen in **Deliverable C1.5** submitted with this report.

Perspectives for continuing the action after the end of the project (Action C1):

- GM will continue to monitor the project impact through KPIs.

Action C.2 Monitoring of the socio-economic impact of the project actions

Foreseen start date	01/07/16	Actual start date	07/09/16
Foreseen end date	31/12/19	Actual end date	31/12/19
Deliverables		**Foreseen due date:**	**Completed**
C.2.1 Initial Socio-economic Analysis and Strategy to increase socio-economic impact (Month 6)		31/12/16	21/12/16
C.2.2 Socio-economic assessment to be submitted with Final Report after project implementation		31/12/19	31/12/19
Milestones		**Foreseen due date:**	**Achieved on:**
Milestone C1.2 Intermediate indicators collected (Month 18)		31/12/18	31/12/18

The aim of action C.2 is the evaluation of the socio-economic impact of the project through the estimation of costs and economic and social benefits from the point of view of the population and local economy. The socio-economic impact assessment is useful to measure the impact and benefits of LIFEPOSITIVEMgOFGD and its actions on the population, economic activity, environment, infrastructure, as well as of any socioeconomic activity, including legislative and regulatory changes. Social indicators can be in many cases subjective or cater to very varied fields of application.

During the proposal stage a list of indicators have been selected and quantified. Deliverable **C.2.1** completed according to schedule. One of the purposes of this deliverable was to review the values of the chosen indicators and add new ones when required, expecting more accurate values by the end of the project. The key indicators included:

- Implication of NGOs
- Full-time equivalents (FTE)
- Running cost/operating costs
- Capital cost expected in case of replication/transfer/continuation after the project
- Savings/revenue expected in case of replication/transfer/continuation after the project
- Payback time
- Continuation/Replication/Transfer Scope
- Entry into new entities/projects, sectors and geographical areas

Moreover, the deliverable C2.1 described the current socio-economic statues and determined the way to achieve the intended indicator values as well as define the specific actions and strategy to achieve the highest possible social and economic impact on a local, national and/or European level. The adopted strategy followed the philosophy and targets of EU’s LIFE Programme. Therefore, it was based on a plan consisting of the following five actions:

1. Adopt strong managerial practices
2. Maximize environmental benefits
3. Disseminate the results
4. Affect Policy
5. Replicate and transfer the technology

Deliverable **C.2.2** Socio-economic assessment after project implementation, is submitted along with the current report, reviewing C.2.1 and updating indicator values. Most of the targets have been achieved. The most important impacts are seen on a local level, due to the lowering of SO_2 emissions from the mine site and on the dissemination levels. A wide audience became familiar with the project and received information about its objectives, results and foreseen actions, raising public awareness about the environmental, social and economic benefits that are gained from the implementation of the project. Relevant stakeholders and the general media were involved. Information and experience was transferred to other groups that are related to magnesia industry and SOx emissions management. Finally, the expected impacts arising from After-LIFE activities are outlined.

The Socio-economic impact indicators have been compiled into the **KPI Database Webtool**.

<u>Perspectives for continuing the action after the end of the project (Action C1):</u>

- GM will continue to monitor the project impact and its socio-economic effects, through KPIs.

ACTIONS D (DISSEMINATION AND COMMUNICATION)

<u>Action D.1 Public awareness and dissemination of results</u>

Foreseen start date	01/07/16	Actual start date	01/07/16
Foreseen end date	31/12/19	Actual end date	31/12/19
Deliverables		Foreseen due date:	Completed:
D1.1.1 Communication plan		31/12/16	29/12/16
D1.1.2 LIFEPOSITIVEMgOFGD website		31/12/16	20/12/16
D.1.1.3 Notice Board		31/03/17	06/04/17
D.1.1.4 Dossier of the communication activities and impact achieved to be submitted with 1st. Progress Report		30/06/17	Cancelled
D.1.1.5 Dossier of the communication activities and impact achieved to be submitted with Mid-Term Report		31/10/17	30/9/17
D.1.1.6 Dossier of the communication activities and impact achieved to be submitted with Progress Report		25/04/19	25/04/19
D.1.1.7 Dossier of the communication activities and impact achieved to be submitted with Final Report		31/12/19	31/12/19
D.1.1.8 Layman's report at the end of the project		31/12/19	31/12/19
D.1.2.1 Database with the information of projects/initiatives/experts groups related to LIFEPOSITIVEMgOFGD		31/12/17	15/03/18
D.1.2.2 Networking report including Final Event Meetings, outcomes presentation, initiatives		31/12/19	31/12/19
Milestones		Foreseen due date:	Achieved on:
D1.1.1 Project website available		31/12/16	20/12/16
D1.1.2 Notice board installed		31/03/17	06/04/17
D.1.1.3 Layman's Report developed		31/12/19	31/12/19

<u>Sub-action D1.1 Dissemination planning and Development of the Dissemination Pack</u>

Deliverable **D.1.1.** Communication plan was developed in cooperation with ENVIRECO Consulting S.A. as part of D1 Action of the project "Public awareness and dissemination of results" and aims to effectively disseminate and communicate the project to all relevant stakeholders and target audience. The development of the communication and dissemination strategy was based on the main objectives of the project implementation, but also on the requirements set by the EU funded, LIFEPOSITIVEMgOFGD project (i.e. grant agreement). The development of the plan conducted by the project team aimed at: (a) raising awareness and informing stakeholders and target audience about the new dry desulfurization technology and (b) maximizing the impact of the project by making the results and deliverables of the project available to the stakeholders and to the wider audience.

The plan identified the following target groups:

- General public of the local community (students, families)
- Collective bodies (e.g. associations, federations, organizations) and Media of local level
- Companies and industries on the limestone mining
- Local and regional authorities and national bodies (e.g. Ministry of environment, Central Macedonia Region, Chalkidiki's Regional unit, Polygyros municipality)
- Scientific community (universities, research centers)
- Policy and decision makers at EU, national, regional and local level (e.g. EC, central government, , EIPPCB)

It was divided into two phases of implementation, following the respective stages of the LIFEPOSITIVEMgOFGD project, which included:

- Communication and dissemination activities of project results and outputs
- Monitoring activities in order to measure the impact of the project communication and dissemination plan

The first phase included all dissemination opportunities such as events (e.g. conferences, workshops, etc.), project publications (e.g. notice boards, brochures, news releases as well as conference papers, articles in professional journals etc.) and project presentations (e.g. to local stakeholders, etc.), complemented also by online activities based around the project website.

The second phase involved the monitoring of the project's communication plan and strategy. All communication and dissemination actions were monitored by the Dissemination and Communication Manager (DCM) against specific key progress indicators at frequent intervals. DCM valorized the progress of the project's communication strategy and provided relevant feedback to the Project Management Committee (PMC) with respect to the effectiveness and the impact of dissemination and communication activities.

Initially, the **main stakeholders** informed about the project's approval and commencement were:

- EUROMINES
- Hellenic Federation of Enterprises (SEV)
- Greek Mining Enterprise Association (GMEA)

- MAGNA (Navarre, Spain)
- MGR Magnesitas de Rubian(MGR) (Lugo,Spain)
- TIMAB Magnesia France

Other stakeholders informed were:
- M DG ENV C.3
- LIFE National Contact Point-Ministry of Environment and Greek Life Task Force Coordinator (LIFE14 CAP/GR/000003)
- DG Env/C.4 Industrial Emissions
- EIPPCB
- CaO Hellas
- Bel Industrial de Transformaciones, S.A.
- OFICEMEN (Spanish Cement Association)
- COMINROC (Spanish Confederation of Extractive Industries of Rocks and Industrial Minerals)
- AINDEX (Spanish National Association of Extractive and Related Industries)
- MAPAMA (Spanish Ministry of Agriculture, Fisheries and Food)
- MINETAD (Spanish Ministry of Energy, Tourism and Digital Agenda)
- FEIQUE (Business Federation of the Spanish Chemical Industry)
- CEMA
- CO2 Technology Platform

The project's **website** came on-line in December 2016 and was made discoverable by search engines in January 2017 (www.betterlife-withmgo.eu). The content is currently up to date. The total impact of the website during the period from 01/01/17 until 31/12/19 has been **1.925 users and 7.508 page views visits from 82 countries. The number of file downloads from the website is 4.564.**

Notice Boards have been installed (2 in the mine area, 1 in the Yerakini touristic settlement, 1 in the R&D center) in March 2017. See Deliverable **D1.1.2** Notice Boards.

GM printed a banner and initial informative brochures about the project, according to the communication plan. Please find enclosed pictures in Deliverable **D1.1.5** Dossier of the communication activities and impact achieved to be submitted with the Mid-Term Report. Furthermore, a hard copy of the Brochure is included within this report submission.

- Project presentation during stakeholder **SEV's Board Meeting** in November 2016 and inclusion in their **website**: http://www.sev.org.gr/grafeio-typou/ta-nea-ton-melon-mas/ellinikoi-lefkolithoi-a-m-v-n-e-e/
- Project presentation during stakeholder **GMEA's Board Meeting** in March 2017 and publication in their **newsletter** on 3/3/2017: http://www.sme.gr/enimerosi/newsletter/174-2017-03-03-11-59-30
- Project presentation during the **Greek LIFE Task Force Events** in the cities of Xanthi and Thessaloniki. The audience included local government officials, academics, state employees and private organizations/companies interested in LIFE. Follow the links for details:
  - http://www.lifetaskforce.gr/index.php/en/events/gr-ltf/eventdetail/22/-/ekdilosi-enimerosis-kai-ekpaidefsis-gia-to-programma-life-call-2017-ksanthi-27-03-17
  - http://www.lifetaskforce.gr/index.php/en/events/gr-ltf/eventdetail/21/-/ekdilosi-enimerosis-kai-ekpaidefsis-gia-to-programma-life-call-2017-thessaloniki-29-03-17
- A **poster** was successfully presented in the **6th Environmental Conference of Macedonia**, Thessaloniki, Greece, 5-7 May 2017 -persynmak.blogspot.gr

- Meeting with MAGES, the **Spanish Association of Magnesia Producers** on 24/5/17 as a first approach for dissemination and transferability within the MgO and Cement Sector.
- GM actively participated in the **Greek Life Task Force Event for the Celebration of** 25 years of LIFE, on May 25th 2017 with a stand, including dissemination material.
- A **poster** on the pilot plant design and its envisaged operation was successfully presented on June 27th in the **6th International Conference on Environmental Management, Engineering, Planning and Economics** in Thessaloniki-Greece (June 25-30, CEMEPE 2017). http://cemepe6.civil.auth.gr/
- The project's results have been presented and discussed to the European magnesia sector (EUROMINES magnesia group) on its assembly (5/11/2019: Brno, Czech Republic).

Three Workshops have been carried out (including Final Event):
- **"Breakfast for the Air Quality"** Workshop for the presentation of the LIFEPOSITIVEMgOFGD project to the **local community**, took place successfully on Thursday, October 19th 2017 at the Chamber of Halkidiki, in the city of Polygyros. The participation of the public was satisfactory (>50 participants), see Deliverable D.1.1.6 Dossier of the communication activities.

- A 2nd Communication and Dissemination Workshop "**Green week satellite Event Organization''** took place on 28/03/2019 in SEV's (Hellenic Federation of Enterprises) offices in Athens**. 67 participants attended the Workshop mainly from industry**), see Deliverable D.1.1.6 Dossier of the communication activities.

- "Final event" that took place 17/12/2019 in Thessaloniki- Conference Center of CERTH (Center of Research and Technology Hellas). A short clip dedicated to the event is available on the web site. https://www.youtube.com/watch?time_continue=28&v=PeKT7zGhRtE&feature=emb_logo

Greek Life Task Force and GM were continuously cooperating. GLTF produced a short video about LIFE projects in Greece which includes footage from the plant's construction and an **interview from the project's Dissemination Manager**. The video is used by both the GLTF and GM in their dissemination activities.

A **project video** in HD, with running time 07mm:39ss has been developed and uploaded to YouTube and the project's website. Spoken language is Greek with English subtitles and text for the international version. https://www.youtube.com/watch?v=PX0G-0jCEZQ&feature=emb_logo (Number of visits of English version: 534)

A **Layman's Report** has been developed in English and Greek and uploaded on the website. http://www.betterlife-withmgo.eu/images/LIFEPOSITIVEMgOFGD-Laymans_Report_EN.pdf . This is **Deliverable D.1.1.8** submitted with the current report.

Deliverable **D1.1.5** Dossier of the communication activities and impact achieved was submitted with the Mid-Term Report. Deliverable **D1.1.6** was submitted within the Progress Report. **D.1.1.7** Dossier of the communication activities and impact achieved is submitted with this Final Report.

Sub-action D1.2 Networking with other projects

Deliverable **D.1.2.1** Database with the information of projects initiatives experts' groups related to LIFEPOSITIVEMgOFGD was submitted with the progress report.

Deliverable **D.1.2.2** submitted with this report provides a comprehensive networking report including final Event Meetings, outcomes presentation and initiatives in relation with the project.

Main networking activities during the course of the project were:

- On 11/10/16 the **LIFE15 Kick-off meeting ENV Air and Health** a meeting was held at EASME/Brussels with the participation the then Environmental Manager and the Administrative Project Manager. Useful contacts made included:
    - DG ENV C.3 (and C.4),
    - EASME and NEEMO staff
    - LIFE15 ENV/ES/000284-LIFE AMMONIA TRAPPING
    -LIFE15 ENV/IT/000631-LIFE CHIMERA

- Meeting held with a **major fertilizer producer** on 7/11/2017. Presentation of LIFEPOSITITVEMgOFGD. Meeting and plant demonstration on 12/09/18 at Yerakini.

- During the **EUROMINES** (11/01/18, Brussels) **Meeting**, Magnesitas Navarras, Magnesitas de Rubian (MgO producers) and TIMAB Fertilisiers were updated on project progress and Transferability and Replication potential. The project was presented by GM to the whole Magnesia Group. Discussion with representatives of Magnesitas Navarras and Magnesitas de Rubian on 11/01/2018 during the event organized by EUROMINES in Brussels on topics related to the project's progress.

-Dissemination Manager attended the **21st European Forum on Eco-innovation for Air Quality** (5-6/02/2018, Sofia, Bulgaria), taking the opportunity to present and discuss the project to several contacts. He also participated in the FGD Workshop organized by SOLVAY (Greek Ministry of Environment). Major contacts made:
    - Unit B.2 – H2020 Environment and Resources, EASME.
    - Environmental Knowledge, Eco-Innovation and SMEs, DGE.
    - NEEMO LIFE Communications Team.
    - Directorate of Climate Change & Air Quality, Greek Ministry of Environment & Energy.
    - Soda Ash & Derivatives, Regulatory and Business Development Manager SOLVAir, Solvay

-CALIX (MgO producer) and kiln technology developer Meeting on 16/02/18 in GM’s R&D Centre. Meeting and plant demonstration to CALIX on 19/06/18 in Yerakini.

-Participation of the project’s communication manager the **Magforum 2018** (Magnesium Minerals and Markets Conference) that was held in Hamburg, 17-19/06/2018. - The LIFE Project was presented to other MgO producers at a dedicated roundtable discussion. Transferability and Replication objectives were presented within the following stakeholders: **LEHVOSS** (MgO trader), **Nedmag** (MgO producer), **RHI Magnesita** (MgO producer).

- Meeting held with **General Abrasivi**, the GM’s distributor of MgO Abrasivi grades in Italy, at Gerakini on 27/06/2018 to discuss the perspectives of the Italian market, presentation of the LIFEPOSITIVEMgOFGD and the posibility for a cost effective MgO By-product discussed. General Abrasivi mentioned that the grinding stone formulation in many cases also contain $MgSO_4$ and they expressed their interest to promote an MgO already containing $MgSO_4$ to the Italian market. GM to communicate results, when available.

- Synergies with new project “Boosting new Approaches for flexibility Management By Optimizing process Off-gas and waste use (**BAMBOO**)” CE-SPIRE-03-2018/IA/SEP-210505375 **-** Horizon 2020 during the KoM (11-12/09/18, Brussels). Presentation of LIFEPOSITIVEMgOFGD Project Results to BAMBOO Participants.

- Climate Change Mitigation in Energy Intensive Industries – ***LIFE Platform Meeting*** (26-27/09/2018, Utrecht). **Participation in Networking session** (http://lifeoptimelt.com/pdf/agenda.pdf)
- GM participated in the **EIT Raw Materials event**, EIT RawMaterials: 3rd Greek Raw Materials Community Dialogue, organized by the EIT RawMaterias HUB – Regional Center Greece – (RCGREECE), in **December 4-5, 2018**, in Athens, Greece. GM presented its activities in Magnesite recovery from old tailings and how this ties in with the LIFEPOSITIVEMgOFGD project.

- GM also updated the participants on the latest developments, progress and results regarding the LIFEPOSITIVEMgOFGD Project in **Magnesite Producers Assembly (05/10/19),** Brno Czech Republic.

- Throughout the project, GM had special relations with **Magnesitas Navarras** - LIFE13 ENV/ES/000605-LIFESO2ZEROEF. GM especially draw from their experience on a project that has very similar background to LIFEPOSITIVEMgOFGD.

<u>Perspectives for continuing the action after the end of the project (Action D1):</u>
The contact with the project's target audience will be maintained. This includes:

- Euromines,
- IPPC Bureau,
- Greek Ministry of Climate and Change
- other major stakeholders identified through the project.
-

Main dissemination tools and actions will continue:

- Distribution of Layman's Report
- Website update
- Project video promotion
- Noticeboards
- Site visits
- Greek LIFE Task Force events
- Presentation of results in sectorial events (Magforum) and conferences

Achieved **<u>progress indicators:</u>**
- 68 average monthly hits in the website with a total of 2.471 sessions
- 1.925 individuals on the website (Target was 1000)
- 3 contacted national authorities and 19 contacted other stakeholders (Targets were 3 and 6 respectively)

6.2 Main deviations, problems and corrective actions implemented

Find below indicated the main deviations, problems and implemented corrective actions during the project:

Methodological deviations

The main deviation was the preparation of the **procurement (open tender**) of most of the prototype and durable equipment goods through an Open Tender procedure instead of a Bidding procedure (foreseen by the GA), as most of the equipment and prototype in question are indivisibly related from a technical point of view and had to be procured under the same tender. Since the related total contract amount exceeded 130.000€, an open tender procedure was followed.

Since GM is a private entity and its internal rules for purchasing do not provide for an open tender, GM was not familiar with this procedure. Moreover, the Greek rules had been analysed also, but no legislation related to open tendering procedures for private entities was found. Therefore, GM had to develop a methodology that had to be checked with EASME, with the advice of NEEMO.

This resulted in a more complex and time-consuming procurement process than anticipated. However, there was only **a minor delay in the installation of the pilot unit (15/02/18 instead the envisaged 31/12/17)**. Commissioning was concluded on 28/2/18. GM devoted significant effort to achieve such a minor delay and not to upset the project's programming.

Managerial deviations

Some minor managerial deviation occurred throughout the project that did not have an impact on the project itself. Minor modifications to the reporting schedule. No Grant Agreement amendments were required.

Implementation deviation

According to original planning, the pilot plant would be able to operate dually: both as a dry desulfurization system and as a semi-dry system. The latter refers to the use of a sorbent slurry in the system. In particular, GM envisaged a conditioning tower able to receive a sorbent slurry when required, instead of plain water. However, during the design phase, such an option proved to be very costly and not practical. Basically, it is possible to design a cooling tower for the use of suspensions but the design of a system for slurry is different to the design for freshwater injection. Moreover, it is not possible to have a conditioning tower alternating between these two modes. The design would have to be dedicated to one option. Furthermore, the evaporation distance of the water in the slurry has to be 3-4 times the distance of a freshwater system (a single droplet evaporates easier than a droplet encapsulating a solid particle). Calculations showed that the cooling tower would have to be 40 m instead of about 12 m, increasing the budget and operating costs significantly. Therefore, it was decided to abandon this option. Project targets were not be affected. No indicators were affected.

The conclusion of Deliverable 2.2 was delayed by one month due to technical issues (April instead of March 2019).

6.3 Evaluation of Project Implementation

The applied methodology adequately followed the project objectives from a technical and economical point of view.

Concerning the **issuing of environmental and installation permits** required by National and European legislation, GM followed all necessary steps in order to obtain them.

Concerning the **purchase of equipment**, it could be argued that an open tender procedure was not considered in the proposal as well as the extra time required to conduct it. However, this issue did not affect the scheduling (with the exception of the minor delay of one month in plant operation) or the cost-efficiency of the project. On the contrary, project implementation became more cost effective concerning the best value for money rule (the selection of one supplier for all main items of the demonstration pilot plant).

Regarding the established indicators at the start of the project, it was foreseen that they will be achieved at the end of the project. An **initial analysis of the baseline** was carried out in order to make proper measurements of LIFE+ indicators. This practice could be considered as a "good practice" of the project. Environmental and socioeconomic impact indicators were evaluated and a strategy to increase socio economic impact was established. Environmental results were immediately visible after the project.

Concerning the **CLM BREF review**, GM met some difficulties in meeting with the stakeholder EIPPCB, identified to influence the next the CLM BREF, because this was not considered a matter of priority for them at the time. Engagement will be possible in due process, when the CLM BREF review commences, in 2021, within the After-LIFE period. To this effect, GM have already prepared the Candidate BAT file for the tested technology, which will be transmitted to the IPPC Bureau in due time and followed up.

Dissemination and communications tasks were carried out in an adequate way and a significant impact has been achieved.

The following table summarizes the objectives and their degree of achievement:

Action	Foreseen in the revised proposal	Achieved	Evaluation
B1: Flow sheet and implementation of the demonstrative installation **B1.1**: Design of the desulfurization installation **B1.2:** Implementation of the demonstrative desulfurization installations	**Objectives:** - To design and implement the new proposed dry desulfurization demonstrative installation that uses MgO as adsorbent reagent in a Rotary Kiln at Yerakini plant. **Expected results:** - Design of innovative desulfurization plant - Implementation of the demonstrative installation	Achieved **progress indicators:** - 1 Demonstration Plant Design - 1 Process Flow Diagram - 1 Mass Energy Balance -1Full-scale implementation	Minor delay of one month for plant installation. Project end dates or deliverables were not affected.
B.2: Validation and determination of operating conditions **B.2.1**: Determination of the operating conditions and optimization **B.2.2**: Validation of the technology and evaluation of the achieved results	**Objectives:** - To carry out the planned industrial tests that will establish the optimum process/operation parameters and demonstrate the technical and economic feasibility of the new technology. **Expected results:** - Reduce the SO_2 emissions below the applicable IED regulation limit - Smooth operation of the desulfurization unit, with a performance of at least 60% - Zero liquid effluents	Achieved **progress indicators:** - Number of individual tests 10 (short term) + 2 (long term) - Flue Gas monitoring monitoring = continuously during the tests and use of half-hour averages - 1 installation and process operation protocol - Reduce the SO_2 emissions below the applicable IED regulation limit - Smooth operation of the desulfurization unit with a performance of 51% - Zero liquid effluents (and 96 % less water spent compared to wet-FGD)	Minor delay of one month (waiting for plant installation). Project end dates or deliverables are not affected. GM made a strong effort to face technical problems and to fulfill ambitious technical objectives (See details in Section 6.1 Action B2) FGD efficiency less than expected.
B.3.1: Characterization and valorisation of the generated waste/residue	**Objectives:**	Achieved **progress indicators:**	Minor delay of one month. Project end dates

B.3.2: Characterization of the residue **B.3.3**: Valorisation of the residue **B.3.4:** Replicability and transferability strategy **B3.5**: Contribution and synergies with strategies of other Union policies	- To determine the exact properties of the by-product, link them to the process conditions mentioned in Action B.2 - To find suitable agricultural and construction applications. - To carry out a Replicability and transferability strategy **Expected results:** - Granulated by-products with minimum 30% sulfate/sulfite content - Validation by end-users - An effective strategy for transfer and replication of results - Exploitation plan	- Granulated by-products out of fertiliser specs for sulfate content, sizing and trace impurities. - Successful Magnesium cement formulation - Fertiliser Application test report - Implication of National authorities and associations =3 - Other stakeholders implication =19 (target:6) - By-product approval by a major European panel producer) - 3 Workshops carried out - Preparation of BAT candidate template - R&T and by-product valorisation planning	or deliverables are not affected. GM has made a strong effort to to find the most suitable techno-economical solution. Technology with restricted R&T potential and sustainability dependent on by-product valorisation rates
C1: Monitoring of the impact of the project actions **C.1.1**: Analysis of initial indicators **C.1.2**: Determination of impact through tracking of indicators	**Objectives:** - To evaluate the level of improvement on the identified environmental problem. **Expected results:** - To accomplish the impact of the project	-Initial refinement of baseline and further elaboration of some targets has been carried out -Impact of the project achieved	According to the initial planning
C2: Monitoring of the socio-economic impact of the project	**Objectives:** - To evaluate the socio-economic impact of the project will be developed. **Expected results:** - To accomplish the socio-economic impact of the project	-Strategy to increase socio-economic impact has been done - Socio-economic impact of the project achieved	According to the initial planning

D: Public awareness and dissemination of results **D1.1**: Dissemination planning and Development of the Dissemination Pack **D1.2** : Networking with other projects	**Objectives:** - To carry out by a Communication Plan, website, Noticeboards Layman's report and Networking with other projects among other tasks. **Expected results:** - Website: 1 - 1000 users of website - Communication Plan: 1 - News releases: Press, Radio and Local TV - Printed Brochures: 1 - Technical article=1 - Workshops=2 + Final Worshop - Participation in Congresses=2 - Notice Boards =3 (Greek and English) - Posters = 6 - Layman’s report = 1 - Networking activities = 3 - 8 committee meetings - Mid-Term Report (month 18) - Progress Report (month 30) - Final Report (month 42+3) - Final audit report - After-life plan	Achieved **progress indicators:** - 1 Communication Plan - 1 Website - 68 average monthly hits - 2.471 sessions - 4.564 download documents - 1.925 users of website - 25 number of contacts stablished by the website - 1 printed brochure - 3 poster - 1 Technical article - 2 conference participations - 4 Notice Boards - 1 Laymans report - 3 Networking activities (contacted projects) - 2 Committee meetings - 10 Project Management meetings - 1 Midterm Report - 1 Progress Report - 1 Final Report - 1 Final audit report - 1 After-life plan	According to the initial planning

6.4 Analysis of benefits

1. Environmental benefits

Burning of fossil fuels produces flue gases rich in Sulfur Oxides (SO_2 and SO_3 or SOx) which are emitted in the atmosphere along with other pollutants. SOx can affect both health and the environment. SOx can harm trees and plants by directly damaging foliage and decreasing growth. Moreover, sulfur oxides can contribute to acid rain which can harm sensitive ecosystems. The largest source of SOx in the atmosphere in Europe are power plants (60% of total emissions in the EEA-33) and the industrial sector (20%), while smaller sources of SOx emissions include ships, vehicles and the heating of buildings. Emissions have been reduced significantly since the previous century have been lately stabilizing to about 5.000.000 tonnes per year.

The main environmental nuisances in the local area come from intensive farming and the mining/metallurgical activities of GM. The latter consist of a) short- and medium-term landscape transformation, b) solid mineral waste and c) air pollution by flue gases. Air pollution is the most prevalent because the rest of the impacts are mediated to a large extent by the company's extensive backfilling and restoration strategy. Flue gases with high SOx concentration are generated by the burning of high sulfur fuels, necessary for the operation of the site's magnesium oxide kilns.

It is known that around the sources of emission (i.e. on a local level), SOx can have direct short- and long-term effects in human health affecting the respiratory system and the function of several organs. Moreover, under certain circumstances, they can also influence the habitat suitability for plant communities, as well as animal life in both local (directly) and long-range (indirectly) levels. For example, SO_3 emissions are a precursor to acid rain with its well-known effects.

The pilot plant operation assures more than 50% reduction in SOx emissions for one of the 3 rotary kilns on site. This reduction corresponds to the 33% of total SOx generated in all the site's kilns, i.e. the operation of the pilot plant has an important positive effect on the whole environmental impact of the mine site. For the Yerakini-Polygyros area the impact is immediate: lower SO_2 emissions mean cleaner air for the benefit of the local population. Although it is not straightforward to assess the exact effect, for the greater Chalkidiki area, a significant reduction of risk of acid rain and the related nuisances can be expected.

Apart from the direct benefit above, the technology has a positive net environmental impact because of the very little amount of water used (96% less than a typical wet-FGD process), the absence of water effluents thus avoiding cross media effects (e.g. pollution of soil and water bodies) and the possibility to valorize almost all the by-product produced (up to 90%), significantly reducing land disposal associated impacts. Moreover, the by-product is not hazardous for the environment and apart from the application of best practices, its land disposal does not require special measures. Finally, the utilization of old stockpiles for the production of the MgO sorbent allows for savings and sound management of valuable natural resources. Table 2 summarises the most important benefits from the plant's operation.

The associated indirect savings of CO_2 emissions and natural resources from the project implementation are given in Table 3 both at the end of the project and after 3 years when by-product valorization rates are expected to maximize.

GM will continue the pilot plant's operation indefinitely because it will cover the kiln requirements for desulfurization and examine the possibility to implement similar techniques for another kiln.

Table 2: Environmental benefits from the plant operation

Parameter	**Unit**	**Value**	**Remarks**
SOx load removed	tpa	520	initial SOx concentration 3.000 mg/Nm^3, attainable FGD efficiency 51,5%
Cooling water consumption	m^3/y	17.640	Water consumption much lower compared to typical wet FGD plants
FGD by-product management	tpa	11.039	• Utilization rate of by-product reaching 90% thus significantly contributing to circular economy • Minimum by-product quantities directed for land disposal • Contrary to the use of other reagents, the generated by-product is not hazardous and does not require special handling for final land disposal
Exploitation of old stockpiles for sorbent production	tpa	21.266	

Table 3: Local Air emissions and raw materials savings (in tons per year)

End of project		**3 Years after**	
CO_2 savings	**Raw Material savings**	**CO_2 savings**	**Raw Material savings**
4.015	25.590	16.438	47.210

2. Economic benefits

No net economic benefits arise from the operation of the pilot plant. The maximized 3-year revenues value will cover 84% of the OPEX.

3. Social benefits

A new Environmental Manager has been employed by GM for the project. Moreover, air quality is related will health and safety, so, local community and GM workers will benefit for this project. Thanks to dissemination and communication activities, awareness about air quality and circular economy has been generated that can benefit a touristic destination such as Yerakini.

4. Replicability, transferability, cooperation

Total implicated NGOs was 22, significantly higher than the targeted value at the end of the project, even higher by 2 than the targeted value 3 years after the project's end.

LIFEPOSITIVEMgOFGD technology has a restricted R&T potential. Concerning Replicability, only one MgO producer have expressed interest in the technology but would only be willing to replicate if a solution is found to increase performance and reduced sorbent consumption. GM will focus on in-site replication to another rotary kiln. For the same reason, as well as due to the low ELVs in other sectors, no transferability is possible either.

By-product valorisation will be realised according to a specific plan which includes in-house valorisation, and identified end-users

Best practice Lessons

The project has developed a strategy to increase Socio-economic impact (Deliverable C1.2) and a Communication Plan (Deliverable D1.1.1). Therefore, good practices will be employed with the deploying of these strategies. Moreover, stakeholder engagement planning was made with a Replication and transferability strategy draft plan (Deliverable B3.5-Month 24) and the revised Replication and transferability strategy (Exploitation plan and Market analysis) (Deliverable B3.6 – month 42). The results of these actions can be appreciated by the following accomplishments and good practices:

- Implication of National authorities and associations =3
- Other stakeholders implication=19 (target:6)
- Take advantage of Magnesite producers Assemblies to present results to the target audience and ensure the participation of GM in next WG to update the **CLM BREF** (2021)
- Cooperation with another MgO producer provide materials
- By-product initially approved **for the production of magnesium oxide panels**
- 2 R&T Workshops carried out
- 1 Final event including a visit to the demonstration plant
- Preparation of BAT template for submission during CLM BREF review
- Inclusion of the project in **2 European initiatives**
- Proper measurements of LIFE+ indicators
- High dissemination activity that achieved a **high number of visits on the website**. Moreover 25 entities contacted through the website
- Joining efforts with **Greek Task Force** in order to achieve a major impact
- **Promotional video** is an attractive format to disseminate results (more than 500 visits up to now)

5. Innovation and demonstration value

The project involves a full-scale demonstration pilot plant implementing a new flue gas desulfurization technique which processes the flue gases of an industrial kiln by utilizing MgO as the main sorbent. Such a use has no application references and offers potential environmental advantages compared to current best practices. The technology reaches an SOx abatement efficiency of 51,5%, achieving emission below 1.500 mg/Nm^3. The **innovative aspects** of the project consist of:

- Use of **MgO** as alkaline **absorbent**, which is not a hazardous substance and has never been used before in dry desulfurization plants.
- The MgO absorbent used is largely produced from old mining waste.
- **The plant has been specifically designed** to accommodate the lower reactivity of MgO towards SO_x. In particular, the desulfurization reactor has been modeled to increase contact time between particle and gas, the recirculation system designed to accommodate higher solid throughputs and the recirculation filter to hold a thicker layer of dust to act as an extra absorption layer. The conditioning tower holds the flue gas temperature in check, in a range that maximizes absorption performance.
- The desulfurization by-product has proven value in Sorel cement formulations. The target is to recycle more than 90% of the generated waste (near to zero waste).
- **Low water consumption and energy consumption** compared to wet scrubbing technologies
- **No risk to transfer pollutants** from air to water.

- **Lower investment cost** and easier to retrofit in existing installations, giving incentives to operators of polluting installations to install environmental protection technologies.

However, the **demonstration value is restricted** due to the low R&T potential and the requirements for high by-product valorisation rates.

6. Policy implications

The Magnesia or magnesium oxide (MgO) production industrial sector (where Grecian Magnesite belongs to) is regulated by the IED and the relevant BREF is the so-called Cement-Lime-Magnesia or CLM BREF and associated BAT.

The current project aims to intervene and include the description of the technology and its results in the CLM BREF during its next revision through the CLM Technical Working Group set up by the European IPPC Bureau (EIPPCB), hopefully during the project's After-LIFE period. The process is supposed to start 8 years after the previous BREF version; therefore, it is not expected until 2021.

It should be noted that the technology does not offer a reduced BAT AEL. However, if the technology is in fact accepted as BAT, it could serve as an operation example and a basis for further development within the sector or elsewhere in the future.

7 Key Project level Indicators

KPIs include several technical/performance indicators related directly or indirectly to SO_2 emissions, desulfurization performance, water and energy consumption, solid wastes generated, reused and recycled. Additional indicators are related to economics, circular economy practices, replicability/transferability, dissemination and networking.

In the next page, Table 4 summarises all the revised key project-level indicators (KPI) and compares them with the originally submitted values, the latter meaning either the GA values or values amended officially at MtR submission.

In the text that follows the table, an extended commentary is provided for each indicator. First, comments and clarifications on the revised values themselves are given and then a discussion/comparison with original values is provided.

To provide an idea on the percentage of accomplished end value targets for the indicators, a count can be made as follows: 56% of the indicators were accomplished, 15% cannot be compared to original submitted ones and 29% are not accomplished.

Table 4: Key Project-level Indicators

No.	Indicator	First/Second Level Descriptors	Revised				Originally submitted				
			Units	Begin Value	End Value	Beyond 3 years value	Units	Begin Value	End Value	Beyond 3 years value	…in
1.5	**Project area/length**	Partial reduction of specific pressures/threats affecting the spatial extent of the project in comparison to the present level	ha	0	2.918.000	2.918.000	Km2	2.918	2.918	25.000	GA
1.6	**Humans (to be) influenced by the project**	Other persons influenced	Number of residents within or near the project area	0	105.908	105.908	Number of residents	105.908	105.908	500.000	GA
2. 2.3 2.3.5 **2.3.5.3**	Water (including the marine environ.) Pressure(s) or risk(s) addressed Resource efficiency-water **Water consumption for production**	The project's environmental or climate action outcomes linked to its main objective	m3/unit produced	8,5	0,24	0,24	m3/year	472.293	55.565	40.000	MtR
3. **3.1**	Waste **Waste management**	01 03 (processing of minerals)/ Mass Reduction due to preparation for reuse	tn/year	21.266	0	0	tn/year	0	12.507	12.507	MtR
		10 01 19 (gas cleaning)/ Mass Reduction due to recycling	tn/year	12.269	10.428	1.227	tn/year	9.482	9.482	8.534	MtR
4. **4.1**	Resource efficiency (including soil, forests and green circular economy) **Resource efficiency-energy**	Electric	kwh/year	1.344.000	630.000	630.000	KWh/SO2	1,60	0,96	0,80	MtR
4. **4.4**	(As previous) **Resource efficiency-circular economy**	10 01 19 wastes from gas cleaning other than those mentioned in 10 01 05, 10 01 07 and 10 01 18/Mass of output of waste per unit produced (or per mass of unit produced)	Kg/Kg of unit produced	0,22	0,16	0,02	-	-	-	-	-
		(As previous)/ Mass of input of actually recycled or reused waste per unit produced (or per mass of unit produced)	Kg/Kg of unit produced	0	0,03	0,16	-	--	-	-	-
		(As previous)/ Number of entities where green circular economy practices are implemented (only if applicable)	n. entities	0	1	6	n. entities for waste and technology	0	2	6	GA

5 5.1 **5.1.2**	Environment and health (including chemicals and noise) Chemicals **Chemicals substitution**	Substitute with chemical from relevant EU legislation and registers	tn/year substituted	0	2.128	4.256	tn/year substituted	0	5.227	31.362	MtR
6. **6.1**	Air **Air-emissions**	SO2/SOx	g/hour	120.000	58.200	58.200	mg/Nm3	4.546	1.500	1.000	MtR
10. **10.2**	Governance **Involvement of non-governmental organisations (NGOs) and other stakeholders in project activities**	Private for profit	number of stakeholders involved due to the project	0	21	21	number of stakeholders	0	6	10	GA
		Public body/bodies	number of stakeholders involved due to the project	0	1	3	number of stakeholders	0	3	10	GA
11. **11.1**	Information and awareness raising to the general public **Website**	Average visit duration (minutes)	number (minutes)	0	2	7	-	-	-	-	-
		No. Downloads	number	0	4.564	10.000	number	0	500	1.000	GA
		No. of individuals	number	0	25	100	number	0	25	100	GA
		No. of unique visits	number	0	1.925	4.000	number	0	1.000	10.000	GA
11. **11.2**	(As previous) **Other tools for reaching/raising awareness of the general public**	Publications/reports	number	0	1	2	number	0	1	2	GA
		Print media	number	0	1	2	no.of copies dist.	0	1.000	3.000	GA
		Other media (video/broadcast)	number	0	1	2	number	0	2	2	GA
		Events/exhibitions	number	0	467	800	number	0	100+300	100+300	GA
		Displayed information (poster, information, boards)	number	0	7	7	number	0	3	3	GA
12. **12.1**	Capacity Building **Networking**	Professionals	no. of individuals	0	30	40	professionals	0	30	30	GA
13.	**Jobs**	Jobs	no. of FTE	0	1	2	no. of FTE	0	1	10	GA
14. **14.1**	Contribution to Economic growth **Running cost/operating costs during the project and expected in case of continuation/replication/transfer after the project period**	Running cost/operating costs during the project and expected in case of continuation/replication/transfer after the project period	€	0	236.680	368.896	€	0	243.948	215.542	MtR
14. 14.2	(As previous) Capital cost expected in case of continuation/replication/transfer after the project	Capital expenditure expected in case of continuation/replication/tra	€	-	-	1.383.825	€	0	1.395.000	1.116.000	MtR

14.2.1	**Capital expenditure expected in case of continuation/replication/transfer after the project period**	nsfer after the project period									
14. 14.2 **14.2.4**	(As previous) (As previous) **Cost reduction expected in case of continuation/ replication/transfer after the project end**	Cost reduction expected in case of continuation/ replication/transfer after the project end	€	-	-	0	€	0	0	105.000	MtR
14. **14.3**	(As previous) **Future funding**	Beneficiaries' own contribution	€	-	-	368.986	-	-	-	-	-
14. 14.4 **14.4.1**	(As previous) Continuation/replication/transfer after the project period **Entry into new entities/projects**	Replication, Continuation		-	0	1	Number	0	0	2	GA
14. 14.4 **14.4.2**	(As previous) (As previous) **Entry into new sectors**			-	0	0	Number	0	0	2	GA
14. 14.4 **14.4.3**	(As previous) (As previous) **Entry into new geographical areas**			-	0	5	Number	0	0	3	GA

1.5 Project area/length

The end value is an area equivalent to the prefecture of Chalkidiki were the Yerakini mine site is situated. Beyond 3 years value is the same area assuming no replication for the next 3 years. Original end value the same, in different units. Target accomplished. The original beyond 3 years value was multiple times higher because it assumed replication/transfer to other locations.

1.6 Humans (to be) influenced by the project

The end value is the population of the prefecture of Chalkidiki were the Yerakini mine site is situated. Beyond 3 years value is the same population, assuming no replication for the next 3 years. Target accomplished. The original beyond 3 years value was multiple times higher because it assumed replication/transfer to other locations.

2.3.5.3 Water consumption for production

Units are given in m3 of water consumed per unit (i.e. ton) of product exiting the kiln the flue gases of which are desulfurized (i.e. kiln productivity). Begin value refers to wet FGD. To compare these to the originally submitted values, a change of units is required, i.e. to m3/year (= [m3/unit] x [unit/year=kiln production capacity]). The revised values become then, 472,293/17,640/17,640 m3/year, much lower consumption than targeted. Therefore, target is accomplished.

3.1 Waste management

01 03 (processing of minerals). Value at the beginning is the actual current rate of old stockpile material available in the mine used to produce the MgO sorbent. This decreases over time reuse increases. End of project = 0 means that all this quantity is currently utilized. Original indicator was different and was referring just to the rate of stockpile reuse without this “decreasing” quality. However, comparison can be made between the actual numbers 21.266 vs 12.507, i.e. much higher reuse rate than envisaged. Target is considered accomplished.

10 01 19 (gas cleaning). Value at the beginning is the actual current rate of by-product generated by the pilot plant; this decreases, corresponding to by-product valorisation. Value at the end of the project is decreased by 15% due to its current valorisation, planned to go up to 90% beyond 3 years, hence the value there is only 10% of the original. Original indicator was different and was referring just to rate of by-product generation without making assumptions about its recycling. In any case, by product generation is 12.269 vs the envisaged 9.482. However, since the end value is still high, due to low recycling rate, the target is considered not accomplished. This will change for the beyond 3 years period.

4.1 Resource efficiency-energy

Begin value refers to an equivalent wet FGD electricity consumption. End and beyond 3 years values, reflect absolute consumption of the pilot plant in KWh/year, reduced by more than 53%. Note that the original indicator was of different units, therefore a transformation of the revised values is required on the basis of the relationship [kWh per year] = [KWh/kg SO2] x [kgSO2/year]. One can therefore transform the reported values to 1,60/1,21/1,21 [KWh/kg SO2 removed], respectively. Now reduction compared to an FGD plant becomes 25% reduction. Originally submitted values were 1,60/0,96/0,80 [kWh/kg SO2 removed], so the pilot plant consumes more energy than planned. Target is not accomplished.

4.4 Resource efficiency-circular economy
10 01 19 – mass of output of waste. This is the ratio of the 3.1 indicator to kiln productivity. Not originally submitted per se.
10 01 19 – mass of input of recycled/reused waste. This is the ratio of the rate of recycled material (can be inferred from 3.1) to kiln productivity. Not originally submitted per se.
Number of units produced. Refers to the productivity of the kiln and serves as the denominator for the above calculations.
Number of entities/green circular economy practices. This is the sum of entities that implement the technology or use the valorised by-product. End value is 1, referring to GM, falling short of the original target where 2 was envisaged. The target is not accomplished. The target of 6 for beyond 3 years, remains valid as efforts for securing by-product end users will intensify.

5.1.2 Chemicals substitution
Reflecting the equivalent hypothetical consumption of hazardous hydrated lime (EC number 215-137-3) in a dry FGD plant. Beyond 3 years reflects 1 replication within the plant. The values fall short compared to the original submitted, target is not accomplished.

6.1 Air-emissions
The value of 120.000 g/h at the beginning is taken to be the SO_2 flow entering the pilot plant which is reduced to 58.200 at the exit. No further decrease is expected for beyond 3 years. Original submitted indicator was of different units (mg/Nm3), however the envisaged emission of 1.500 mg/Nm3 is accomplished (1.455 mg/Nm3), hence target accomplished, although desulfurization efficiency is lower.

10.2 Involvement of non-governmental organisations (NGOs) and other stakeholders in project activities
Private for profit. End of the project, the NGOs are 21: The indicator is not expected to increase in the 3 years after. This result is significantly higher than the 6 (end) and 10 (3 years) originally submitted. Target is accomplished.
Public Bodies. End of the project, the only one involved is the Greek Ministry of Environment. DG Environment and EIPPCB were also contacted. EIPPCB especially, denied implicating themselves further, before the official commencement of the CLM BREF review process. Target not accomplished. The indicator will increase to 3 after 3 years with the inclusion of DG Env and EIPPCB.

11.1 Website
Average visit duration. No comparison can be made, this is a new indicator
Downloads. Significantly higher than targeted. Accomplished.
Individuals. Accomplished.
Visits. These are unique number of visits. They are significantly higher than originally submitted, even given the fact that the old indicator referred to total visits and not unique. Accomplished.

11.2 Other tools for reaching/raising awareness of the general public
Publications/reports. The end value corresponds to the Layman's report. Target accomplished.
Print media. Layman's report (LR) was also printed out to hardcopies, hence the indicator of 1. No comparison can be made with original value due to a change in units. The old indicator was 1.000 copies, while the LR was printed only to 100, since the 1.000 was considered an exaggeration given the availability through electronic media. Target can be considered accomplished.

Other media. 1 project video was made compared to 2 originally submitted. Target not accomplished.
Events/exhibitions. The units are in a No. of people. The value is the summation of attendance in Workshops (167) and conferences (300) higher than the original value of 100 + 300 = 400. Target is accomplished.
Displayed information. This value refers to the summation of 4 Notice Boards + 3 posters, much higher than originally targeted. Target is accomplished.

12.1 Networking

The number of professionals in the networking efforts of the project is 30, same as the original target. Target accomplished.

13. Jobs

During the project, one new full-time position was covered (new Environmental Manager). Target accomplished. For the 3 years after period it is expected that one more full-time position will be created, so the indicator is expected to increase to 2, significantly lower than the value of 10 originally submitted (which assumed replication/transfer outside GM).

14.1 Running cost/operating costs during the project and expected in case of continuation/replication/transfer after the project period

The values are actually €/year. The end value reflects the running costs of the project per se and not the operating cost of the pilot plant (OPEX) while the beyond 3 years value is the net OPEX assuming 90% valorisation of by-product. The end value matches closely the original submission (i.e. the program budget for personnel, travel, consumables, other, overheads divided by the project duration), i.e. target accomplished. The beyond 3 years value is 70% higher than originally submitted.

14.2.1 Capital expenditure expected in case of continuation/replication/transfer after the project period

The beyond 3 years value is per adopting plant. Compared to the original submission, this is increased by 24%. The target is considered accomplished.

14.2.4 Cost reduction expected in case of continuation/ replication/transfer after the project end

No reduction of cost is expected. Initially estimated cost reduction was assumed on the basis of replication of FGD. Target not accomplished.

14.3 Future funding

Regarding the continuation of the Yerakini pilot plant, the indicator reflects reflects Grecian Magnesite's own yearly funds in order to cover the rest of the net OPEX after 3 years. There was no original submission of this indicator to compare to, but since the value depicted in the table is reasonable, the target is considered accomplished.

14.4.1 Entry into new entities/projects

Target not accomplished.

14.4.2 Entry into new sectors

See 14.4.1, target not accomplished (0 vs 2 originally submitted).

14.4.3 Entry into new geographical areas

Although no replication beyond the Yerakini site can be foreseen, entry into new geographical areas can be made through sales of the by-product in panels, fertilisers and other. This is higher than the original target, therefore it can be considered as accomplished.