NTUA Research Team
NATIONAL TECHNICAL UNIVERSITY OF ATHENS

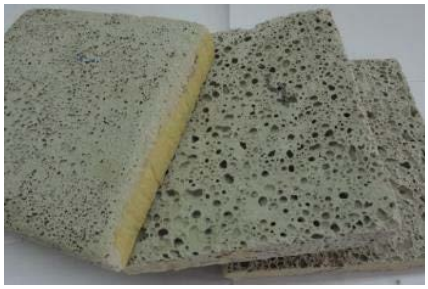
Raw Materials Exploitation & Sustainable Energy Solutions

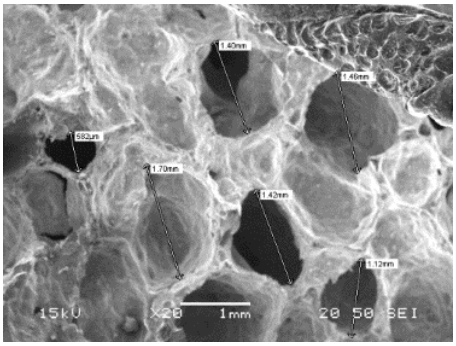
Overview:

The activities of "Raw Materials Exploitation & Sustainable Energy Solutions" NTUA team are mainly focused on research and technology development in the field of extractive industries, including development of energy efficient processes, processing technologies for ores and industrial minerals, design, simulation and techno-economical and environmental footprint evaluation of new production processes, design of environmental protection processes and synthesis of high added-value materials from ores and industrial minerals. Only in the last 10 years, the team was involved in more than 30 National and European research projects, attracting in total more than 10 million Euros in funding and producing more the 300 scientific publications in international journals and international scientific conferences. The approved research funding of the team for the next 3 years is 6 million euros. Furthermore, the team is a Partner in EIT Raw Materials.

Raw Materials sector:

The team has gained considerable expertise and reputation in the field of construction materials research, which can be proven from the number of research projects and publications in the field. In LEEMA project the team has developed and tested novel inorganic polymer materials suitable for insulating both new and retrofitted buildings, based on mineral wastes and industrial by-products. In EASEE EU-FP7 project a new, inorganic Synthetic Perlite was developed to be applied as bulk insulation in cavity walls by using mainly mineral wastes, recycled materials and industrial by-products. In the framework of ECO-Binder H2020 project the team is developing a new generation of mortars/plasters, based on common binding systems and innovative insulating fillers, aiming at new, totally inorganic, energy efficient finishing solutions with improved insulating properties and suitable for applications where fire resistance is a prerequisite. Significant results were also obtained through its participation to NU-ROOF and Cool Coverings projects targeted on the improvement of the NIR reflective properties of covering materials, by developing paints and coatings for roofs and facades.





In the field of extractive industry the team coordinates EURARE EC FP7 Collaborative project for the Development of a sustainable exploitation scheme for Europe's Rare Earth ore deposits and SCALE H2020 project for the Production of scandium compounds and scandium aluminium alloys from European metallurgical by-products. The team also participates in H2020 projects like ENSUREAL: Integrated cross-sectorial approach for environmentally sustainable and resource-efficient alumina production and SIDERWIN: Development of new methodologies for industrial CO2-free steel production by electrowinning.

The team is a member of the EIT Raw Materials community with current participation in 9 funded projects while in Horizon2020 the team participates in 5 projects (Minland, MIREU, MIN-GUIDE, SCREEN, MSP-Refram) related to policy guidance and networking. Team leaders have an active role in the sector through their participation on the Ad-Hoc working group of SHERPA Group on the Raw Materials Score Board, being a member of the ERECON group and of the Operational Group 1 of the EIP on RM.

Energy efficient processes

The team operates an energy self-sustained building H2Sus (525 m^2) with zero CO_2 emissions, which is harvesting energy from RES and stores it in high pressured H2, based on an intelligent hybrid energy system. The building is situated in Lavrion Technological Park which hosts two solar parks, wind generators and battery storage banks. In the local district the team has installed intelligent energy monitoring equipment and BMS at two buildings for evaluating technological solutions for sustainable energy management. These facilities enabled the successful implementation of H2SusBuild FP6 project and AMBASSADOR (FP7-2012-NMP-ENV-ENERGY-ICT-EeB) Autonomous

Management System Developed for Building and District Levels research project. During this period a SmArt BI-directional multi eNergy gAteway (SABINA), Horizon2020 project is planned to implemented on the site.At the University Campus in Athens, the team operates and evaluates a demonstration plant with customizable size PV modules installed under the framework of Construct- PV, (FP7-ENERGY-2011-2)

Life cycle assessment

The team provides also life cycle assessment (LCA), cutting-edge services in environmental foot printing, eco design, sustainable supply chains and environmental communication by using SimaPro and GaBi software. For example in LoCoMaTech (H2020) project a Low Cost Materials Processing Technologies for Mass Production of Lightweight Vehicles is going to be evaluated through LCA. In ENTHALPY (FP7) LCA was combined with Process System Engineering for the dairy production chain for 16 possible routes combining conventional and innovative technologies. LCA studies were applied to ECOSTONE (LIFE+ 08 EN), AXIOMA (NMP-2008-4.0-8), I-STONE (FP6-2003-NMP) and LICYMIN (EC Growth, 2000).

Facilities and equipment / or services

Team laboratories are equipped with modern equipment for:

- **Full physicochemical characterization** using ICP-MS, ICP-OS, XRF, UV spectrometer, XRD, FTIR, SEM, TEM, EDS, TG/DTA/DSC, laser particle analyser, BET specific surface analyser and carbon and sulfur analyser (LECO).
- **Construction material testing** measuring compressive strength, bending strength, thermal conductivity(meets the industry standards ASTM C518, ISO 8301, JIS A 1412, DIN EN 12939, DIN EN 13163 and DIN EN 1266), material testing in climatic chambers, thermal emittance, solar reflectance (on a UV-Visible-NIR Spectrophotometer, complied with ASTM E903), determination of the solar reflectance index.
- **Mockup testing for construction materials**
- **Raw materials preparation and mineral processing** with jaw crushers for primary crushing, rotor ball mills for secondary crushing, mills for grinding and equipment for screening and separation.
- **Processes upscaling** for insulation/ construction materials and also for pyrometallurgical and hydrometallurgical processes.
- **Engineering simulation** using complementary tools such as TRNSYS, SuperPro, ANSYS and FLUENT.
- **Environmental impact assessment** using dedicated software (Gabi and Simapro) for Life Cycle Assessment, enabling modelling approaches through systems Engineering Life Cycle.

	Team Leaders		
@	***Prof. Ioannis Paspaliaris*** paspali@metal.ntua.gr	***Prof. Dimitris Panias*** panias@metal.ntua.gr	***Assist. Prof. Maria Taxiarchou*** taxiarh@metal.ntua.gr

Few samples of our activities at YouTube:

https://www.youtube.com/watch?v=4q1KqNQMlRA	**[SCALE, Euronews broadcast]**
https://www.youtube.com/watch?v=sX_y17Ob9bAv	**[3rd part of the video, H2SUSBUILD, Euronews broadcast]**
https://www.youtube.com/watch?v=UKsR15S7a1U	**[Enexal Project]**
https://www.youtube.com/watch?v=4mfZKvpK1UI	**[NanoHVAC Project]**
https://www.youtube.com/watch?v=lrr-DGjEY-c	**[Ambassador]**
https://www.youtube.com/watch?v=fZPguP1jJuY	**[LEEMA]**

National Technical University Of Athens

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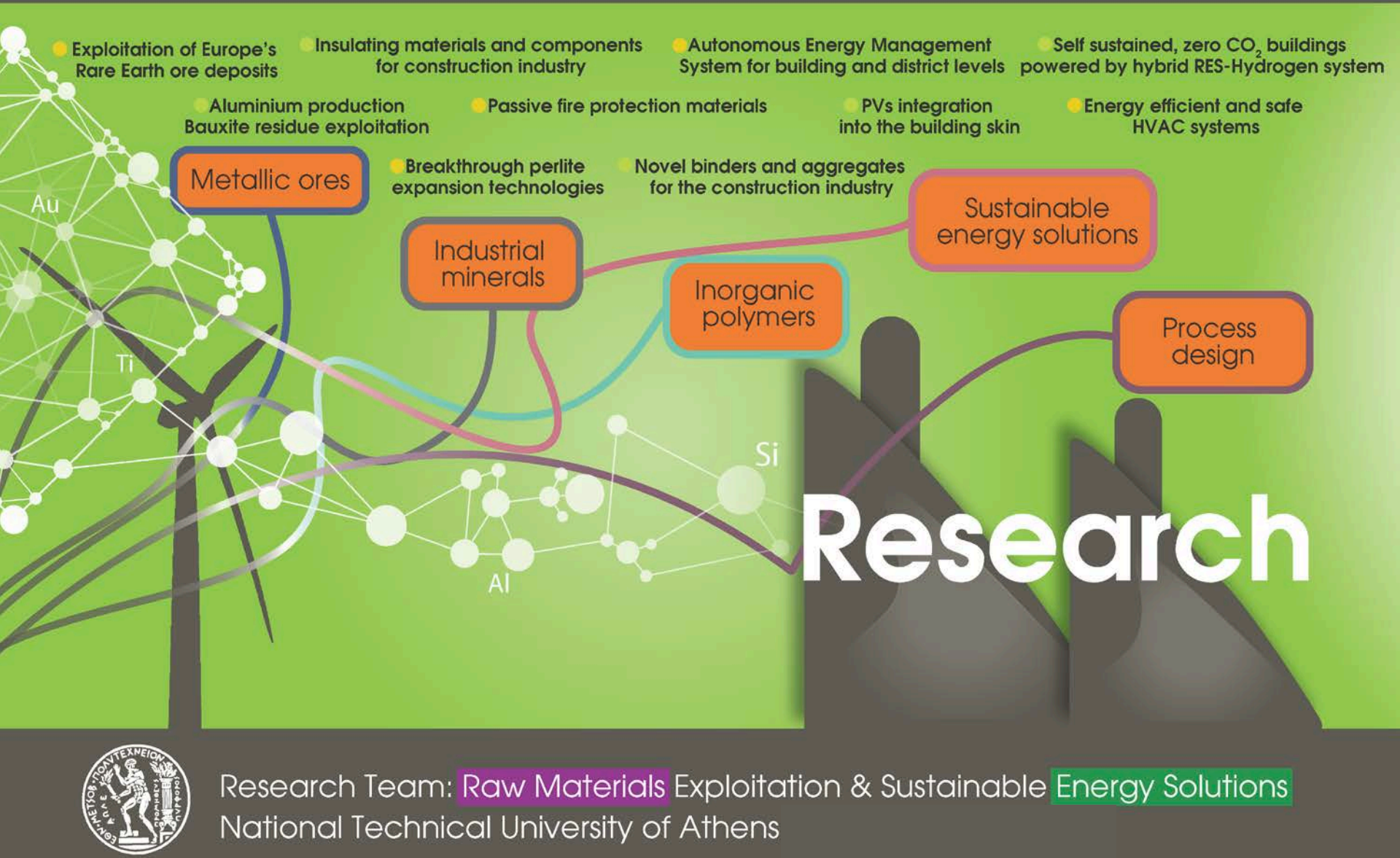

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KNOWLEDGE PRODUCTION

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Funding in the last 5 years: > **12M €**

According to the **European Research Ranking, 18% of the total research budget of NTUA** (new contracts signed in 2013 under FP7) **is related to our team**.

Since 1990 **more than 90 research projects have been undertaken**, 35 national and 55 international (mainly from the EC).

Research activity over the last 10 years have resulted in more than **200 original research publications**

KNOWLEDGE PRODUCTION

NTUA is ranked **3rd on "Energy" FP7 Thematic priority**

- ✓ Has a notable performance with strong overall scores but particularly for **Specialisation Index [SI]** (an indicator of research intensity in a given research area)
- ✓ Has one of the **highest ARIF scores (1.69)** a field-normalised measure of the scientific impact of publications produced based on the impact factors of the journals in which they were published and is clearly specialised in energy

Table XXXV Scientific performance as measured in Scopus for the selected 25 ERA universities in Energy (2007–2011)

University	CC	Pubs (FULL)	Pubs (FRAC)	Con by Univ Hosp (%)	SI	ARC	ARIF	Top 10 (%)
World		237,368	237,368	n.c.	1.00	1.00	1.00	10.0
Total ERA		58,969	51,788	n.c.	0.68	1.40	1.33	14.6
Univ of London, Imperial Coll London	GB	889	579	0	1.19	1.68	1.45	17.0
DTU-Technical University of Denmark	DK	783	540	0	2.96	2.82	1.69	30.4
TUDelft - Delft University of Technology	NL	702	461	0	1.85	0.75	1.19	7.9
Royal Institute of Technology	SE	692	426	0	2.38	1.42	1.44	16.4
University of Manchester	GB	643	409	0	0.98	1.68	1.44	14.0
NTNU - Norwegian Univ of Sci and Tech	NO	564	345	0	1.95	1.45	1.28	13.5
École polytechnique fédérale de Lausanne	CH	551	292	0	1.36	1.83	1.47	19.0
Chalmers University of Technology	SE	512	328	0	3.01	2.39	1.62	23.8
Polytechnic University of Milan	IT	509	359	0	2.19	1.15	1.16	11.9
Politehnica University of Bucharest	RO	493	368	0	3.54	0.42	0.46	2.1
Katholieke Universiteit Leuven	BE	471	193	0	0.50	1.37	1.18	11.1
NTUA - Natl Tech University of Athens	GR	462	343	0	3.01	1.85	1.69	16.1
ETHZ-Swiss Federal Inst of Tech Zurich	CH	439	245	0	0.73	2.05	1.55	27.1
University of Cambridge	GB	410	267	0	0.52	2.28	1.78	25.8
Polytechnic University of Turin	IT	408	278	0	2.20	1.21	1.28	10.5
Technical University of Lisbon	PT	404	215	0	1.41	1.90	1.44	25.1
Pierre and Marie Curie University	FR	388	179	0	0.46	1.55	1.67	17.1
Polytechnic University of Valencia	ES	368	269	0	1.78	1.27	1.50	10.3
Aristotle University of Thessaloniki	GR	332	228	0	1.16	1.71	1.51	21.5
RWTH Aachen University	DE	329	190	0	0.79	1.19	1.42	11.9
UNIROMA1 - Sapienza University of Rome	IT	319	191	0	0.63	2.02	1.66	28.6
University of Leeds	GB	287	195	0	0.78	1.91	1.55	19.7
Uppsala University	SE	283	171	0	0.77	1.77	1.71	20.9
Aalto University	FI	282	178	0	1.26	1.77	1.56	18.7
Joseph Fourier University	FR	281	159	0	1.02	2.30	1.66	26.4

Note: *Ibid.*
Source: Computed by Science-Metrix using Scopus

Data extracted from "Scientific Output and Collaboration of European Universities"
European Commission, 2013

INFRASTRUCTURE

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1600 m^2 of total laboratory space + Demonstration site

Equipment for:

- Chemical and mineral analysis – measuring physicochemical parameters
- Hydrometallurgical Processing
- Pyrometallurgical Processing
- Environmental Protection and Soil Remediation
- Pilot Scale Technology Demonstrations

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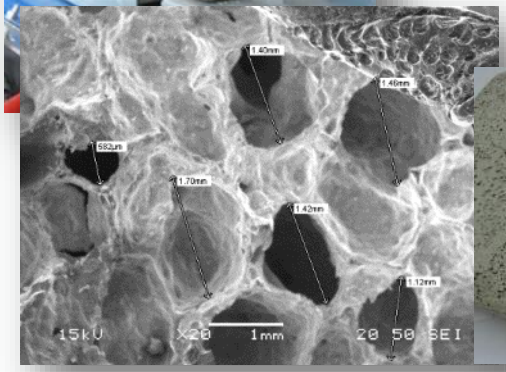
RESEARCH ACTIVTIES – Targeted applications

LEEMA
Low Embodied Energy Insulation Materials

Scientific coordination

Low Embodied Energy Advanced (Novel) Insulation Materials and Insulating Masonry Components for Energy Efficient Buildings

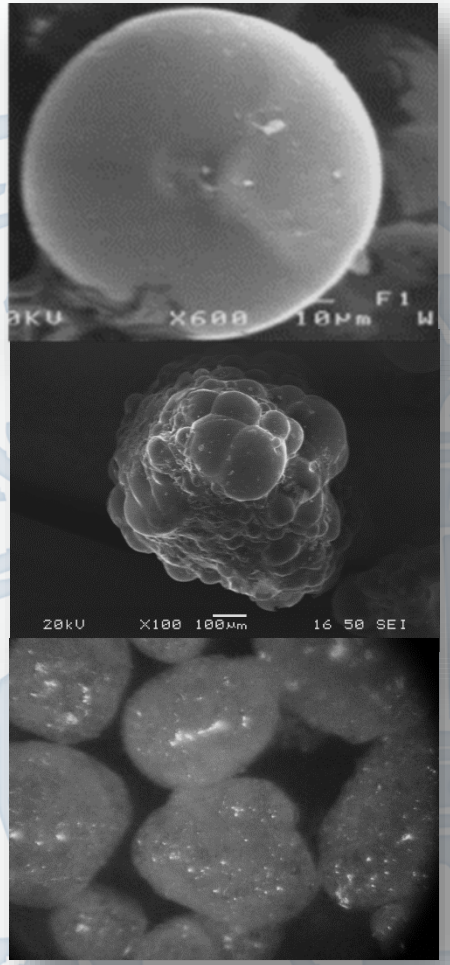
- Significant reduction of the embodied energy at component level
- 15% cost reduction compared to existing solutions
- Improved durability
- Improvement of the quality of the building indoor environment



Lightweight aggregates

Inorganic materials produced from minerals with the following properties can be tested

- ✓ Bulk density: 50-300 kg/m^3
- ✓ Thermal conductivity (depends on bulk density): Materials 0,034 W/m.K (minimum) has already developed
- ✓ Good mechanical properties
- ✓ Low water adsorption
- ✓ Lab experiments have shown good compatibility with cement
- ✓ Fire resistant materials
- ✓ Embodied energy much lower than polystyrene beads



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RESEARCH ACTIVTIES – Construction industry

SUStainable, **innovative and energy-efficient CONcrete**
based on the integration of all-waste materials

The increase of EU competitiveness requires new ideas, innovative and cost-effective products and self-sufficiency in materials and processes. The environmental protection policy demands that all technological achievements should be as environmentally friendly as possible with as low embodied energy as possible. The challenge for the construction sector therefore is dual: the development of original, high added value products based on EU resources that will also be eco-sustainable and eco-friendly. The SUS-CON project meets the challenge by introducing a **waste-based lightweight concrete** with **improved thermal, acoustic and insulation performance.**

DESIGN FLEXIBILITY

Custom made products designed according to application

PRODUCTS	Compressive strength (MPa)	Thermal conductivity (W/mK)
GEO screed underlay_P-18	11,50	0,180
GEO panel_P-17	6,50	0,167
GEO block_P-31	8,50	0,311
GEO block_P-21	15,00	0,205
GEO block_P-16	5,50	0,157
GEO panel_R-35	7,00	0,344
GEO block_R-27	18,00	0,266
GEO block_T-32	4,00	0,323
Perlite Geoblock_P	4,00	N/A
Perlite Geopanel_R	6,00	N/A

DEMONSTRATION ACTIVITIES

Production of prefabricated elements (compatible with conventional production practices)

Mockup assembling for online monitoring and product evaluation

Benefits - Impact

- Wastes exploitation
- High-added Value
- Lightweight
- Improved Thermal Properties
- Low CO_2 footprint
- Low Embodied Energy

SUS-CON

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RESEARCH ACTIVTIES – Construction industry

Development of insulating concrete systems based on novel low CO_2 binders for a new family of ecoinnovative, durable and standardized energy efficient envelope components

CONCEPT

The overall concept of the project builds on previous research on new cement binders to develop a novel family of low CO_2 binders based on Belite, Ye'elimite and Ferrite phases (BYF cements). In BYF technology, the superior early age strength contribution of calcium-sulfo-aluminates (CSA) is combined with durability provided by belite. The raw materials and the production process for BYF cements, are similar to those of Portland cement (OPC), but the CO_2 emissions are lower as shown in preliminary LCA calculations due to:

- **lower calcium content of the raw materials (less limestone usage)**
- **lower clinker burning temperature of around 1250 - 1300°C**
- **lower grinding energy demand**

These same factors also results in a significantly lower embodied energy than OPC.

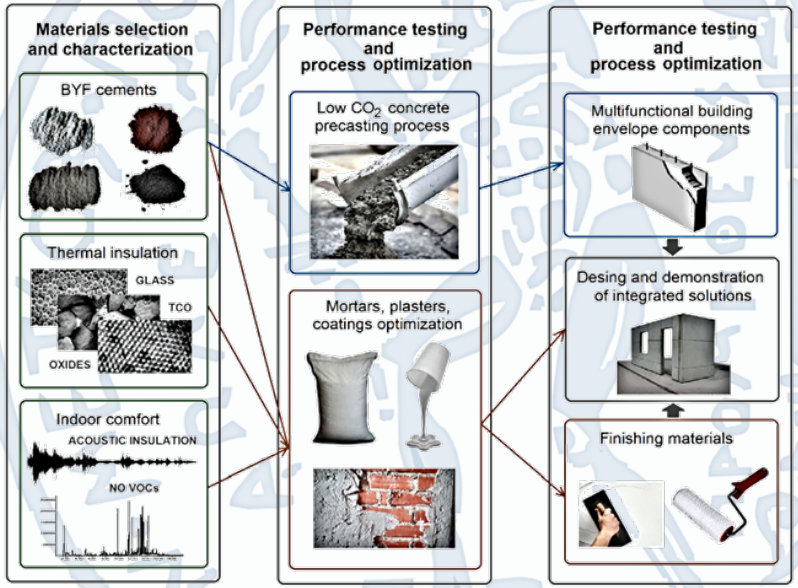
Combining these novel binders with insulating materials and advanced functional finishing methods will permit the development of novel concrete systems with low CO_2 and low embodied energy suited for a wide range of envelope components, without compromising technical, health and environmental standards.

Material science research on BYF cement and concrete and on advanced finishing materials like mortars, plasters, paints or coatings, will lead to the development of concrete elements with reduced embodied energy, improved insulation properties and providing multifunctional surface properties like:

- **thermal reflection**
- **anti-stain**
- **antibacterial**
- **self-cleaning**

METHODOLOGY

The barycenter of the project lies on innovation activities and bridging barriers to market for building envelope components made with low CO_2 BYF binders. The overall methodology is conceived to bring results from materials science research and apply them into industrial applications, with a strong market oriented approach.



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RESEARCH ACTIVTIES – WHOLE CHAIN

Novel technologies for enhanced energy and exergy efficiencies in primary aluminium production industry

Overall coordination

- ✓ Complete Bauxite Residue Treatment for the Production of Pig-iron and Mineral Wool Products
- ✓ Carbothermic co-reduction of alumina and silica

Re-engineering of natural stone production chain

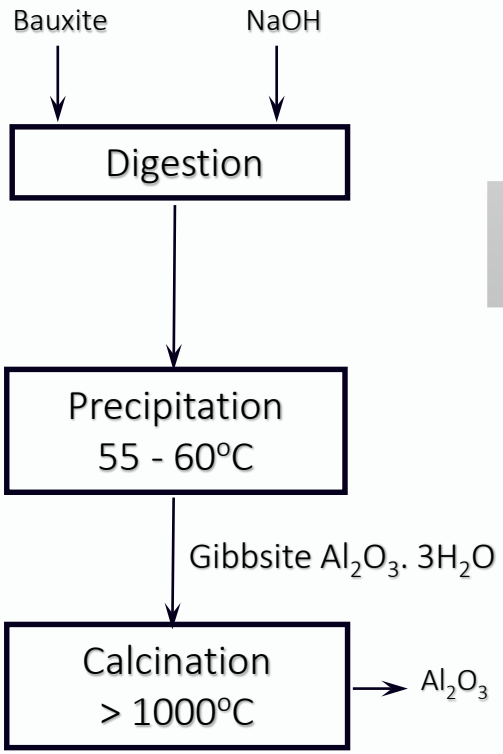
Scientific coordination

New technologies and machines which reduced the wastes generated from the whole production chain by 30%

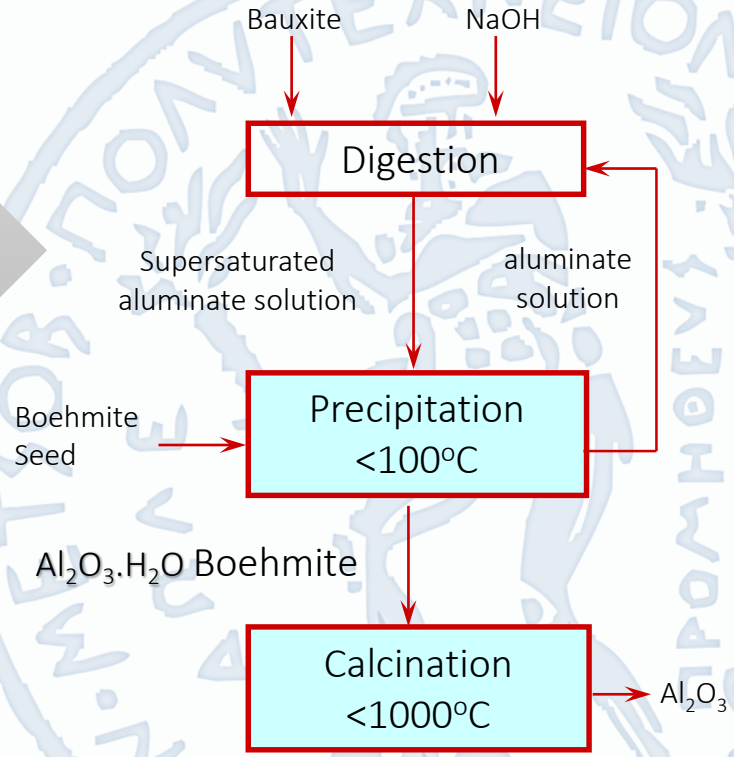
Alumina production: 1.8 GJ/ton Al_2O_3 less energy for calcination

Patent

CONVENTIONAL METHOD



INNOVATIVE METHOD



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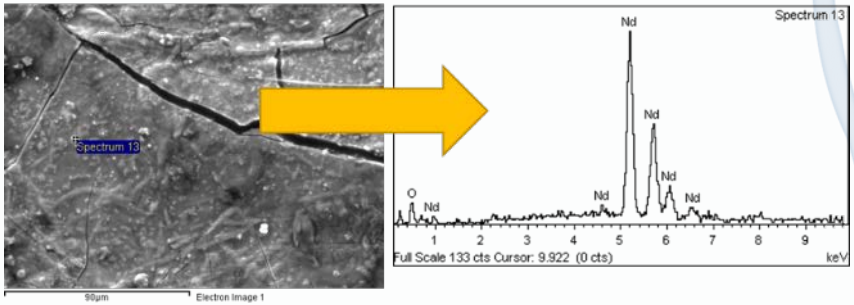
RESEARCH ACTIVTIES – Extractive technologies

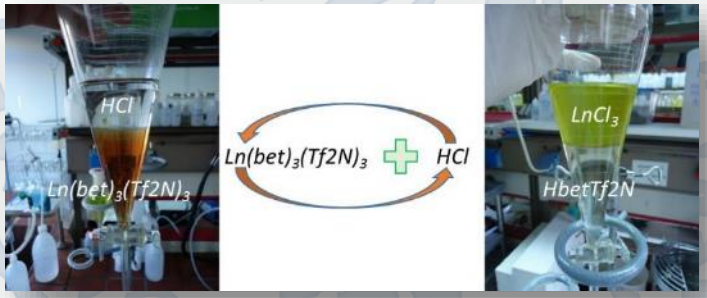
eu Rare 57-71 sustainable exploitation

Overall coordination

Development of a sustainable exploitation scheme for Europe's REE ore deposits"

- Leaching of REE from primary and secondary resources using ionic liquids (ionometallurgy)
- Electro-recovery of REE from ionic liquids (Ils) at near room temperature





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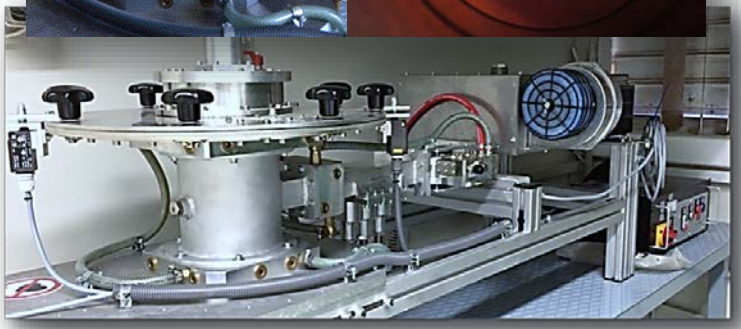
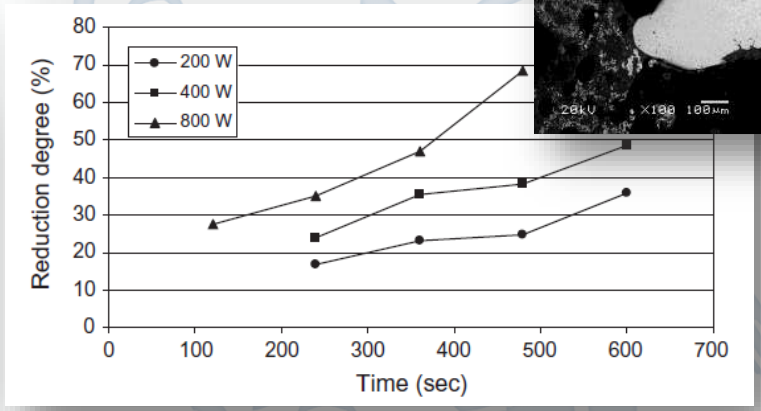
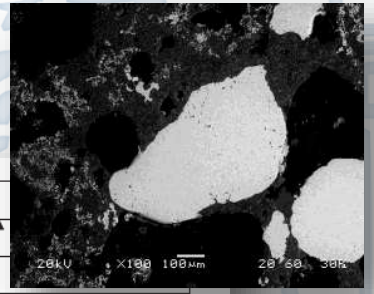
RESEARCH ACTIVTIES – Extractive technologies

Application of microwaves in pyrometallurgy

- Reductive roasting of a nickeliferous laterite
- Reductive roasting of a red mud residue







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RESEARCH ACTIVTIES – Environmental Technologies

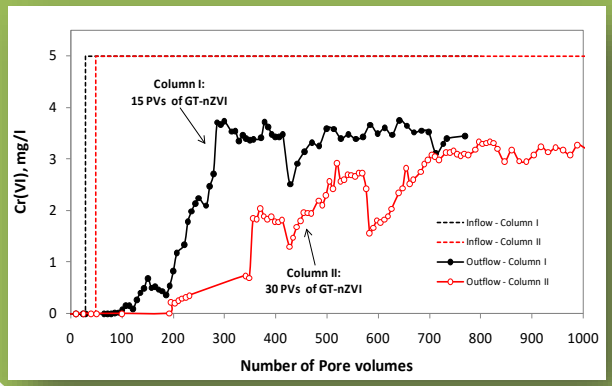
Novel Technologies for Soil Remediation and Ground Water Purification

Overall coordination

Treatment of Cr-VI polluted ground water (Asopos region)

- Synthesis of nanoparticle iron nZVI with herb extracts
- Development and in-situ demonstration of the nZVI purification technology

Lab scale kinetic leaching tests in column reactors



In-situ demonstration

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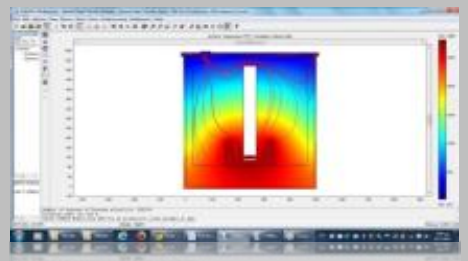
TECHNOLOGY SCALING UP

RESEARCH – TECHNOLOGY DEVELOPMENT – INDUSTRIAL SCALE

Design and Modelling	Pilot testing	Technology demonstration

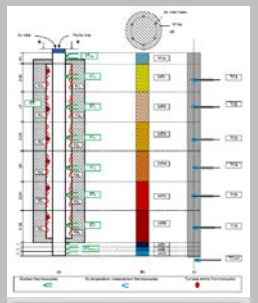
ENEXAL Project

Novel Technologies for Enhanced Energy and Exergy Efficiencies In Primary Aluminium Production Industry



ExPerl Project

Efficient exploitation of EU perlite resources for the development of a new generation of innovative and high added value micro-perlite based materials for the Chemical, Construction and Manufacturing industry



Life Cycle Analysis

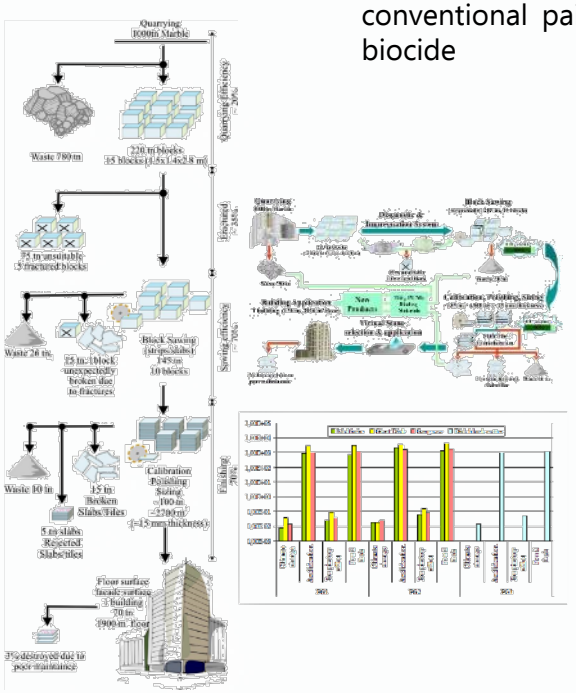
LICYMIN: LCA for ore processing and metal production processes

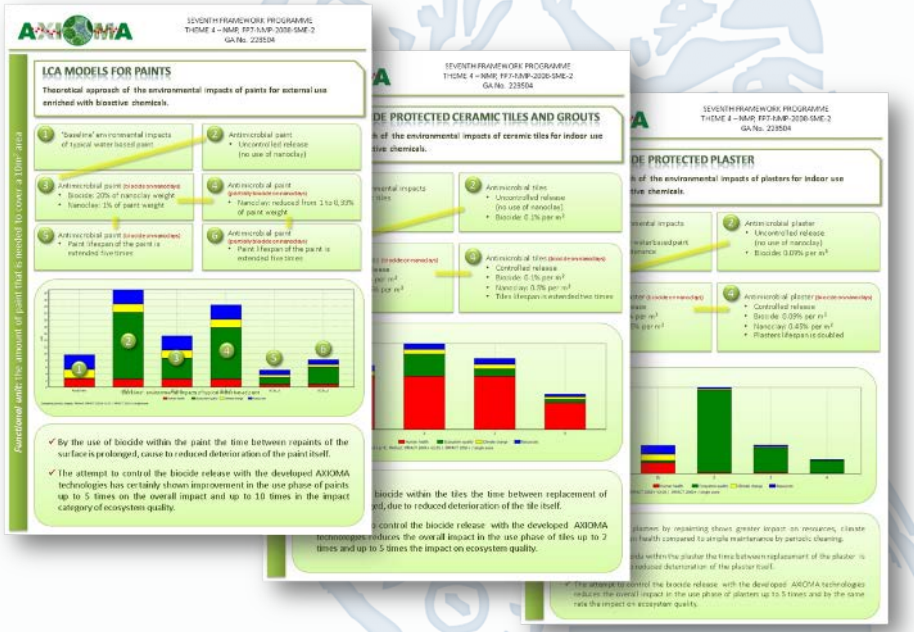
I-STONE: LCA focused on waste management challenges and efficiency optimization of dimensional stone production chain

LIFETIME: LCA analysis of the overall environmental performance of buildings and civil infrastructures

ENVIMAN: LCA combined with risk assessment for polluted sites from mining and metallurgical activities, waste minimization and long term control of rehabilitated sites

AXIOMA: comparative analysis of the environmental footprint (LCA combined with risk assessment) between conventional paints and antimicrobial paints adapting smart release concepts of eco-acceptable biocide





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THEMATIC NETWORKS

- The Laboratory has coordinated and participated in numerous thematic networks
- Research achievements have received media attention (Euronews, RAI, TV5)

- EIT Raw Materials
- Network on European Sustainable Mining and Processing Industries (NESMI)
- European Thematic Network On Extractive Industries) (EUROTHEN) [Coordinator]
- LIFETIME ENGINEERING OF BUILDINGS AND CIVIL INFRASTRUCTURES
- OSNET (Thematic Network on Ornamental Stones) [Coordinator]

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Partnerships

Institutions

euromines
SGU Sveriges geologiska undersökning Geological Survey of Sweden
NGU Geology for Society since 1858
BGS 1835 British Geological Survey NATURAL ENVIRONMENT RESEARCH COUNCIL
IUGS
Geological Survey of Belgium
GTK
GEUS
Geoscience for a sustainable Earth brgm

Technical and scientific consulting services to:

TVX GOLD INC
LARCO
EMED SLOVAKIA
S&B
SCHLAGMANN POROTON
HELLAS GOLD ΕΛΛΗΝΙΚΟΣ ΧΡΥΣΟΣ Α.Ε.

Industries-Companies

FEN MINERALS AS
LCM less common metals
TANBREEZ
DNV
morando
neorem magnets
SMA
Schneider Electric
TASMAN METALS LTD
MEAB
Kemakta Konsult AB
Etex GROUP
EMED MINING
GREENLAND MINERALS AND ENERGY LTD
Thermal Ceramics Insulating Our World
D'APPOLONIA
Outotec
CISCO
Johnson Matthey

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EU policies

European Commission

European Innovation Partnership (EIP) on raw materials

Raw Materials : Study on Innovative Technologies and Possible Pilot Plants

European Rare Earths Competency Network

Third Trilateral EU-US-Japan Conference on Critical Materials

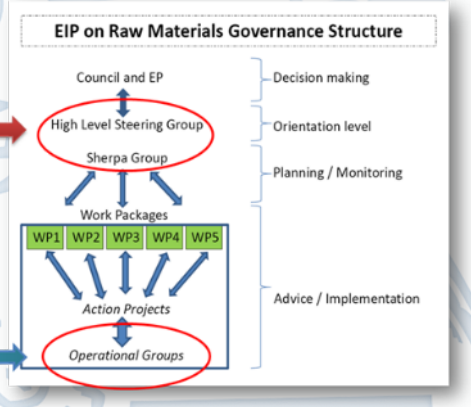
Official Journal of the European Union
Legislation

Mine Waste Directive (MWD), 2006/21

European Commission

MINISTRY OF ENVIRONMENT, ENERGY AND CLIMATE CHANGE

5 members
(2 members from LabMet)



SCHOOL OF MINING AND METALLUGICAL ENGINEERING

Laboratory of Metallurgy – Lavrion industrial park

Conference center

Lavrion Technological and Cultural Park (LTCP)

Place of the old French Mining Company of Lavrion
(Compagnie Francaise des Mines du Laurium) [close to Athens]

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Conference center-LabMet

Energy Self-sufficient building (530 m^2) with zero CO_2 emissions

Research Team:
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