DISCLAIMER

EUROPEAN UNION
The NEMO project has received funding from the European Union's Horizon2020 research and innovation programme under grant agreement No 776846

NEMO website: https://h2020-nemo.eu/
Mika.Paajanen@vtt.fi +358407370910
Lieven.machiels@kuleuven.be +32494918649

Near-zero-waste recycling of low-grade sulphidic mining waste for critical-metal, mineral and construction raw-material production in a circular economy

The NEMO project has received funding from the European Union's EU Framework Programme for Research and Innovation Horizon 2020 under Grant Agreement No 776846

NEMO general presentation - version April 2020

HORIZON 2020 Innovation action project

NEMO "Near-zero-waste recycling of low-grade sulphidic mining waste for critical-metal, mineral and construction raw-material production in a circular economy"

NEMO Project presentation

Version 30/04/2020

Author: Lieven.machiels@kuleuven.be

https://h2020-nemo.eu/

The NEMO project has received funding from the European Union's EU Framework Programme for Research and Innovation Horizon 2020 under Grant Agreement No 776846

Why NEMO?

With an estimated volume of 600 Mtonne/yr and a historic stockpile of 28,000 Mtonne, sulphidic mining waste from the production of Cu, Pb, Zn, Ni and other metals represents the **largest volume of extractive waste in Europe.**

When poorly managed, these "tailings" may cause environmental **problems** such as acid mine drainage and can pose **risks,** E.G. tailings dam breakage.

In 2016 EIP Raw Materials launched a "call to arms" to transform the "extractive-waste problem" into a "**resource-recovery opportunity**", as "tailings" still contain valuable & critical metals.

The NEMO concept

Using a "4 PILOTS – 2 case-studies" concept, NEMO develops, demonstrates and exploits, **a first-of-a kind, near-zero waste processing scheme for sulphidic ores**

the 4 PILOTS are located at key points in the near-zero waste flowsheet, encompassing:

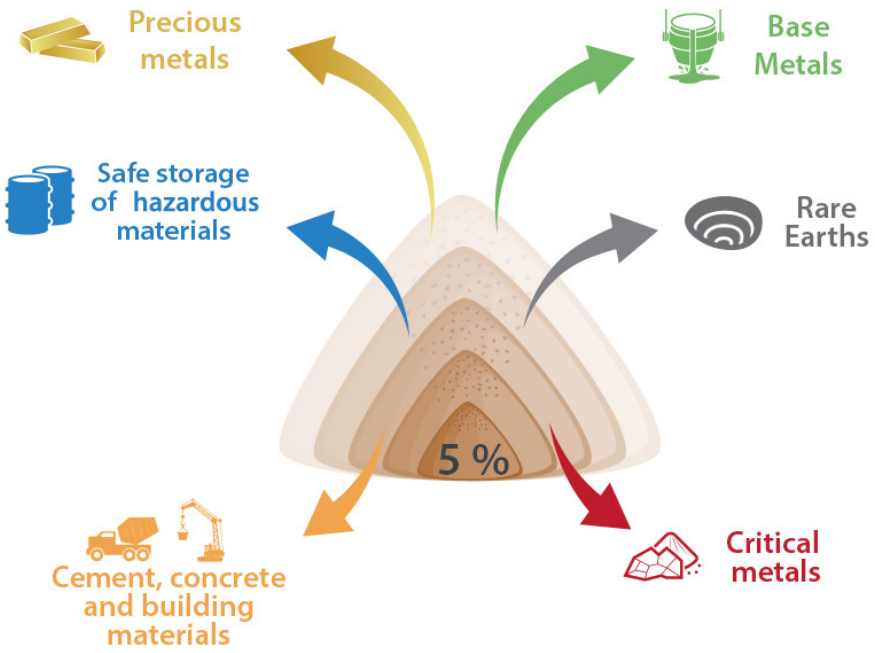
- the leaching and recovery of valuable & critical metals,
- the removal of sulphides and hazardous elements,
- and the treatment of the "cleaned" residual mineral fraction, either for use in cement, concrete and construction products, or for safe back-fill and post-closure mine rehabilitation

Hereby, NEMO aims to reduce the **waste to only 5%** of its original volume

Extractive-waste problem

Resource-recovery opportunity

The NEMO concept



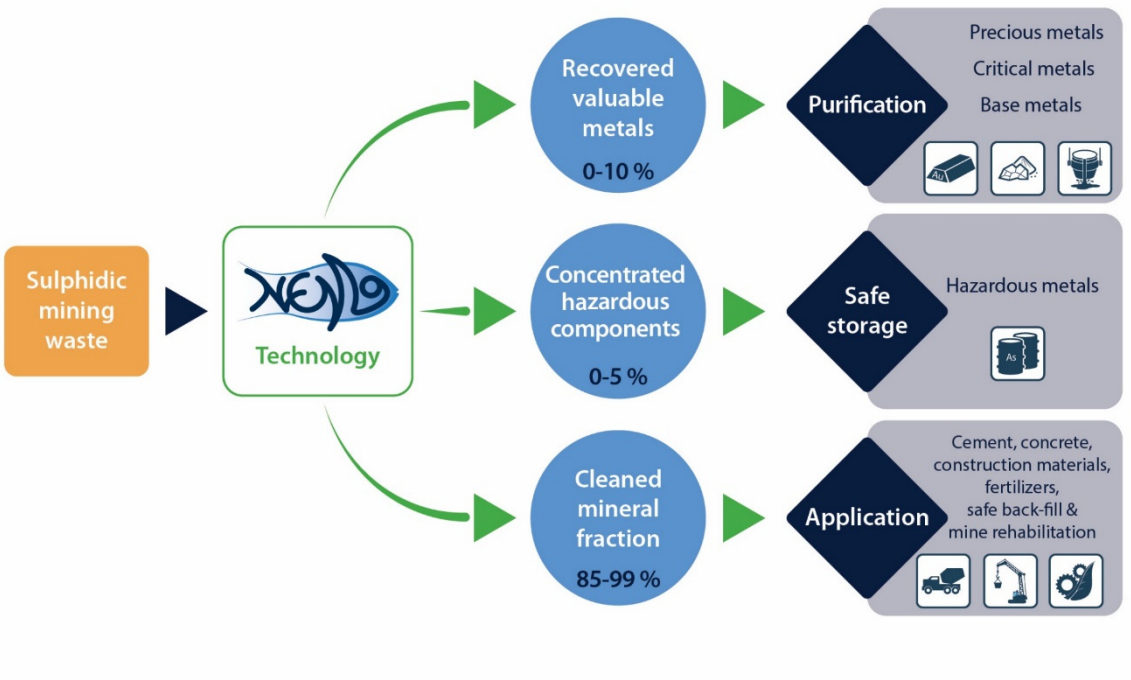
Extractive-waste problem

Resource-recovery opportunity

The NEMO concept

NEMO is in line with a general evolution in the mining sector:

- Recovery of a few ppm/tonne (E.G. gold mining)
- Recovery of associated metals
- NEMO: integral valorisation of the ore



The NEMO concept

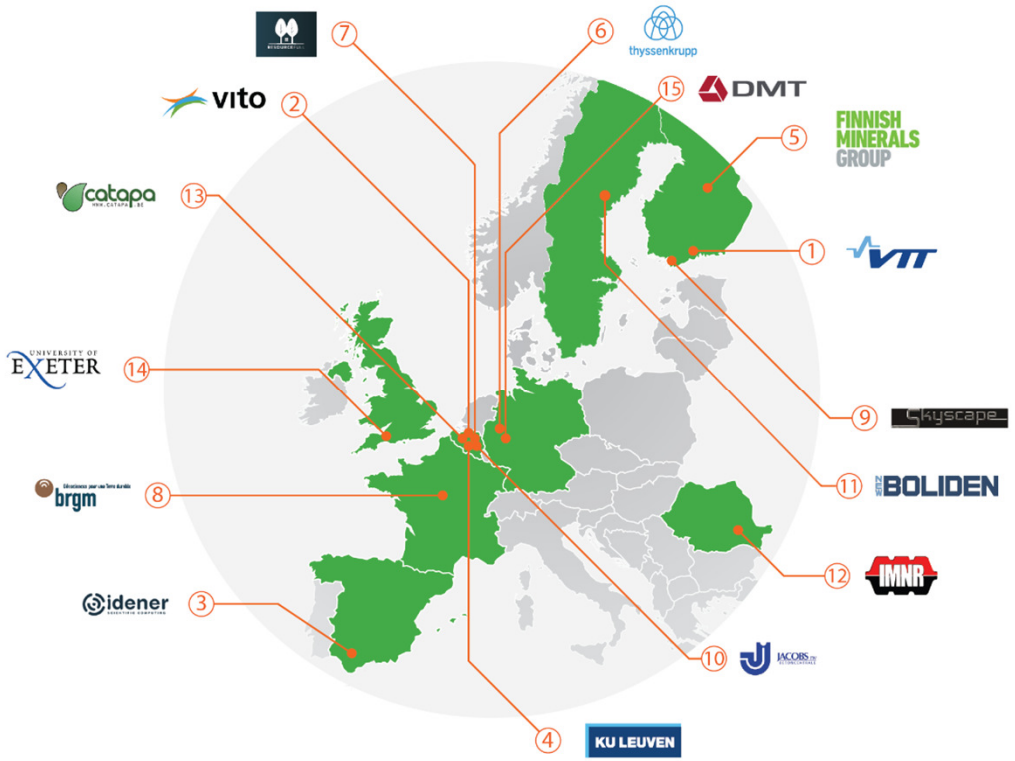
Positive side effects NEMO concept..

- Full conversion of sulphides = elimination of acid mine drainage risk
- Conversion of sulphides to sulphates, which can be valorised as fertilizer, in cement, Etc.
- Enhanced leaching results in “cleaned” mineral fraction, allowing its use in construction applications or for safe back-fill and post-closure mine rehabilitation
- Hazardous elements are no longer diluted in the mineral fraction but concentrated and safely stored

NEMO public abstract

With an estimated volume of 600 Mtonne/yr and a historic stockpile of 28,000 Mtonne, sulphidic mining waste from the production of Cu, Pb, Zn and Ni, represents the largest volume of extractive waste in Europe. When poorly managed, these "tailings" may cause major environmental problems such as acid mine drainage. In 2016 EIP Raw Materials launched a "call to arms" to transform the "extractive-waste problem" into a "resource-recovery opportunity", as "tailings" still contain valuable & critical metals. Using a "4 PILOTS – 2 case-studies" concept, NEMO develops, demonstrates and exploits, therefore, new ways to valorise sulphidic mining waste. The 2 cases are the Sotkamo Ni-Co-Zn-Cu mine in Finland and the Luikonlahti processing facility in Finland; the 4 PILOTS are located at key points in the near-zero-waste flowsheet, encompassing the recovery of valuable & critical metals, the safe concentration of hazardous elements, the removal of sulphur as sulphate salts, while using the residual mineral fraction in cement, concrete and construction products. NEMO has established an interdisciplinary consortium, including 8 industrial partners (2 mining, 4 engineering, 1 machine manufacturing & 1 construction material company), 4 research institutes, 2 universities and 1 civil society group. NEMO's near-zero-waste technology will provide the EU with both direct and long-term, indirect advantages. The former range from new resources (e.g. base metals: Cu, Zn, Ni, Au; critical metals: Co, Sc, Nd, Y, Sb; SCM and aggregates etc.), CO_2 savings from metal recovery and the replacement of Ordinary Portland Cement), new job creation, new revenues from the multiplication of the former benefits, while eradicating acid-mine drainage and other environmental issues, and ensuring an enhanced dialogue (framework) between industry and civil society, to obtain and maintain the License to Operate mines in EU.

NEMO consortium



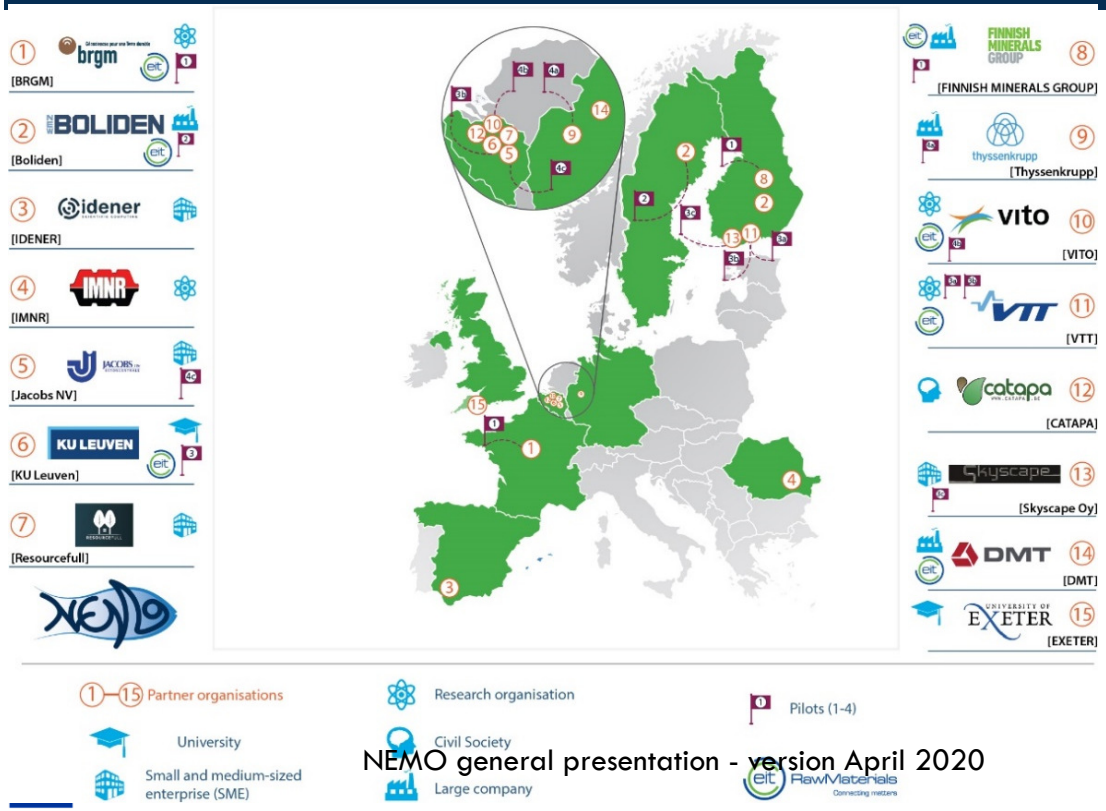
VTT	Finland	Coordinator
VITO	Belgium	
Idener	Spain	
KU Leuven	Belgium	
Terrafame/Finnish Minerals Group	Finland	
Thyssenkrupp	Germany	
Resourcefull	Belgium	
BRGM	France	
Skyscape	Finland	
Jakobs	Belgium	
Cobre Las Cruces	Spain	till 12/02/2019
IMNR	Romenia	
Catapa	Belgium	
University of Exeter	UK	
DMT	Germany	
Boliden	Sweden	from 01/06/2019

NEMO pilots

NEMO aims to step up the technology-readiness-level (TRL) of different pilots:

	TRL now	TRL end
PILOT 1: Innovative pond/enhanced heap bio-leaching	4-5	6-8
PILOT 2a: Tank bio-leaching	4-5	6-7
PILOT 2b: Metal precipitation and solvent extraction for Co and Ni production	4	5-6
PILOT 3a: Sulphide precipitation (Cu, Zn, Ni, Co)	5	6
PILOT 3b: Solvent extraction system for REE and Sc separation and recovery	4	5-6
PILOT 3c: Advanced sulphide and hydroxide precipitation pilot	4-5	6
PILOT 4a: Production of cementitious materials by flash calcination.	4–5	6-7
PILOT 4b: Production of artificial aggregates for construction purposes	5-6	6-7
PILOT 4c: Production of concrete end-products	6-7	7-8

Locations of NEMO pilots



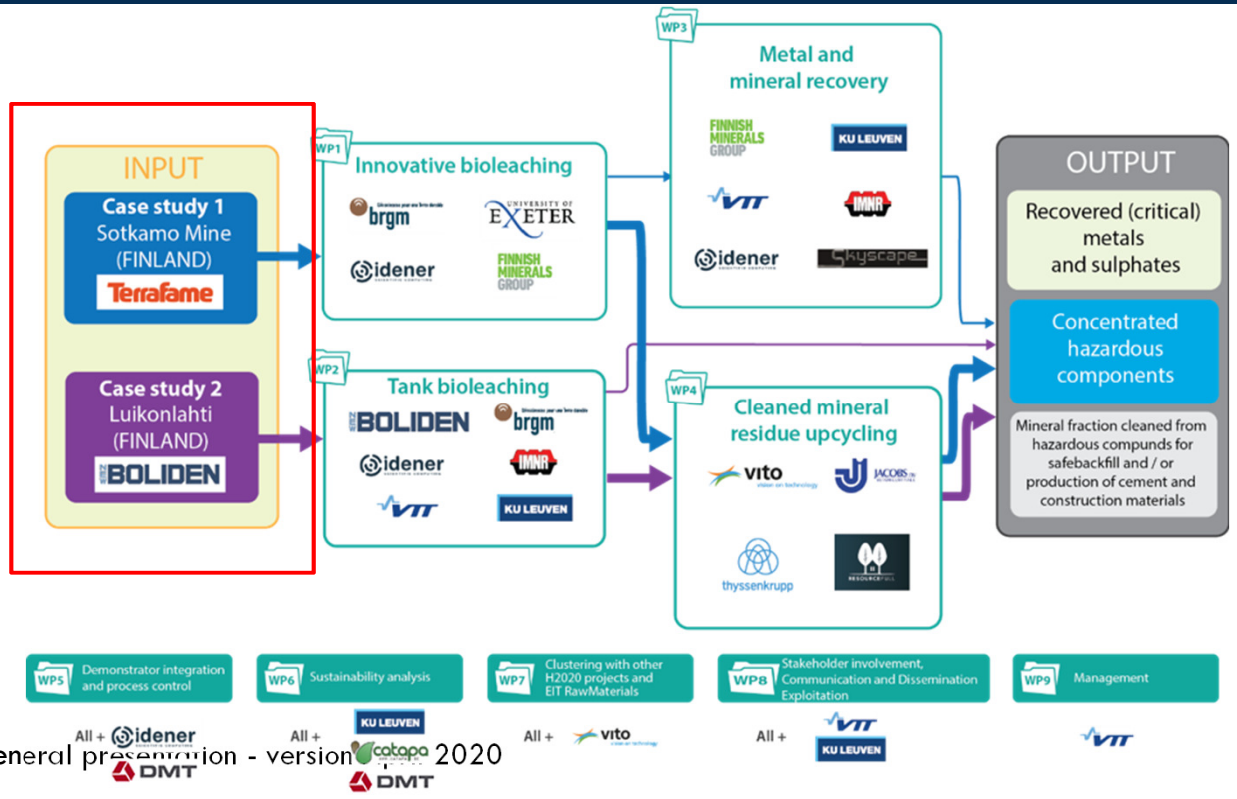
Pilots in:

- Bioleaching (in tanks, ponds, heaps) (pilot 1, 2a)
- Metal recovery from leach solutions & metal purification through sulphide and hydroxide precipitation and solvent extraction (pilot 2b, 3a,b,c)
- Mineral fraction valorisation in cement and construction materials (pilot 4a,b,c)

NEMO project structure

2 case studies:

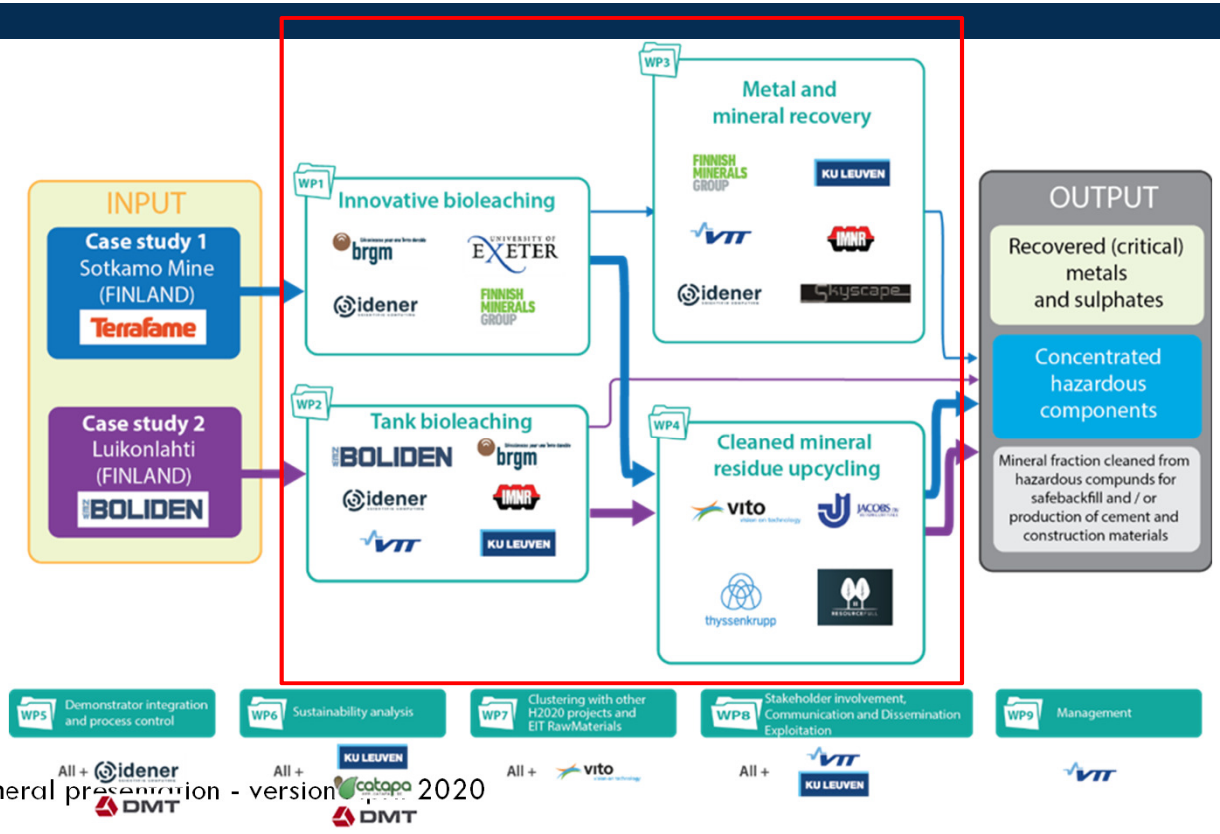
- Sotkamo Ni-Co-Zn-Cu mine, Finland
- Luikonlahti Cu-Zn-Ni-Co-Au processing plant, Finland



NEMO project structure

4 technical work packages:

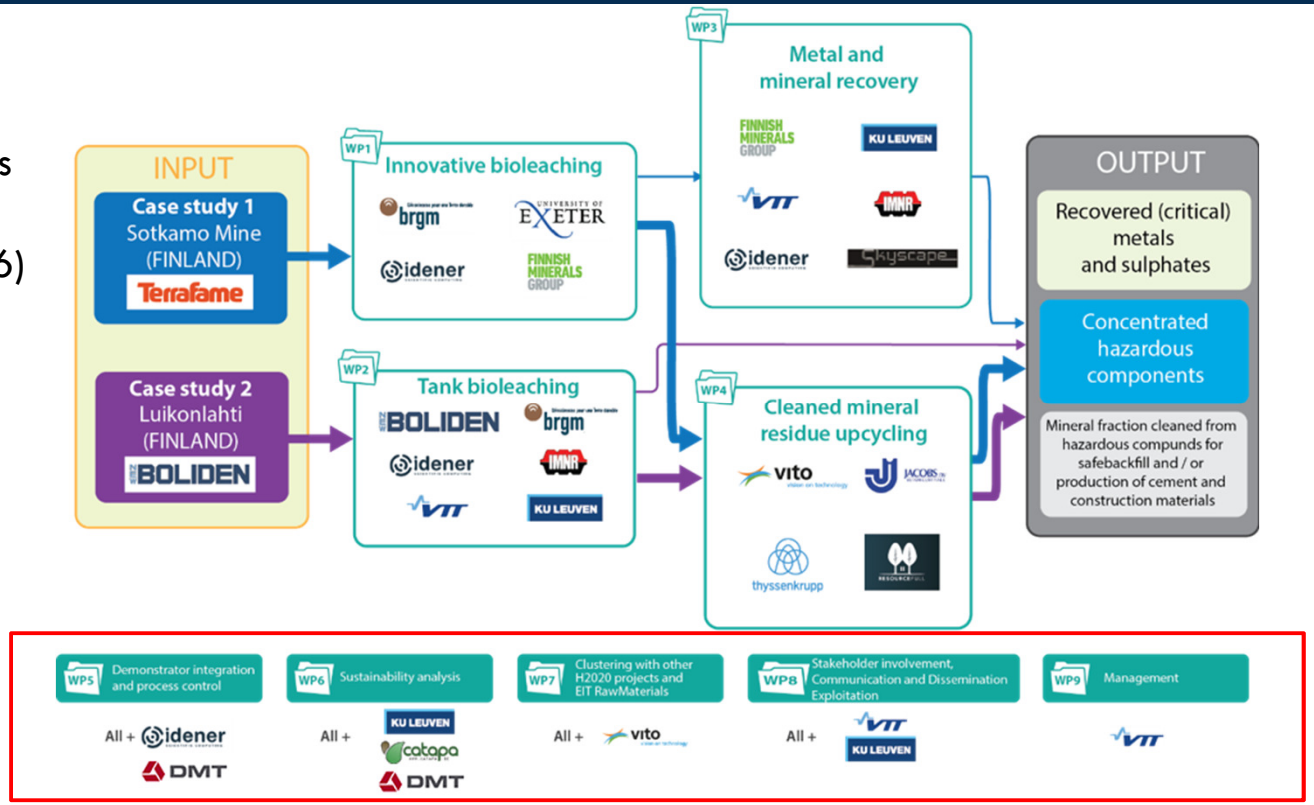
- **bioleaching** (in tanks, ponds, heaps) (WP1-2)
- **metal recovery** from leach solution (sulphide and hydroxide precipitation) & metal purification (solvent extraction) (WP2-3)
- **mineral fraction** valorisation in cement and construction materials (WP4)



NEMO project structure

5 supporting work packages:

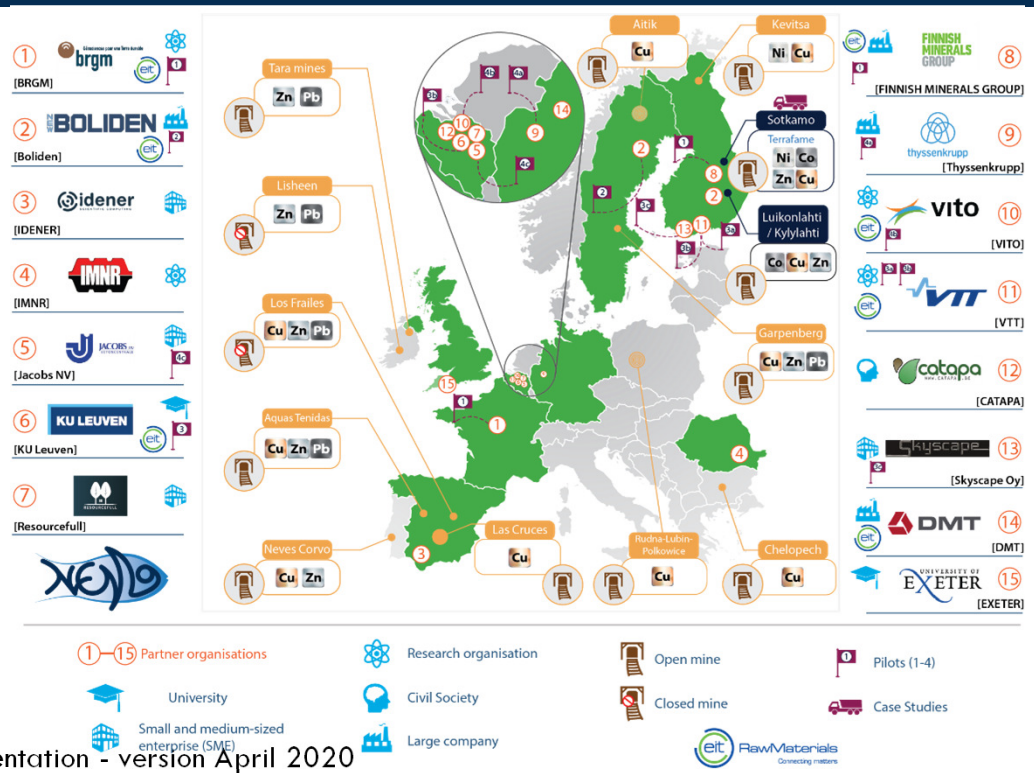
- Pilot integration and process control (WP5)
- Sustainability analysis (WP6)
- Clustering (WP7)
- Stakeholder engagement, communication and dissemination, Exploitation (WP8)
- Management (WP9)



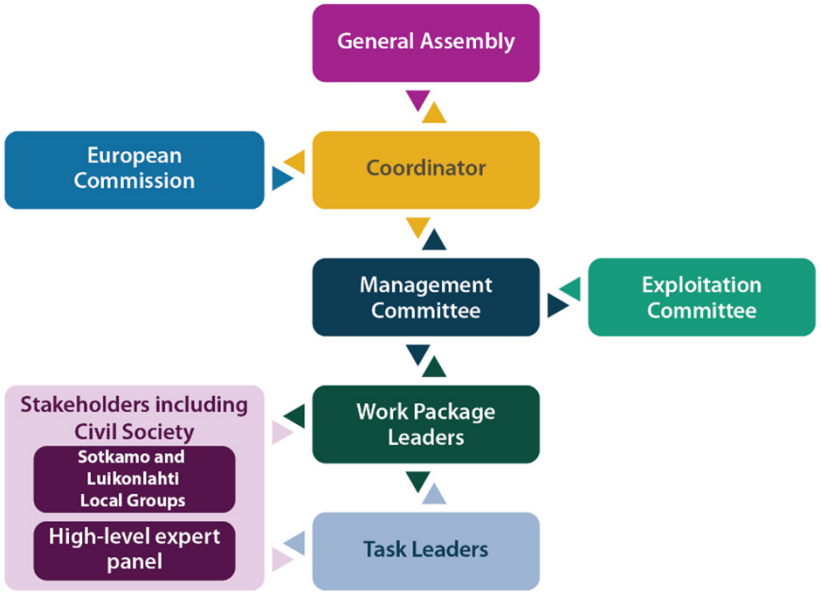
NEMO replication

NEMO aims to replicate its technologies and concepts to other mines within the E.U. and beyond.

Already during the project, it is aimed to link to 3 additional sites to evaluate the replication potential



NEMO organisational structure



Work package 1: Innovative bio-leaching

Work Package leader: Gwenn Guezennec – BRGM (a.guezennec@brgm.fr)
Partners: Terrafame/Finnish Minerals group, Idener, University of Exeter
Activities:

- Develop/optimize/upscale enhanced bioleaching strategies, using either **heap bio-leaching or pond bio-leaching**
- Test the technology at TRL 7-8 for the Sotkamo primary heap leaching residues using a test heap at the Terrafame premises and a 2m^3 reactor at the BRGM premises
- Perform preparatory and supporting work, i.e. testing of micro-cultures, process simulation, reactor design and engineering, economic assessment

Work package 2: Pilot-scale bio-leaching of processing residues

Work Package leader: Anders Sand – Boliden (anders.sand@boliden.com)
Partners: VTT, Idener, KU Leuven, BRGM, IMNR
Activities:

- To demonstrate how multi-metal sulphide tailings can be processed, utilizing different leaching, recovery and purification processes. Focus is on bioleaching, metal precipitation and metal purification using solvent extraction.
- The flowsheet is tested on the Luikonlahti sulphur concentrate using a newly built bio-leaching reactor and complementary equipment at the Boliden piloting site in Sweden at a final TRL of 7.
- Preparatory work includes the testing of the materials in different mini-pilots

Work package 3: Metal and mineral recovery

Work Package leader: Kaisa Kiipula, Finnish Minerals Group (kaisa.kiipula@mineralsgroup.fi)
Partners: Terrafame, VTT, Idener, KU Leuven, Skyscape
Activities:

- To demonstrate the improved/additional metal recovery from pregnant leach solution derived from sulphidic ores
- More specifically, the following aspects are upscaled and demonstrated:
  - Sulphide precipitation - (Ni,Co)S, CuS and ZnS
  - Solvent extraction - mixed REE precipitate
  - Non-aqueous solvent extraction - separation and purification of REE from mixed REE precipitates
  - Oxide and sulphide precipitation using NH_3 – Ni, Co, Cu, Zn, Al/Fe-group metals
  - Recovery of Mn and Mg

Work package 4:
Cleaned mineral residue upcycling

Work Package leader: Jost Lemke, Thyssenkrupp (jost.lemke@thyssenkrupp.com)
Partners: VITO, Resourcefull, Jakobs
Activities:

- Design and construction of a mobile TRL7 prototype for mineral fraction upcycling to artificial aggregate and concrete.
- Pilot production of novel construction materials, i.e. (1) novel composite cement by flash-calcination, and (2) artificial aggregates by granulation from cleaned tailings
- Demonstration of (1) ready-mix concrete production and application and (2) pre-cast concrete element production at the industrial scale

Supporting work packages

Work package 5: Pilot integration and process control
Work Package leader: Maria Tripiana, Idener (maria.tripiana@idener.es)
Partners: KU Leuven, DMT

Work package 6: Sustainability analysis
Work package leader: Andrea Di Maria, KU Leuven (andrea.dimaria@kuleuven.be)
Partner: DMT, Catapa

Work package 7: Clustering with other Horizon2020 projects and EIT RawMaterials
Work Package leader: Liesbeth Horckmans, VITO (liesbeth.horckmans@vito.be)
Partners: VTT, Idener, KU Leuven, DMT

Supporting work packages

Work package 8: Stakeholder engagement, communication and dissemination, Exploitation

Work Package leader: Teuvo Uusitalo (Teuvo.Uusitalo@vtt.fi)

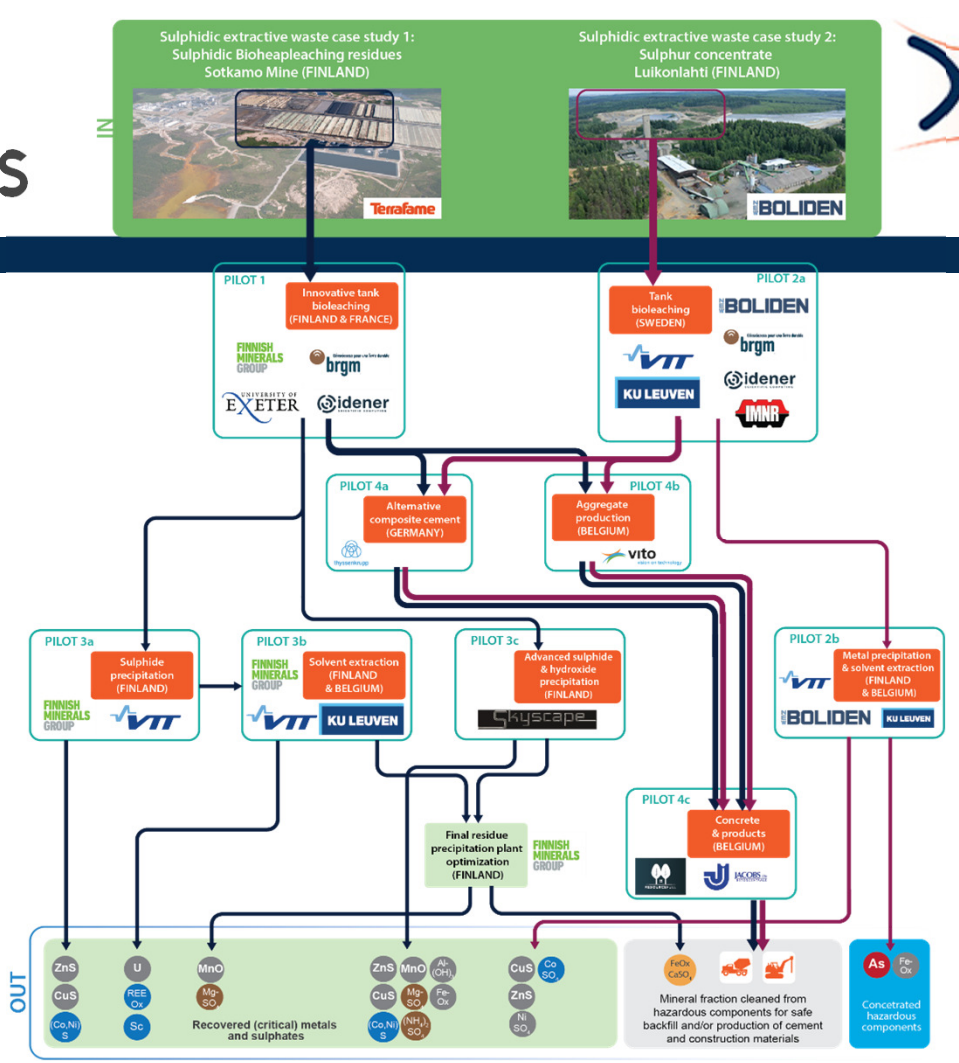
Partners: KU Leuven, Catapa, all

Work package 9: Management

Work package leader: Mika Paajanen (Mika.Paajanen@vtt.fi)

Case studies

Overview input materials, in-scope technologies and expected output materials

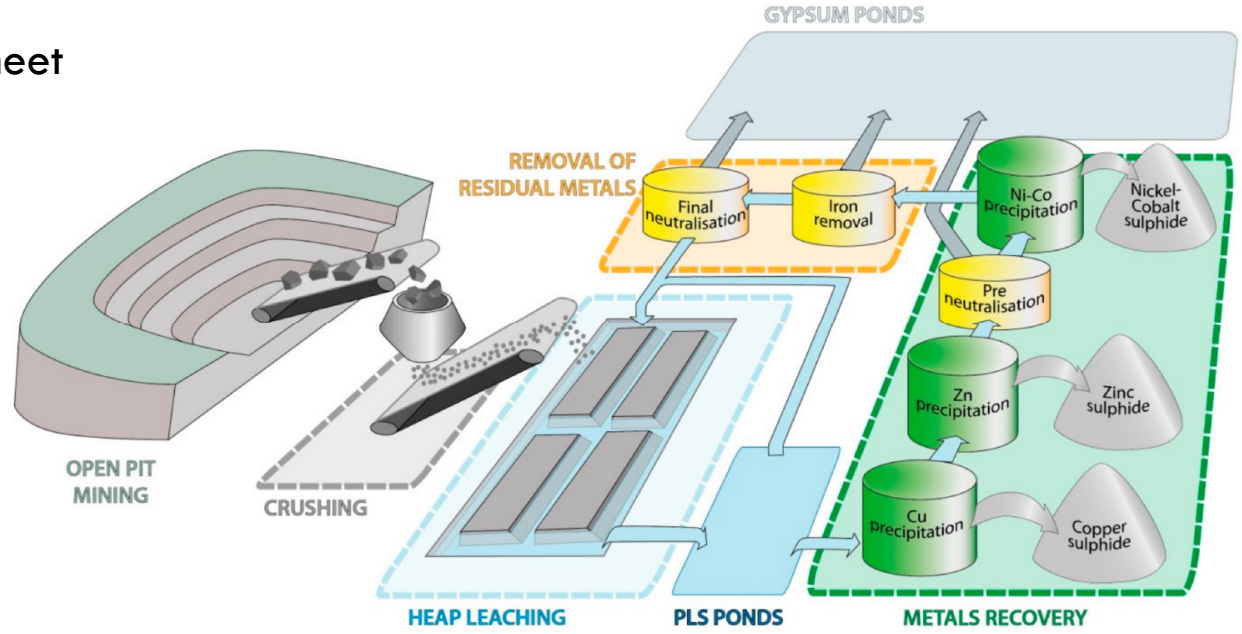


Case study – Sotkamo Ni-Co-Zn-Cu mine, Finland

Source: Terrafame.com

Case study – Sotkamo Ni-Co-Zn-Cu mine, Finland

Current flowsheet



Source: Geosciences **2018**, 8, 66; doi:10.3390/geosciences8020066

Case study – Sotkamo Ni-Co-Zn-Cu mine, Finland

Current products: (Co,Ni)S, ZnS, by-product CuS

NEMO objectives:

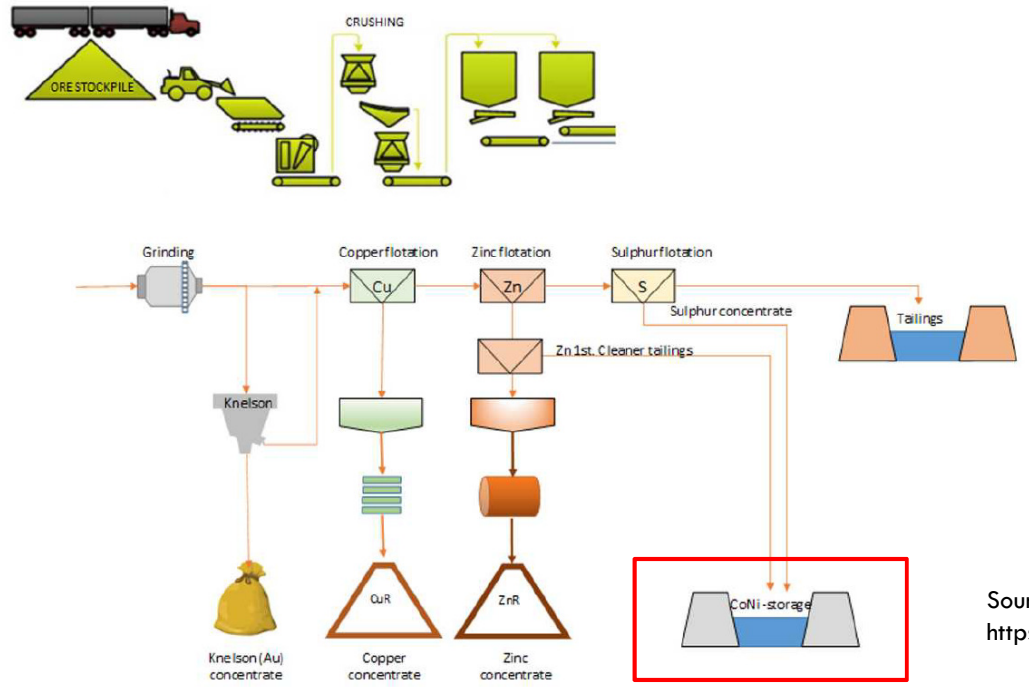
- Improve leaching from secondary heaps & imrove recovery of Co, Ni, Zn & Cu from pregnant leach solution
- Additional metal recovery from pregnant leach solution (metals currently ending up in waste precipitates): Mn, Mg, REE, Sc
- Cleaned mineral fraction: heaps remain in place after leaching = final storage of mineral fraction // alternative: valorisation in building products (no business case as mine is located very remotely)

Case study – Luikonlahti Cu-Zn-Ni-Co-Au processing plant, Finland

Source: https://www.boliden.com/

Case study – Luikonlahti Cu-Zn-Ni-Co-Au processing plant, Finland

Current flowsheet



Source: https://www.boliden.com/

NEMO feed material

Case study – Luikonlahti Cu-Zn-Ni-Co-Au processing plant, Finland

NEMO objectives:

- Further process the Co-Ni concentrate produced at the final flotation stage of the Luikonlahti plant
- Recovery and purification of Co, Ni, Cu, Zn
- Production of Fe-rich residue as a sink for arsenic
- Recycle $CaSO_4$ to produce CaO
- The cleaned leaching residue is aimed to remain at the site

NEMO website

https://h2020-nemo.eu/

Main contacts

Project coordinator:

Mika Paajanen (VTT, Finland) – Mika.Paajanen@vtt.fi

Science & Technology coordination:

Lieven Machiels (KU Leuven, Belgium) – Lieven.Machiels@kuleuven.be

Communication and dissemination:

Giorgian Dinu (KU Leuven, Belgium) – Giorgian.Dinu@kuleuven.be

Civil society engagement:

Piet Wostyn (KU Leuven, Belgium) – Piet.Wostyn@kuleuven.be

The NEMO project has received funding from the European Union's EU Framework Programme for Research and Innovation Horizon 2020 under Grant Agreement No 776846 - https://h2020-nemo.eu/