This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

ALiCE

Al-rich industrial residues for mineral binders in the ESEE region

Within its second year (2020), the RIS ALiCE project has been disseminated on various levels and in different events, such as:

- In **seminars** at 5 partner institutions: SIJ Acroni from SIJ - Slovenian Steel Group (Slovenia), Slovenian National Building and Civil Engineering Institute and Geological Survey of Slovenia (Slovenia); TU Wien (Austria); Bay Zoltan Nonprofit Ltd. (Hungary).

- In 6 **scientific conferences:** VII Terrestrial Radioisotopes in Environment – International Conference on Environmental Protection (VII. TREICEP), Veszprém, Hungary, August 2020 (3 conference papers: "Radiological properties of fly ash as a raw material for low carbon cements", "Radiological assessment of red mud as an Al containing precursor in inorganic binders for the building industry", "Valorisation of Al containing mineral residues for sustainable inorganic binders"); BEFIB2020, Valencia, Spain, September 2020 (1 conference paper: "Influence of the Curing Temperatures on the Mechanical Properties of Hemp Fibre Reinforced Alkali Activated Mortars"); the European Geosciences Union (EGU) 2020, May 2020 (co organization, presentation, Section ERE 5.5 Sustainable mining and circular economy: waste characterization and exploitation supported by geophysical methods; 1 conference paper: "Al rich industrial residues for mineral binders in ESEE region"); International Conference on the Management of Naturally Occurring Radioactive Materials (NORM) in Industry, Vienna, Austria, October 2020 (poster presentation: "Potential of coal fly ash in building materials"); the first Student Conference of Young Scientists and Designers, Skopje, North Macedonia, October 2020 (an online conference, where the RIS ALiCE promotion material was distributed among the participants); 3rd International Conference on Technologies and Business Models for the Circular Economy (TBMCE 2020), December 2020 (an online conference; presentation of RIS ALiCE project: Al rich industrial residues for mineral binders in the ESEE region).

- To more than 110 **students** at the Ss. Cyril and Methodius University in Skopje in North Macedonia (technical staff from cement factory USJE Cementarnica – TITAN Group organized a webinar "Towards Cements with Low CO_2 Emission" at the Faculty of Technology and Metallurgy and at the Faculty of Civil Engineering); to students at the Institute "Kemal Kapetanović" in Zenica, Bosnia and Herzegovina.

- In 4 **workshops:** the staff from the Vinča Institute of Nuclear Sciences, Belgrade University in cooperation with the Scientific and Educational Centre for Children and Youth in Serbia presented the project to children and their parents; an online international workshop "Building the registry of Al rich secondary resources for the production of low carbon and low energy mineral binders within the RIS ALiCE project" was organized by the Slovenian National Building and Civil Engineering Institute, Geological Survey of Slovenia, Salonit Anhovo d.d. and the Vinča Institute of Nuclear Sciences, Belgrade University; the Vinča Institute of Nuclear Sciences, Belgrade University and the Slovenian National Building and Civil Engineering Institute organized the workshop "Recycling and environmental radioactivity of Al rich residues" with participants from Hungary, Slovakia, Slovenia, Italy, North Macedonia, Montenegro and Serbia, where the training school was announced and presented; the project partner Bay Zoltan Nonprofit Ltd. organized an online workshop for Hungarian registry users to introduce the first version of the RIS ALiCE registry.

- In the 59th Sejem Dom **(Home Fair)**, which took place in Ljubljana, Slovenia.

- During 3 site visits to producers and landfills of industrial by products: steel mill in SIJ Acroni company in Slovenia, steel slag processing plant SIJ Metal Ravne in Slovenia, EFT Mine and Thermal Power Plant Stanari, Bosnia and Herzegovina.

- In 5 different **professional journals:** the Slovenian journal Revija SIJ in March and May 2020 ("A lot of knowledge from different fields with common goals" and "A step towards sustainable development: the use of processed steel slag for BCSA clinker"); in the Slovenian journal Finance, the Okolje in energija supplement in June 2020 ("Thus they will reduce the carbon footprint in the cement industry"); in the Slovenian journal Naš list in September 2020 ("Slovenian Partnership for the Circular Economy"); in the Slovenian Magazine Geonovice (Vol. 3, No. 3) in September 2020 ("The registry of Al rich secondary resources in ESE Europe – RIS ALiCE"); in the Slovenian journal EOL (Vol. 154/155) in December 2020 (within the article "From words to the market is a long way, examples of optimism"; "Secondary mineral raw materials for decarburization of the cement industry").

- In **social media:** 2 LinkedIn posts on (Lucis d.o.o.: Project: RIS ALiCE on 12 Feb 2020 and PROJECT UPDATE: RIS ALiCE PLUS on 4 Dec 2020); 1 Facebook post (the Geological Survey of Slovenia announced information about an article on the RIS ALiCE project in the "Mineral & Gradnja" journal on their Facebook wall); 1 Facebook post (the Faculty of Technology and Metallurgy announced the information after the webinar "Towards Cements with Low CO2 Emission" realization on their Facebook wall) on 21 Oct 2020.

- In the RIS **Cluster Waste2Resource event.** The project partners from the RIS CURE, RIS RECOVER, RIS ALICE, and RIS RESTORE projects (all projects are funded by European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation) gathered together to link projects dealing with zero waste extraction to form a RIS cluster Waste2Resource.

The internal seminar at the Slovenian National Building and Civil Engineering Institute.

The internal seminar at TU Wien.

A visit from representatives of the Slovenian National Building and Civil Engineering Institute to SIJ Acroni d.o.o. (archive SIJ Acroni) (left) and representatives of the Metallurgical Institute "Kemal Kapetanović" Zenica to the EFT – Mine and Thermal Power Plant Stanari, Bosnia and Herzegovina (right).

Screenshot from the TBMCE 2020 international conference.

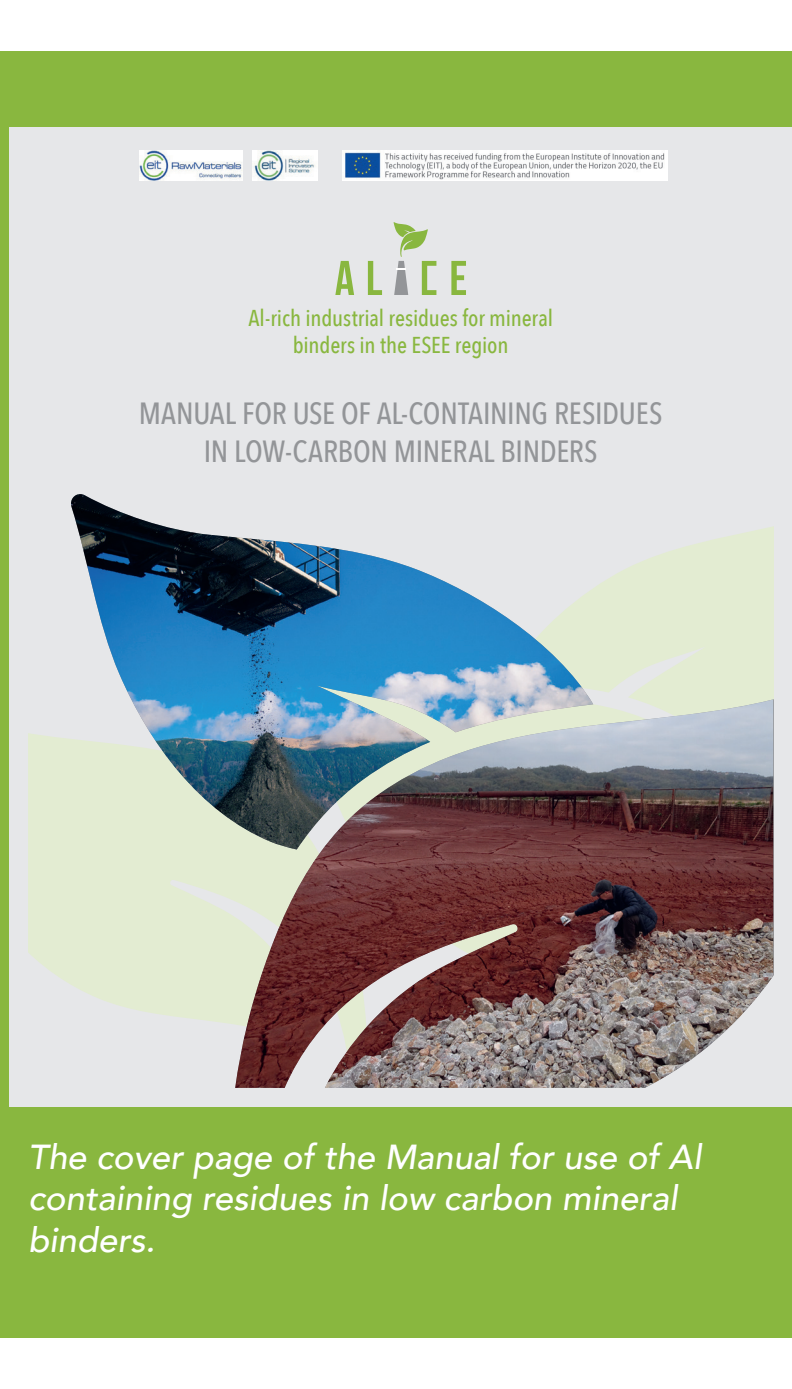
International workshop "Recycling and environmental radioactivity of Al rich residues".

The new RIS ALiCE leaflet.

Screenshot of paper from the "Mineral & Gradnja" national journal.

In 2020, the RIS ALiCE team prepared the ***"Manual for use of Al containing residues in low carbon mineral binders"*** (available in print version and online at: http://www.zag.si/dl/manual-alice.pdf). This manual addresses the legislative aspects governing the use of secondary raw materials in construction products, and contains a description of the most common Al containing industrial and mining residues (bauxite deposits, red mud, ferrous slag, ash and some other industrial by products), the potentiality for their reutilization and its economic aspects, potential requirements/barriers for the use of secondary raw materials in the cement industry, and a description of belite sulfoaluminate cements, which are a promising solution for implementing the circular economy through the use of large amounts of landfilled Al rich industrial residue and mining waste cement clinker raw mixture. This manual was prepared by the partners of the RIS ALiCE project. It provides a popular content, which targets the relevant stakeholders as well as the wider society. Moreover, it offers educational material for undergraduate, master and PhD students.

International workshop "Building the registry of Al rich secondary resources for the production of low carbon and low energy mineral binders within the RIS ALiCE project".



The cover page of the Manual for use of Al containing residues in low carbon mineral binders.

A new project **leaflet** was prepared by the Slovenian National Building and Civil Engineering Institute in web and printed edition. It was shared among partners who distributed it amongst the interested stakeholders. The leaflet was uploaded to the project website (http://ris-alice.zag.si/about) where the interested parties and partners can access it and print extra copies for use in their workshops and events.

Screenshot of paper from the "Naš list" national journal.

In order to establish a **network of relevant stakeholders** in the area of currently unused and landfilled Al rich industrial residues, besides the 19 stakeholders confirmed in 2019, the following **22 stakeholders** officially confirmed their **interest in the RIS ALiCE project in 2020:**
Earth Science Department – University of Torino, Italy • LafargeHolcim – Geocycle, France • Faculty of Civil and Geodetic Engineering, University of Ljubljana, Slovenia • Termit d.d., Slovenia • MYTILINEOS S.A., Greece • Goriške opekarne d.o.o., Slovenia • Calcit d.o.o., Slovenia • SIJ Metal Ravne d.o.o., Slovenia • Faculty of Civil Engineering, University of Belgrade, Serbia • Faculty of Sciences and Mathematics, University of Belgrade, Serbia • Faculty for Technology and Metallurgy, University of Belgrade, Serbia • Faculty of Technical Sciences, University of Novi Sad, Serbia • Lead and Zinc Mine, GROT d.o.o., Serbia • MOL Plc, Hungary • Femalk, Hungary • Faculty for Computer Science and Engineering, Ss. Cyril and Methodius University in Skopje, North Macedonia • Radiation Safety Directorate, North Macedonia • Makstil AD Skopje, North Macedonia • Natron – Hayat d.o.o. Maglaj, Bosnia and Herzegovina • IPI Institut za privredni inženjering Zenica, Bosnia and Herzegovina • "Rudnici Boksita Jajce" d.d., Bosnia and Herzegovina • Lukavac Cement, Bosnia and Herzegovina

In the framework of the RIS ALiCE project, the following activities were completed in 2020:

The main objective of WP3 (Mapping and assessment of Al rich residues in the ESEE region) is to collect the available data on the Al rich industrial and mine residues from the ESEE countries with respect to their suitability for use in the low CO_2 mineral binder. In 2020, we continued with the detailed assessment and valorisation of Al rich secondary raw materials, and the information obtained within WP3 will serve as input data for the registry created in WP4. In addition to further data collection on aluminium containing secondary raw materials in Slovenia, Hungary, and Bosnia and Herzegovina, which were already included in the first year of the project, data were also collected for two additional countries – Serbia and North Macedonia. Based on previous studies, data were collected on mining waste from bauxite and metal tailings, red mud, steel slag, to fly ash and bottom ash from various industries and other types of waste. In terms of samples of Al rich residues, besides first sampling from Slovenia, Hungary and Bosnia and Herzegovina (conducted in 2019), the first sampling was conducted in 2020 also in Serbia and North Macedonia. So far, **we have collected 41 samples** within the project (1 red mud, 8 slags from the steel industry, 16 ashes from the thermal power plant, 1 ash and 1 slag from the paper industry, 5 bauxite, 5 mine wastes and 4 residues from other industries). In parallel with the sampling, field visits also took place, but in 2020 they were slightly less extensive (fewer people involved) due to the health situation regarding COVID 19.

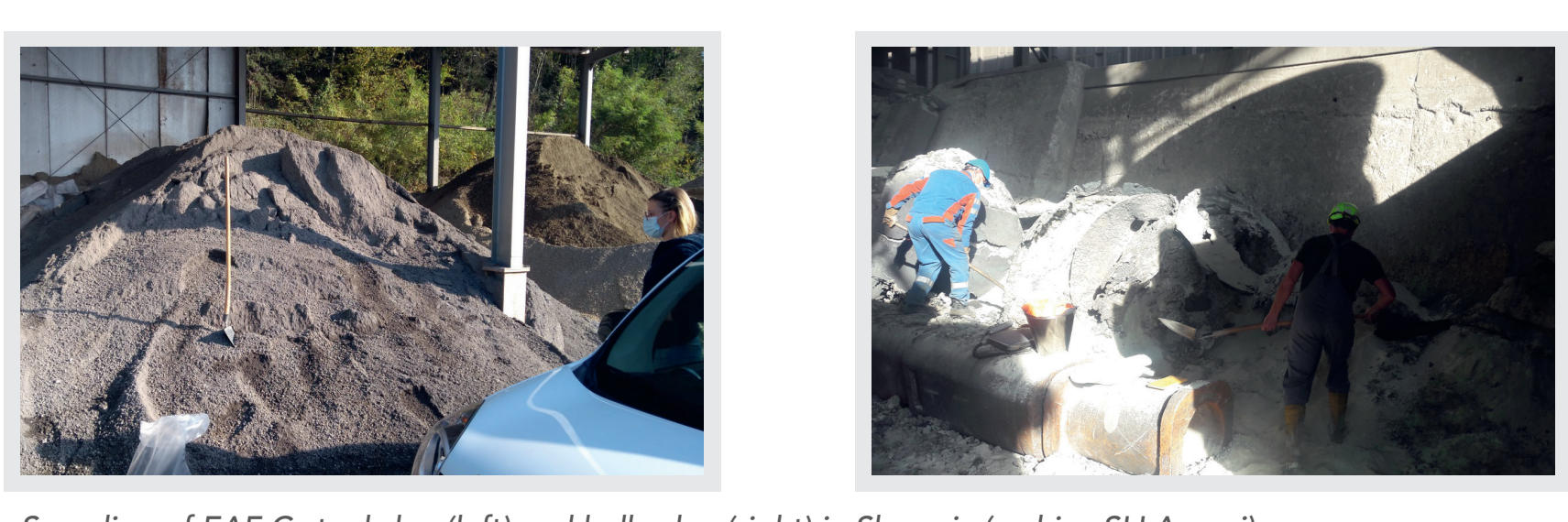
Sampling of mine waste in Slovenia.

Sampling of low-grade bauxite in Slovenia.

Sampling of fly and bottom ash in Hungary.

Sample of crushed brick rejects in Slovenia.

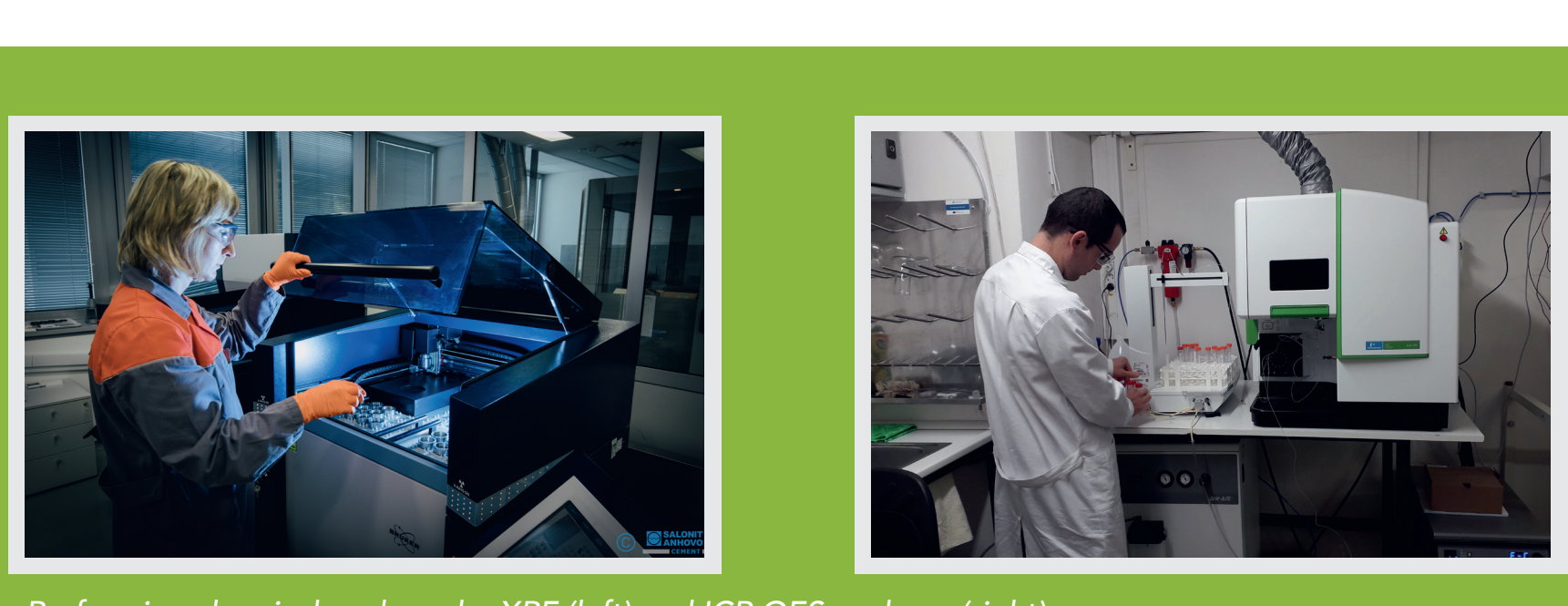
Fly ash spreader in North Macedonia.



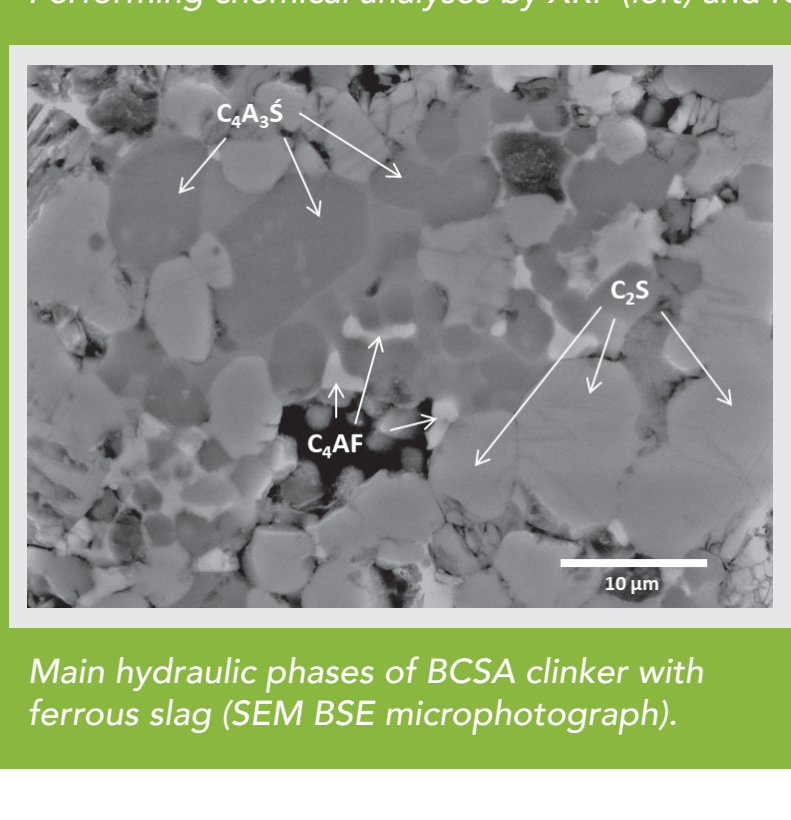
Sampling of EAF C steel slag (left) and ladle slag (right) in Slovenia (archive SIJ Acroni).

Sampling of fly ash in EFT – Mine and Thermal Power Plant Stanari, Bosnia and Herzegovina.

The collected aluminium containing residues were **characterized with respect to their chemical** (main elements, trace elements, moisture content, mineral composition, presence of organic matter), **physical** (granulometry, BET specific surface area, specific weight bulk density) and **radiological composition** (content of radionuclides ^{40}K, ^{226}Ra and ^{232}Th). Various analytical methods were used: X ray fluorescence spectroscopy, ICP optical emission spectrophotometry, gravimetry, X ray powder diffraction, gamma spectroscopy, etc. As concerns the Al_2O_3 content of individual samples, it varies from **1.0 wt.% in mine waste to 24.9 wt.% in fly ash** from thermal power plants; other samples contain between **8.7 and 15.5 wt.%** Al_2O_3 on average.



Performing chemical analyses by XRF (left) and ICP OES analyses (right).



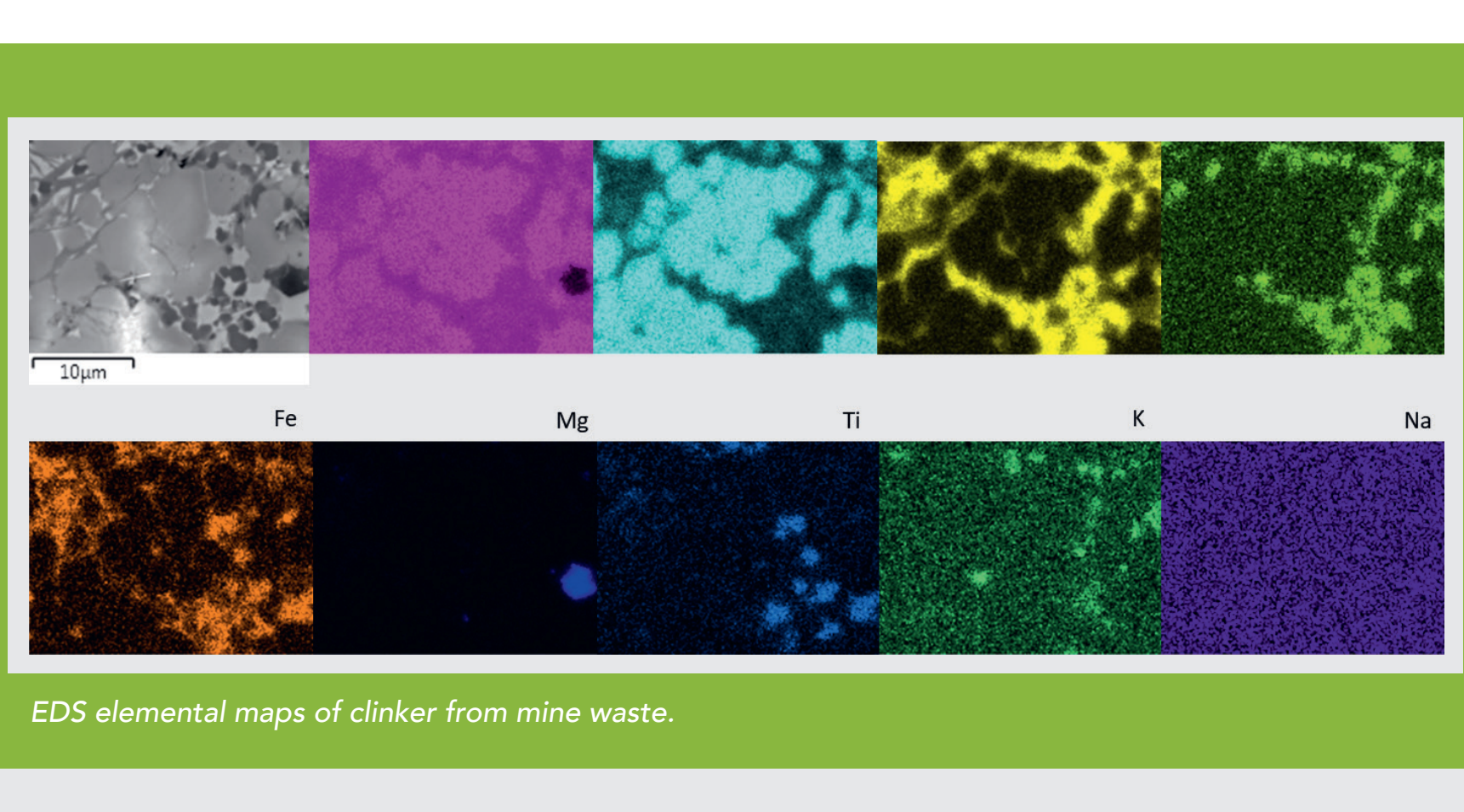
Main hydraulic phases of BCSA clinker with ferrous slag (SEM BSE microphotograph).

Website of the online registry.

In the field of industrial waste recycling, **LCA** has been applied to investigate the performance of waste management strategies and assessing innovative usages of waste. Generally, reuse of industrial waste prevents excessive landfilling and allows the saving of non renewable resources, which is reflected in the life cycle assessment results. By now, the LCA methodology has been set – there are many choices that had to be made since LCA allows many techniques of modelling waste and by products. Furthermore, the data collection process has begun, with thermal power plants being the first ones to respond with data about electricity production that has ash by product used in the project. With this data, environmental burdens of the main production can be allocated to the residue by economic allocation. Furthermore, the system expansion method will be used too, to provide multiple viewpoints on the subject of the environmental impact of the use of industrial residues in innovative products.

In the end of the WP3, the best scenarios for valorisation will be defined by combining data from collected residues analysis, cement plants and waste/residue locations, LCA & LCCA and laboratory scale demonstrations on belite sulfoaluminate (BCSA) clinker. From the collected Al rich residues from RIS countries in 2020 the first few BCSA clinker raw mixtures have been already formulated. We started with two raw mixtures with slag from the steel industry, three raw mixtures with fly ash from the thermal power plant and two raw mixtures with mine waste. **From 7.4 wt.% to 43.2 wt.% Al rich secondary raw material was added to the raw mixtures.** Selected raw mixtures were sintered at 1250°C, BCSA clinkers were characterized with mineralogical and microstructural analyses. Further BCSA cements were prepared and the compressive strength of cement pastes after 7 and 28 days of hydration was determined. For selected clinkers, early age hydration was investigated by isothermal calorimetry.

The main goal of Work Package 4 (Al rich residue registry) is the development of an online registry of Al rich waste materials in the ESEE region. In 2020, the RIS ALiCE WP4 team was focused on the registry prototype implementation. This work was done in several phases: registry coding, internal and external testing by RIS ALiCE partners and interested stakeholders. Registry was implemented by using open source software exclusively: web development was done by using the PHP 7.3 scripting language, and the database was implemented on a relational MySql database. The application is built on the OctoberCMS platform, using PHP technology, with Laravel 5.5 at its core. The technology stack runs on the Linux operating system. Map viewing tool uses the OpenStreetMaps project. After the testing stage had been finished, a registry was published to the web. **The registry domain www.alice-registry.eu** and additional server space were purchased with an external company for the next 3 years. The registry was promoted through different channels, including social networks, journals and web events. The next step is to populate the registry with the data obtained by the RIS ALiCE consortium, for it to be tested by the stakeholders, and to attract many new users. In 2021 we plan to further improve the registry according to the stakeholders' feedback and launch it in the ESEE region.



EDS elemental maps of clinker from mine waste.