

BRAVO Raw Material Commitment

1. Introduction

1.1 Title: Bauxite Residue and Aluminium Valorisation Operations

1.2 Acronym: BRAVO

Co-ordinator: University of Limerick

2. Objectives of the commitment

- To boost the innovation capacity of the aluminium value chain with respect to secondary raw materials recovery
- To foster international co-operation among 30 key players ,their 54 members across the aluminium value chain from extraction to recycling
- The creation of new value chains for the recovered raw materials from by-products of the manufacturing process by collaboration and integration of downstream industries
- To test the viability of solutions and holistic processing concepts for secondary raw materials processing via pilot actions
- To mobilise a significant part of the aluminium value chain to increase the impact of research , innovations and achieve technology transfer both along the aluminium value chain and from parallel industries such as recycling
- To enhance the conditions of the raw materials value chain in order to optimise raw materials flows through improved cooperation of actors
- To promote socially acceptable, environmentally responsible and economically viable technologies
- Waste as a resource: generation of a more valuable waste which can be processed to recover critical raw materials

3. Description of activities

a. Research Activities: Projects

Al-Ore: Optimising the alumina and aluminium manufacturing process to increase the intrinsic value and recyclability of by-products including red mud

Al-Source: Using the red mud by-product as a source of critical raw materials including gallium, titanium, selenum, germanium, dysprosium, cerium (pilot activity)

Al-Build: Production of construction Raw Materials from Red Mud (pilot activity)

Al-Chain: Development of a waste residue value chain and synergising the outputs of the Al-Ore, Al-Source and Al-Build. Including research on EU policy aspects and co-operation in the EU aluminium sector.

Al-Aware: public awareness, acceptance and trust regarding aluminium sector activities and generation and management of red mud

In addition to the above outlined collaborative projects of BRAVO, our partners also undertake significant in-house research in aluminium and residue processing and applicable recovery technologies. The contribution of these to the BRAVO commitment is captured in the partner profiles.

b. Innovation & Commercialisation Activities

- I. Intellectual property (IP) management: agreements between partners, clearly defined background IP and IP strategy at project level
- II. Assessment of patentability of products, technologies and processes from the “Al- projects” and proceeding to registration of patents as required.
- III. Implementation and roll-out strategies for “new processes” developed by the Al-Ore project, which increases source efficiency
- IV. Market analysis for potential products from Al-Source and Al-Build projects including cost effectiveness, product “Return on Investment”, ability of the product to compete in the market place
- V. Business plan development for products from Al-Source and Al-Build projects including scale up activities, costing and cash flows, sourcing initial customer, beta trailing of products and sourcing investment funds as required
- VI. Technology transfer procedures and establishment of a Technology Transfer Board for guidance and input

c. Co-operation Activities

- I. Co-operation of partners across multifunctional teams to undertake specific tasks including research and pilot activities (Delivery Partners)
- II. Collaboration of Key players across the aluminium value chain via the establishment of a cross sector stakeholders forum including players from mining and extraction, smelting, by product handlers, legislators, researchers, metallurgists and recyclers (Stakeholder Partners)
- III. Annual conference of partners and stakeholders , regulators and policy makers, to discuss research and commercialisation activities, presentation of work and networking
- IV. Specialist workshops with relevant partners on IP, technology transfer, authoring and reviewing papers, reports and EC policy affecting the aluminium sector
- V. Formulation of a strategy for increased public awareness, acceptance and trust regarding aluminium sector and red mud generation and management; specifically addressing recent disasters such as in Hungary
- VI. Collaborative activities between academic institutes and industry via researcher secondment, Visiting lecturers , key note talks by industry and creation of part time research masters for key personal and researchers in areas such as technology transfer, entrepreneurship and science to further education and skills across the aluminium sector.
- VII. International co-operation among partners connections, links and activities in non-EU countries: Establish regular contacts with countries in Latin America, Africa, Russia, China, and Australia envisaging a multilateral conference, exchanges of staff; project funding; facilitate cooperation of industry clusters

d. Monitoring Activities and Annual Report

- I. Assessment of BRAVO activities quarterly and generation of internal one pager to update partners and stakeholders
- II. Completion of EIP and monitoring indicators templates at end of year
- III. Generation of annual report
- IV. Generation of feedback from BRAVO partners and stakeholders on barriers to innovation in the aluminium sector
- V. Generation of Feedback on EU policy on Raw Materials and recommendations for future implementation.

4. Description of the expected impacts

BACKGROUND

First, alumina is obtained by refining bauxite in the Bayer process (termed **alumina refining**). The next step uses molten cryolite which dissolves alumina and then it is electrolytically reduced to aluminium (termed **aluminium smelting**). Electric power represents about 20% to 40% of the cost of producing aluminium, depending on the location of the smelter. Aluminium producers tend to locate smelters in places where electric power is both plentiful and inexpensive. In 2005, the People's Republic of China was the top producer of aluminium with almost a one-fifth world share, followed by Russia, Canada, and the USA, reports the British Geological Survey.

In 2011, **European countries** produced 3.2 million tonnes of bauxite out of the 15.5 million tonnes bauxite needed for their alumina production (6.8 million tonnes alumina). A further import of 4.0 million tonnes of alumina was needed to fulfil the demand of the primary aluminium producers in Europe. From a total aluminium metal supply of 13.2 million tonnes in 2011, 35% is produced by European primary smelters, 30% is net-imported and 34% is recycled by European refiners and remelters. Finally, the metal is processed into 4.5 million tonnes rolled products, 3.0 million tonnes extruded products, 3.2 million tonnes of castings, and another 1.2 million tonnes is produced in the form of wire, slugs, powder and some other applications. The aluminium industry in Europe directly employs around 255,000 persons [European Aluminium Association].

In spite of increasing global demand for aluminium, since 2003 ten primary aluminium smelters have closed in the EU, while none have opened or are planned to open. Therefore, a new Commission study looks at the **situation in the aluminium sector** and how its competitiveness is affected by regulatory costs. European Commission Vice President Antonio Tajani, Commissioner for Industry and Entrepreneurship, said: "Restoring the aluminium industry to competitiveness is an urgent issue. We need to carefully consider the effects of all relevant EU policies on this sector" [EC - MEMO/13/954 06/11/2013]. European competitiveness in this sector is imperative to both stabilise and reduce EU dependency on imports, promote production and protect jobs.

In addition to this situation, the **safe environmental management** of by-products and wastes from aluminium value chain is critical. Alumina and aluminium processing creates a range of waste products, the most significant being:

- Bauxite residue (red mud) from alumina refining which are normally landfilled

- Mercury emissions, which occur through refining operations as mercury naturally occurs in bauxite
- Spent Pot Lining (SPL), the waste produced from aluminium smelting process when the carbon and refractory lining of smelting pots reaches the end of its serviceable life.

In the event of improper disposal of waste residues such as red mud in rivers or lakes, there are fatal environmental hazards. The rain water run off from the red mud landfills increases river and stream water alkalinity which will convert lands into alkali soils when used for irrigation purpose. In October 2010, approximately 1,000,000 m³ of red mud from an alumina plant near Kolontár in Hungary was accidentally released into the surrounding countryside in the Ajka alumina plant accident, killing ten people and contaminating a large area. All life in the Marcal river was said to have been "extinguished" by the red mud, and within days the mud had reached the Danube. It is estimated the 5-6 million tonnes of red mud is generated per annum in Europe and the majority of this waste is being landfilled.

Currently, some European plants are slated to be closed because their red mud landfills are filled and governments are unwilling to give authorization to build new ones. A report published in 2010 by the International Aluminium Institute, states that storage volume reduction and revaluation of waste residues is a main strategic goal of the industry (>20% by 2025).

BRAVO believes this represents an opportunity to increase the competitiveness of the aluminium sector in Europe and be at the forefront of resource efficient technologies.

IMPACTS of BRAVO

The BRAVO commitment focuses to address the above issues across the entire European aluminium value chain via the "described activities". This is a gathering of key players to tap the full potential of primary and secondary materials by creating a pan-European raw materials knowledge base, developing innovative, sustainable technological solutions to access new raw materials from residues and establishing a friendly legal framework regarding mining waste and economically attractive environment across the EU, which takes into account environmental and social aspects. The specific impacts are as follows:

Al-Ore Impacts [SIP Action Area I.3]

Al-Ore focuses to optimise the aluminium value chain to reduce waste by products, residues and tailings, increase their subsequent processability and reduce their environmental impact. The entire chain will be evaluated with respect to waste tailings and techniques such a Variation Mode Effect and Analysis will be applied to minimise tailings and their effects. Optimised and alternative processing techniques and methodologies will be designed and tested on the various aluminium manufacturing process steps. Input from BRAVO partners along the value chain will be key to the success of such tests, specifically as the output of one step is the input to the another step in the chain. For example, alumina output is the input to the aluminium smelter while bauxite residue output is the input to the recyclers. Techniques such as "in-situ" leaching, solution mining and biotechnologies will be investigated to achieve the above and pilot plant investigations among partners will be conducted. Pilot output data will include red mud volume per alumina tonne, composition, pH and grain size. The designed processes will also be evaluated for different geographical site locations taking into account starting materials composition variations per region. The key impacts include:

- Develop environmentally sound alternative techniques to reduce aluminium tailings including red mud. **[Measurement: 1 registered process patent]**
- To push EU to the forefront of alumina and aluminium processing technologies **[Measurement: 1 BRAVO Key Note Speech]**
- To reduce the risks to population and environment of red mud landfills and spillages **[Measurement: up to 30% reduction in the alkalinity of Red Mud]**
- Stabilise jobs in the European aluminium value chain by making the industry more competitive. The cost of red mud disposal is expensive, accounting for about 2% of the alumina price. For example, the alumina price is about US\$439 per ton in China, so the disposal cost of red mud would be nearly US\$9 per ton of alumina production. **[Measurement: demonstrate a cost reduction of up to 30% per alumina tonne related to reduced disposal requirements]**
- Public demonstration of innovative pilot and public education **[Measurement: 1 pilot test site]**

Al-Source and Al-Build Impacts [SIP Action Area I.4]

Al-source focuses on using the bauxite residue (red mud) as a source of critical raw materials including gallium, titanium, selenum, germanium, dysprosium and cerium. These complex wastes contain high value metals in small volume fractions combined with a low grade bulk component composed of iron oxides. The output fraction of the Al-source project is the input fraction for the Al-build project where the bulk material will be recovered and processed for the construction sector. While Spent Pot Lining waste materials will also be investigated for commercial value and viable downstream processing options. The effect of varying composition due to differing sources of materials (composition and grain size) and processing parameters will also be quantified.

These projects will combine a series of complex and integrated solutions to convert residue wastes to raw materials and products. Al-Source will include developing a holistic design and optimisation of an integrated metallurgical system (including pyro-, hydro-, bio-, electro-chemistry) for the metal recovery from red mud and residues. This will be done via the expertise of the BRAVO commitment (involving academia, industry and technology suppliers) in metallurgy. While Al-build will focus on the remaining bulk low grade residue, investigating techniques and processes from alternative industries including the construction sector. The impacts of Al-source and Al-Build include:

- To unlock the volume of various raw materials from red mud residue & increase the range and yields of recovered raw materials **[measurement: achieve gallium, titanium, selenum, germanium, dysprosium and cerium recovery]**
- To result in higher economic viability and investment security of processing operations **[Measurement: 1 business plan and strategy document to illustrate viability of new technology]**
- To push Europe to the forefront in the area of raw materials processing technologies **[Measurement: 1 BRAVO key note speech]**
- To increase availability of recovered raw material and create added value products through reducing the quantities of the industrial waste and residues to be disposed or landfilled. **[Measurement: 15% of residue redirected from land fill at test facility]**
- To create numerous new jobs in processing **[Measurement: calculation of increased revenue generated by recycling operation and number of people required to carry out processing]**

Al-Chain Impacts [SIP Action Area II.1 and II.10]

The Al-Chain project focuses on both policy, co-operation across the aluminium value chain and the creation of innovation across the chain. Al-Chain will undertake the Innovation and Commercialisation activities of the BRAVO commitment previously detailed and support the co-operation activities including the following:

- Review the management of alumina residue waste as a resource including liability issues around old tailings facilities.
- Benchmark analysis of existing national policies regarding residue waste management in the EU
- Carry out at EU level a fitness check to assess the cumulative effect of EU policies/legislation on the aluminium sector focusing on waste management policy (augmenting the recent EC - MEMO/13/954 Nov 2013) and develop a minerals policy scoreboard.
- Exchange of best practices via the organization of different targeted workshops among BRAVO partners aiming at inter alia improving the current EU minerals policy framework.
- Joint annual meetings at EU level of Member States' mining relevant authorities, agencies, inspectors, including National Geological Surveys via BRAVO partners.
- Develop EU guidance on the streamlined application of the EU environmental legislation to alumina and aluminium residue waste management, and including R&D activities through the whole aluminium chain (EIA Directive2)
- Dissemination day on the Commission's guidance on Natura 2000 and non-energy extractive industries
- Assist in policy development in the area of industrial and mining waste deposits in the framework of Europe 2020
- Review and provide guidance on the legal status of the residue waste and reprocessing as a raw material
- Investigate Tax incentives for the promotion of uptake of new products
- BRAVO is a multistakeholder platform for the aluminium sector. Partners from across value chains – mining, processing, recycling, application, public sectors, and pan European associations
- Optimised raw materials flows along value chains; It is a cross sectorial partnership and facilitate knowledge exchange among the partners as well as total life cycle assessment

Al-Chain impacts in include:

- Improve the environmental management, including the EIA. This will reduce time and costs on one hand and increase stakeholders' engagement and trust on the other **[measurement: *guidelines on new techniques and processes for waste residue management*]**
- Improve the transparency of information on raw materials through public reporting **[measurement: *publication in high impact journal*]**
- Contribute to develop monitoring systems on raw materials flows and early warning systems on EU dependency on certain raw materials with our partner the International Aluminium Association **[measurement: *BRAVO monitoring system*]**

- Interdisciplinary and transnational cooperation will boost raw material sector in the EU [**measurement: 1 international conference held, establish a staff secondment programme**]

Al-Aware Impacts [SIP Action Area III.4]

Al-Aware focuses both on public awareness as well as skills, educations and knowledge within the European aluminium value chain and internationally. Al-Aware will pre-dominantly undertake the co-operation activities of the BRAVO commitment previously detailed. This will include:

- public awareness, acceptance and trust regarding aluminium sector activities and generation and management of red mud; workshops, public conferences, open days and campaigns [**measurement: minimum 1 workshop, 1 conference, 1 open day**]
- Travelling lectures/short courses on industry-related mineral resource skills [**measurement: minimum: 1 lecture, 1 course created**]
- Establish regular contacts with our mining/smelting partners operations in countries in Latin America and Africa, including multilateral conferences, exchanges of staff; facilitate cooperation of industry clusters . BRAVO partners have current projects with CAP S.A. (Chile), Codelco (Chile) and Instituto de Ecologia (Mexico), Sencico (Peru), Mintek (Africa) [**measurement: conference and establish secondment programme**]
- Increase of overall knowledge and skills of people working in the sector [**measurement: lecture, courses and workshop**]
- Through acquaintance of new specific education, improve the technological and economic management in the aluminium sector, tackling as well industrial development (environment friendly mining techniques) as well as environmental protection (waste and best practices for waste management) [**measurement: lecture, courses and workshop**]
- In the long term, through better knowledge about raw materials and the mining industry, change the negative perception of people towards the residue waste of aluminium processing [**measurement: Flash Eurobarometer on public acceptance and surveys**]

Contribution of BRAVO to the EIP Objectives

1. Reduction of import dependency and the promotion of production and exports

From a total aluminium metal supply of 13.2 million tonnes in 2011, 35% is produced by European primary smelters, 30% is net-imported and 34% is recycled by European refiners and remelters. The main world producer of aluminium in 2010 was China (41% of the total). Russia (11%), Europe (10%) and North America (11%) traditionally remain important production areas, but regions such as the Middle East and India are emerging as important producers of primary aluminium.

Rare earth elements are a group of 17 speciality metals used in high-tech products like smart phones and wind turbines. The EU imports more than 90% of its rare earth metal needs from countries like China as there is not enough internal supply. The alumina residue represents a source of these rare earths which can be sourced within the EU.

Long Term Target: Reduce net aluminium imports by 10%; (achieved through more efficient €/t cost via reductions through EU friendly regulatory cost and waste management costs); initially reduce rare earth import by up to 5%.

1a. Improve supply from within the EU

At about 2.1 million tonnes in 2012, EU's production of primary aluminium has been stable during the last three decade but it has been reduced by 19% from 2011 to 2012. On an increasing trend since the 1980's, the production of recycled (remelt and refined) aluminium in the EU reached about 4.1 million tonnes in 2012.

However, as the downstream production has constantly increased, and has recovered faster after the crisis, the import dependence of the EU aluminium industry has passed from roughly 35% to 50% (about 5.4 million tonnes imported in 2012).

Long Term Impact: Increase aluminium production within EU to 3 million tonnes (related to improved cost management along the value chain)

1c. Resource efficiency (inc Recycling)

It is estimated the 5-6 million tonnes of red mud is generated per annum in Europe and the majority of this waste is being landfilled. Reducing red mud landfill offers a 'return on commitment' for the environment: Red mud disposal landfills have an environmental footprint and land take. This improves the resource efficiency assessment for the mud stack (value and productivity of the lost resource in land covered)

Long Term Target: Reduce red mud land filling by 15%; achieving a recycling rate of red mud up to 30% by weight

2. Putting EU to forefront of raw materials sectors

BRAVO commitment and partners have aimed for a total indicative budget of € 45million investment in R&D across the value chain for the life of the commitment. The aluminium industry in Europe directly employs around 255,000 people. It is estimated that jobs in this sector can be increased by 5% with the initial introduction of new technologies to process waste residues within Europe.

2a. Make EU a leader in Raw Materials capabilities

Knowledge: 11 International scientific publications, 4 Patent applications or 2 licence

Skills: minimum 5 research masters in mining, refining, metallurgy created

Public acceptance: 1 EU survey of public acceptance for mining and refining (Eurobarometer)

2b. Mitigate environmental social and health impacts

Accidents: Major accidents like the Ajka alumina plant where approximately 1,000,000 m³ of red mud from an alumina plant was accidentally released into the surrounding countryside, killing ten people and contaminating a large area. All life in the Marcal river was said to have been "extinguished" by the red mud, and within days the mud had reached the Danube. Recycling of Red Mud and reduction of red mud landfill can have a significant environmental impact on the areas surrounding these processing plant.

Long Term Goal: Reduce red mud landfilling by 15%

Eco-efficiency: Minimising the amount of residue waste generated is of primary importance and is in line with the hierarchy of reduce, reuse and recycling model. Investigating the manufacturing process for eco-efficiency gains, support the reduce waste principle early on in the value chain.

Long Term Goal: Reduce red mud generation by 15%

Impact through BRAVO Partners

The BRAVO partnership consists of 6 private SMEs, 7 private large companies, 4 Research and Technology Organisations, 3 Public bodies, 2 NGO and 8 academic partners. The BRAVO partners are from across the entire value chain of the aluminium sector from mining, alumina refining, aluminium smelting, recycling, metallurgical recovery, research, down stream by-products and social dissemination.

The partners include University of Limerick (Ireland), Ceinmat (Spain), International Aluminium Association (UK), Rusal (Ireland), Ecocem (France), Aristotle University of Thessaloniki (Greece), Tecnicas Reunidas (Spain), Universitat Politecnica de Valencia (Spain), Aidico (Spain), Votchnik (Ireland), Geonardo (Hungary), Tecnalía (Spain), Fraunhofer (Germany), Loser Chemie (Germany), National Technical University of Athens (Greece), BRGM (France), Environment Protection Agency (Ireland), Acciona (Spain), University of Hull (UK), Sintef (Norway), Enval (UK), Hydro Aluminium (Norway), TU Bergakademie Freiberg (Germany), UC Rusal Engineering and Technology Centre LLC (Russia), Euromine (Belgium), Alteo Gardanne (France), National Agency for New technologies, Energy and Sustainable development (Italy), European Aluminum Association, Università di Napoli (Italy), and Trinity College Dublin (Ireland).

5. Innovation outcomes

- √ New products to the market
- √ New processes
- √ New technologies
- New business models
- New ideas to the market
- Societal innovation
- Other aspects

6. Comments (900 characters)

AI-Ore: 1 process patent, 1 pilot test, 2 publications, 1 presentation, 1 Licence.

AI-Source: 1 process patent, 1 pilot test, 2 publications, 1 presentation, 1 business plan for scale up, 1 Licence.

AI-Build: 1 process patent, 1 pilot test, 2 publications, 1 presentation, 1 business model for scale up, 1 Licence, 1 new product in construction, 1 product patent.

AI-Chain: 1 residue waste guidelines, 3 publications, 1 presentation, 1 mining residue policy document, 1 internal BRAVO monitoring system, 1 secondment programme.

AI-Aware: 1 international joint research collaboration, 2 publications, 1 presentation, 1 international secondment programme, 1 best practice on residue waste management document, 1 research master education programme.