THE EU FUNDED FAME PROJECT: HELPING EUROPE BECOME LESS RELIANT ON IMPORTED RAW MATERIALS

C P Broadbent and K Oliver[1)]
[1)]Wardell Armstrong International Ltd,46 Chancery Lane, London WC2A 1JE, UK

ABSTRACT

FAME was a first-generation Horizon 2020 EU funded Research & Innovation Project looking at **F**lexible **A**nd **M**obile **E**conomic Mineral Processing designed to facilitate the commercial exploitation of European skarn, greisen and pegmatite deposits.

The FAME Consortium comprised 16 beneficiaries from 7 different EU28 states. It commenced on 1 January 2015 and ended on 31 December 2018.

FAME test work was carried out on six reference ores, two examples of each of the ore types:

- Pegmatites: Länttä (Keliber), Finland and Gonçalo, Portugal;
- Greisen: Cinovec, Czech Republic and Tellerhäuser, Germany; and
- Skarn: Tellerhäuser, Germany and Tabuaço, Portugal.

Scouting and bench scale mineral processing test work led to pilot plant testing of two, innovative process flow sheets:

1. Goncalo ore (pegmatite) to produce a Li-mica (Lepidolite) concentrate with recover of by-products (cassiterite, feldspar concentrate and quartz); and
2. Tellerhäuser ore (skarn) to produce a commercially acceptable tin concentrate with co-recovery of valuable by-products (zinc and copper sulphides and magnetite).

Both pilot plant campaigns were undertaken at TRL 6/7.

The Gonçalo pilot plant test work successfully demonstrated that production of Li-mica concentrates suitable for the conversion to lithium compounds for use in Lithium Ion Batteries.

The Tellerhäuser pilot plant test work successfully produced tin concentrates appropriate for primary smelting. Indeed, interest of a local tin smelter operating currently, exclusively on secondary tin production, could return primary smelting to Europe after a gap of more than two decades.

1 INTRODUCTION AND BACKGROUND

In 2008 the EU launched a "Raw Materials Initiative" with the aim to secure sustainable supplies of non-energy, non-agricultural raw materials. An integrated strategy was established to boost resources efficiency and recycling, ensure a level playing field in access to resources in third countries and foster sustainable supply from European sources. The EU recognised also that many of the raw materials vital to European industry were reliant upon importation from outside the EU28 with China dominating the production of many of these commodities. In 2010 the EU published a list of 14 Critical Raw Materials (CRM's) which was updated to 20 CRM's in 2017 and extended to 27 CRM's in 2017[(1)]. The current CRM list is shown in Table 1 below.

Table 1: EU CRM List – as amended 2017				
Antimony	Baryte	Beryllium	Bismuth	Borates
Cobalt	Coking coal	Fluorspar	Gallium	Germanium
Hafnium	Helium	Indium	Magnesium	Natural Graphite
Natural Rubber	Niobium	PGMs	Phosphate Rock	Phosphorous
REEs (Heavy)	REEs (Light)	Scandium	Silicon Metal	Tantalum
Tungsten	Vanadium			

It is notable that lithium does not satisfy the 'criticality' test and is currently not one of the 27 CRM's. This is due principally to its relative abundance; however, it is regarded by the EU as a key strategic metal.

One of the EU28 responses to the global financial crisis of 2007-2008 was a recommitment towards industry within Europe and in 2011 the EU Heads of State and Government called on the European Commission to bring together all the previous EU Research and Innovation (R&I) funding into a single common strategic framework. Horizon 2020 [(2)] became the biggest EU R&I funding programme ever, with nearly 80 Billion Euros of funding available over 7 years (2014-2020) and is the financial instrument implementing the Innovation Union a Europe 2020 flagship initiative aimed at securing Europe's global competitiveness.

FAME (Flexible and Mobile Economic Mineral Processing) was one of the initial cohort of Horizon 2020 projects with funding commencing on 1 January 2015 (7.4 million Euros) and was one of the first projects that was part of the H2020 Societal Challenge, 'Climate action, environment, resource efficiency and raw materials' (Societal Challenge 5). FAME was a mineral processing R&I project which was industry driven and the FAME consortium comprised European mineral developers, technical and research orientated small and medium sized enterprises, research institutes, academia and raw materials networking companies. The Consortium Partners are show in Table 2.

Table 2: FAME Consortium Composition

Project Number	641650	Project Acronym	FAME

List of Beneficiaries					
No	**Name**	**Short name**	**Country**	**Project entry date**	**Project exit date**
1	WARDELL ARMSTRONG LLP	WAI	United Kingdom		
2	GEOKOMPETENZZENTRUM FREIBERG EV	GKZ	Germany		
3	G.E.O.S.INGENIEURGESELLSCHAFT MBH	GEOS	Germany		
4	NICKELHUTTE AUE GMBH	NHA	Germany		
5	EUROCOLT RESOURCES UNIPESSOAL LDA	Eurocolt	Portugal		02/03/2018
6	GEOMET SRO	Geomet	Czech Republic		
7	Keliber Oy	KBO	Finland		
8	GBM MINERALS ENGINEERING CONSULTANTS LIMITED	GBM	United Kingdom		
9	BUREAU DE RECHERCHES GEOLOGIQUES ET MINIERES	BRGM	France		
10	GEOLOGIAN TUTKIMUSKESKUS	GTK	Finland		
11	Laboratorio Nacional de Energia e Geologia I.P.	LNEG	Portugal		
12	THE UNIVERSITY OF EXETER	UNEXE	United Kingdom		
13	NATURAL HISTORY MUSEUM	NHM	United Kingdom		
14	UNIVERSITE DE LORRAINE	UL	France		
15	UNIVERSIDADE DO PORTO	UPORTO	Portugal		
16	LULEA TEKNISKA UNIVERSITET	LTU	Sweden		
17	Asociación para la Investigación y Desarrollo Industrial de los Recursos Naturales	AITEMIN	Spain	01/01/2015	01/12/2016
18	SAXORE BERGBAU GMBH	SAXORE	Germany	01/04/2016	
19	UVR-FIA VERFAHRENSENTWICKLUNG UMWELTSCHUTZECHNIK - RECYCLING GMBH	UVR	Germany	01/01/2018	

Note: Project Entry date 01/01/2018 unless otherwise stated

1.1 FAME SCOPE

FAME was established to increase the competitiveness of European enterprises developing mining and mineral processing operations based on skarn, pegmatite or greisen ore bodies within EU28. The project focussed on 'ore type' rather than a specific commodity as these three ore types are relatively common through Europe and contain many of the CRM's and Lithium. The aim was to stimulate private investment in the European mining sector and help maintain key mineral processing skills and expertise within EU28. This latter point was regarded as crucial as many metallurgical and mineral processing skills were in danger of being lost to Europe. The contraction of the European mining industry since WW2 had led to the closure of not only metallurgical plants in Europe but also many of the schools and universities where disciplines such as mineral processing were taught.

One of the principal reasons why skarns, pegmatites and greisens were chosen as ore types to work on in the FAME programme was that they were relatively abundant in Europe and often relatively small scale but mineralogically complex nd, hence, most approriate to flexible and mobile mineral processing strategies. Furthermore, the European examples of these or types were known to contain a number of CRM's, giving FAME a CRM focus, thereby supporting directly other EU initiatives [3].

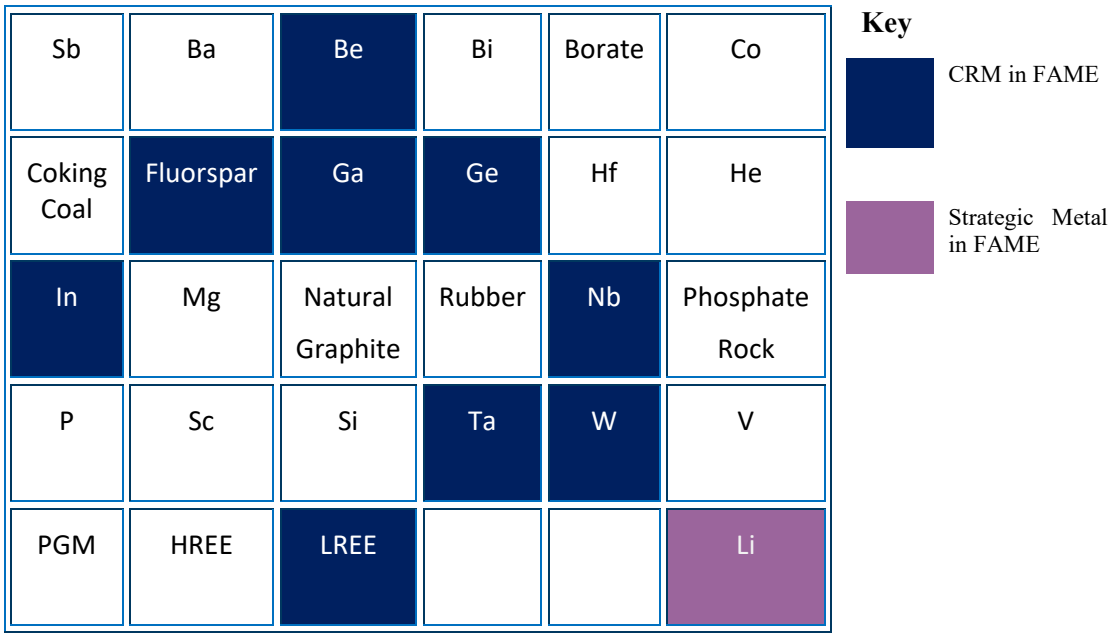

Figure 1: Highlighted CRM's and Strategic Metals Present Frequently in European Skarn, Pegmatite or Greisen Deposits

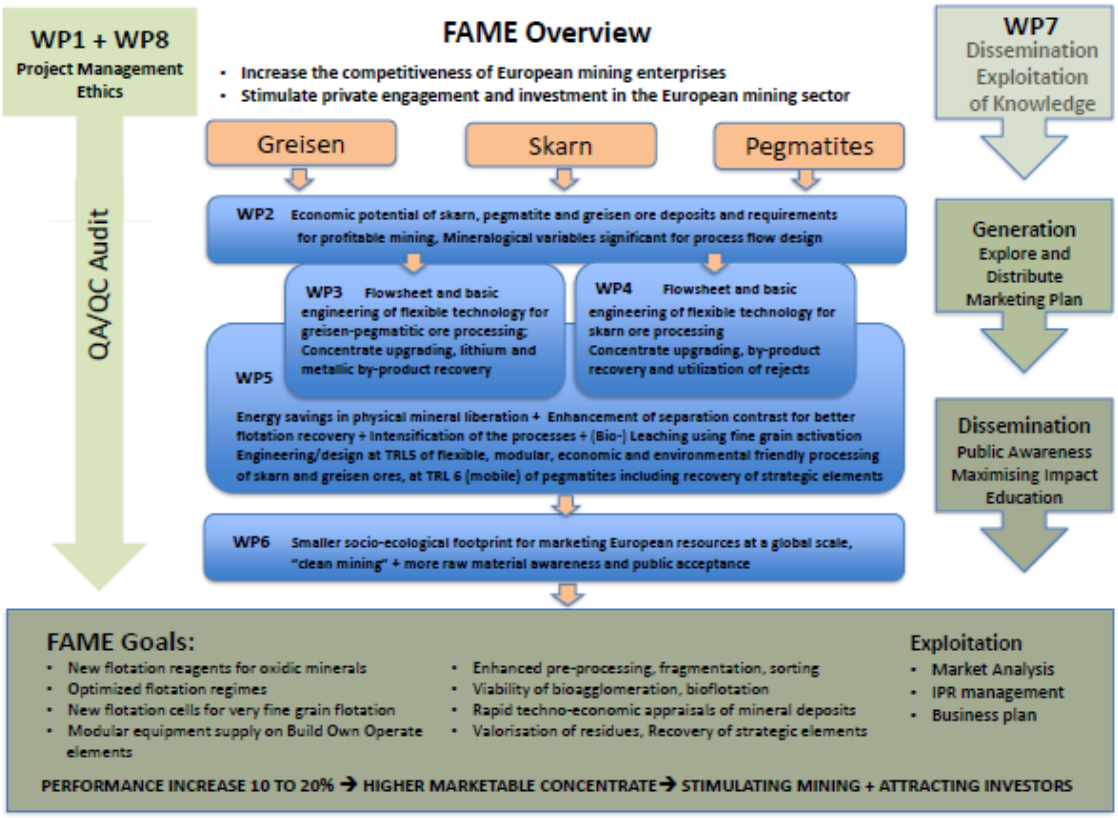

Figure 2: Schematic Overview of the FAME Project

FAME was a 4-year project commencing 1 January 2015 and the grant ended on 31 December 2018. An overview of the Project is presented in Figure 2. FAME delivered mineral processing flowsheets that can enable the exploitation of European ore deposits in an environmentally acceptable manner.

Test work was carried out on six reference ores (see Figure 3). These comprised two examples of each of the three principal ore types. Although bespoke flow sheets were developed to unlock the mineral potential of the actual ores, it was always envisaged that the mineral processing strategies that were developed should be sufficiently flexible so that generic solitons could be applied to other, similar ore deposits.

Figure 3: FAME Reference Sites

A number of tentative mineral processing flow sheets were developed but he culmination of the FAME project has been to undertake pilot plant test work at TLR6/7[4] on two different ores:

1. Gonçalo – Lithium mica pegmatite Portugal – with pilot tests undertaken at LNEG, Porto; and
2. Tellerhäuser – Tin greisen/skarn ore, Saxony, Germany with pilot plant tests undertaken at UVR-FIA, Freiberg, Germany.

FAME Work Package (WP) 2 consisted of detailed mineralogical characterisation and chemical analysis of the ores and was a precursor to all subsequent process test work. WP3 dealt with bench scale processing of skarn and pegmatite ores whereas WP4 dealt with bench scale test work on greisen ores. WP5 essentially extended this work to larger scale, demonstration activities (the pilot plant test work) bringing the work closer to commercialisation.

1.2 FAME RESULTS

The significance of lithium as a battery metal vital to the implementation of the electrification of vehicles grew dramatically since the submission of the FAME proposal in 2014. As FAME was the only H2020 Raw Materials project dealing with the upstream production of lithium the FAME Steering Committee concluded that one of the principal demonstration projects within FAME should revolve around the production of lithium mineral concentrates. 3 of the 6 FAME reference ores can be regarded as potential lithium resources. Indeed, FAME partner Keliber hope to produce a lithium spodumene mineral concentrate from their own mine in 2021[5].

Pilot Scale production of lithium mica (lepidolite) concentrates containing up to 5.0% (m/m) lithium oxide (Li_2O) has been undertaken successfully by LNEG[6] using a development of THE generic mineral processing concept for processing lithium bearing hard rock minerals developed by the FAME programme (see Figure 4).

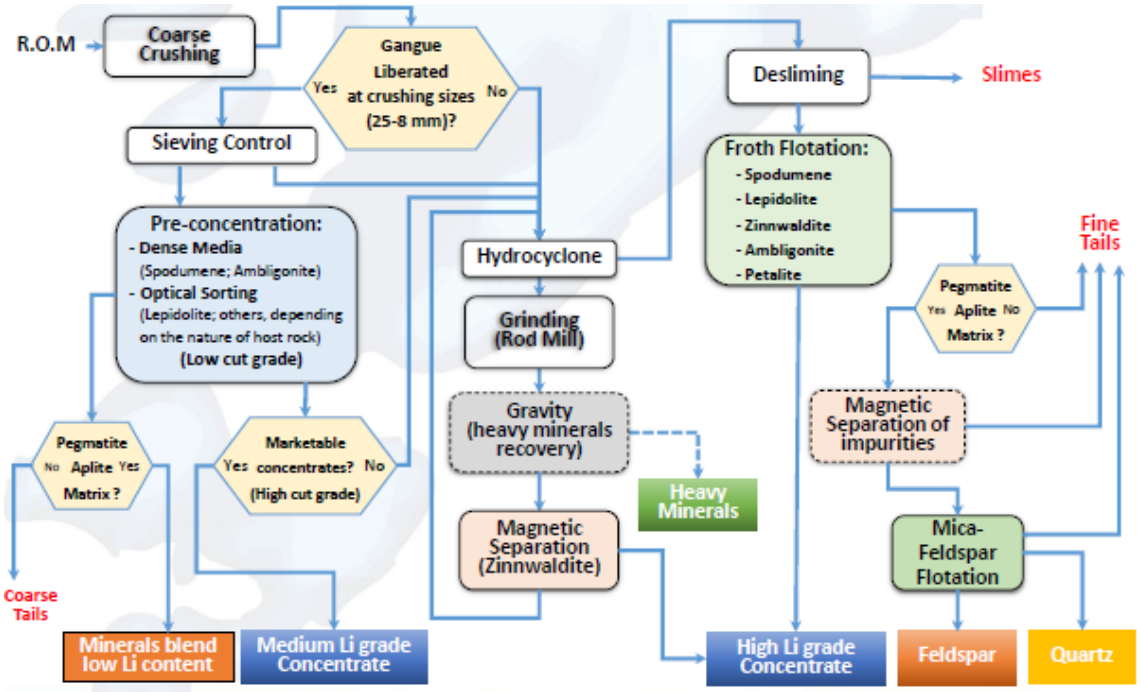

Figure 4: Generic Conceptual Flow Diagram for Processing Hard Rock Lithium Minerals – Author M. Machado-Leite 2018.

FAME Partner GBM derived preliminary OPEX and CAPEX figures for a 1Mt/a and a 350,000 t/a mineral processing plant. CAPEX was estimated at approximately 75M USD and 40M USD respectively with OPEX between 150-350 USD/t (towards the upper estimate for the smaller plant). The MOTA Group (owner of the Gonçalo licence) is evaluating currently whether to expand their business portfolio to include Li-mica production. Whether this happens is likely to be dependent largely upon the availability of conversion plants to convert the mineral concentrate into lithium carbonate or lithium hydroxide within own economically viable distance. Currently there are no such facilities within EU28 and such facilities will be required in future should the electrification of vehicles proceed as anticipated and European automobile manufacturers wish to retain some security of supply by having a proportion of battery materials (and/or the batteries produced in Europe rather than relying on 100% importation from China.

The Tellerhäuser deposit is a polymetallic skarn hosted deposit in the Western Erzgebirge in Saxony, Germany. It hosts tin, zinc, indium, copper, iron, silver and gallium. The deposit was explored extensively in the late 1960's to late 1980's by SDAG Wismut a Soviet-East German joint venture focussed on uranium mining. This exploration concluded with the statement that due to the complex mineralogy the ores were difficult, if not impossible to process viably. Saxore Bergbau GmbH (SBG) is a German registered company set up to hold Anglo Saxony Mining's (ASM's) project in Germany. The main focus of SBG is the Tellerhäuser Project. SBG is a Partner in FAME as well as a German nationally funded project AFK. In 2018 FAME, AFK and SBG formed a unique research alliance to bundle ideas, results, work force,

finances and know-how to create additional benefit for all parties. The results of this collaboration was to create an industrial scale pilot plant at UVR-FIA in Freiberg, Saxony, with UVR-FIA joining the FAME Consortium formally in mid 2018. The pilot plant campaign lasted until early December 2018 and the analysis and interpretation of all the data generated in the test work is still under way.

Figure 5: Pilot Plant Developed at UVR-FIA to Treat Tellerhäuser Ore.

However, M Roscher, MD of SBG concluded at the FAME Closure Conference in London in December 2018 that the FAME-AFK collaboration had resulted in the successful production of marketable tin concentrate with the co-recovery of sulphides (zinc and copper) and magnetite. Indeed, the statement that the Tellerhäuser ore was "too difficult" to process had, with the application of modern, flexible mineral processing technologies, been shown to be incorrect.

1.3 IMPACT AND CONCLUSIONS

FAME has delivered significant impact to the European mining and minerals sectors. This was recognised in July 2018 when the FAME consortium was awarded the IOM3 Medal for Excellence for "significant contributions to the art and science of mineral processing over a number of years".

Figure 6: IOM3 Medal for Excellence

The output for FAME has been considerable with over 20 published papers (with more in the pipeline) and presentations at over 20 International Conferences (in Europe, Asia and the Americas). Furthermore, FAME has helped maintain key mining and metallurgical skills within Europe.

FAME has had a strong impact on SME's within and associated with the FAME Consortium, it has:

- assisted Keliber in by-product valorisation, keeping it on track to become Europe's first significant Lithium producer by 2021;
- provided the MOTA group with an opportunity to expand its business portfolio to include production of lithium concentrates;
- helped fast-track the commercialisation of the Tellerhäuser deposit by SBG; and
- undertaken SAG mill testing – now incorporated in to flowsheet for European Metals.

1.4 ACKNOWLEDGEMENTS

The authors would like to thank all members of the FAME Consortium for their efforts over the last 4 years and the EU for the provision of a Grant (No. 641650) under the EU's Horizon 2020 Research and innovation Programme.

REFERENCES

(1) C Blackmore and W Reimer 2017, Security of Supply in Europe, Materials World
(2) www.EC.Europe.EU – what is Horizon 2020?
(3) https://publications.parliament.uk – Technology Readiness Levels
(4) European Commission, Brussels 13.9.2017. Communication from the Commission to the European Parliament, the Council of the European Economic and Social Committee and the Committee for the Regions in the 2017 list of Critical Raw Materials for the EU.
(5) P Lamberg, T Korhonen and D Salvador 2018, Implementation of the Keliner Mining Project, pp 36-43 in Flexible and Mobile Mineral processing in the 21st Century – The FAME closure Conference, London 5-6 December 2018.
(6) M Machado Leite 2018, Pilot Plant Trials of Li-mica Concentrate Provision from Gonçalo Pegmatite (Portugal), pp 45-51 in Flexible and Mobile Mineral processing in the 21st Century – The FAME closure Conference, London 5-6 December 2018.