TECHNISCHE UNIVERSITÄT
BERGAKADEMIE FREIBERG
Die Ressourcenuniversität. Seit 1765.

Das „Chilean Technologies Institute“ und Ideen an der TU Bergakademie hierzu

Foto: Reuters.
Aus Wirtschaftswoche 29.8.2016

Prof. Michael Schlömann, TU Bergakademie Freiberg
CAMCHAL 11.10.2019

Ausgangslage

Globale Herausforderungen:

- Klimaerwärmung
- Trend zur Elektromobilität → mehr Bedarf an Cu, Li, Co
- Energieverbrauch durch Bergbau und Metallurgie
- Wasserverbrauch u.a. Umweltprobleme durch Bergbau und Metallurgie

Situation Chiles:

Potenzial:
- größter Kupferproduzent, größte Kupferreserven
- größte Lithiumreserven
- höchste Sonneneinstrahlung (doppelt so hoch wie in Deutschland

Probleme:
- geringer Anteil an Wertschöpfung im Land
- noch geringer Ausbau erneuerbarer Energien, aber z.Z. extrem dynamisch
- z.T. veraltete Technologien

Ziele: - Angehen der globalen Herausforderungen
- wirtschaftliche Entwicklung Chiles

Grundidee

- **Aufbau eines neuen Institutes in der Region Antofagasta, das bis 2030 in seinen Arbeitsgebieten weltweite Sichtbarkeit erlangt hat**

- **Nutzung von 193 mio USD bis 2030 aus Vertrag von CORFO**

- **Zweistufiges Verfahren:**
  Request for Information: Deadline 20.5.2019
  Request for Proposals: Veröffentlichung ursprünglich geplant für 24.6.2019
  Deadline ursprünglich geplant für 23.10.2019

Von CORFO erwartete Effekte

- **Entwicklung neuer Materialien und Innovationen um einen Mehrwert zu schaffen für Lithium, Salze u.a. Materialien für Elektromobilität und grünes Wachstum**

- **Entwicklung von Photovoltaik und konzentrierenden Energietechnologien angepasst an das extreme Wüstenklima**

- **Entwicklung und Transfer von Technologie für die Bergbauindustrie, um bis 2030 zu erreichen, dass**
  - „Zero-Emission-Fuels“ Diesel zu 50% ersetzen,
  - in einigen Bergwerken Solarenergie die Hauptenergiequelle ist,
  - Prozessinnovationen gemacht und Solarthermie genutzt wird.

- **Training von mindestens 100 hochqualifizierten Fachkräften durch Entwicklung von Masterarbeiten und Doktorarbeiten, Postdoc–Aufenthalten etc.**

- **Unterstützung von mindestens 100 Geschäftsideen oder Ausgründungen und Schaffung eines „Ökosystems“ für Innovation und Unternehmergeist**

Rollen und Funktionen des CCTI

- **Forschung und Entwicklung**
  u.a. Patente, Entwicklung von Prototypen, Aufbau von pilotanalagen

- **Bereitstellung von Dienstleistungen**
  u.a. für Nutzung von Pilotanlagen, Demonstrationsversuche, Beratung
  (muss über marktübliche Dienstleistungen hinausgehen)

- **Entwicklung und Stärkung des Humankapitals**
  u.a. Aus- und Weiterbildungs-Aktivitäten, Graduiertenausbíldung,
  Promotionsprogramme, Postdoc-Aufenthalte

- **Verbreitung und Ausweitung**

- **Unterstützung von Unternehmergeist und Innovationen**
  Schaffung von Arbeitsplätzen

Arbeitsfelder

1. Solar Energy

CHALLENGE 1: Solar electricity:
Integration of solar electricity generation solutions from Photovoltaic (PV) and Concentrating Solar Power (CSP) technologies, covering from the current state of technology to the challenges and opportunities presented by the solar resource in Chile to competitively supply the industry.

CHALLENGE 2: Solar fuels:
Development and integration of production solutions and efficient use of fuels produced by solar energy, including, among others:

- Production, storage, transport and distribution of **solar hydrogen** through electrolysis on an industrial scale, in extreme desert and high altitude conditions.
- Production, storage, transport and distribution of **synthetic fuels** based on solar energy through photochemical, electrochemical, thermochemical processes or others.
- Development and scaling of technological solutions using **solar fuels for transportation**, inputs and processes that reduce emissions from mining industries and others.

Arbeitsfelder

1. Solar Energy

CHALLENGE 3: Solar heat:
Developing systems that allow the use of solar energy to supply the thermal requirements of industrial and mining processes for different levels of temperature and pressure, with special attention to solutions that minimize the effects of solar radiation variability, including, among others:

- Technological innovations to **integrate solar heat in mining and industrial processes**.
- Technological innovations for the application of direct **solar energy in mineral transformation processes** (systems for drying, calcination, smelting and transformation of minerals and/or metals).

CHALLENGE 4: Desalination and water treatment using technologies based on solar energy.
Development, scaling and integration of technological solutions that use solar energy as the primary source for water treatment, provided that this represents a challenge of applied research or cutting-edge technological development.

- Desalination and solar power concentration systems.
- Small-scale desalination outside the electric grid.
- Solar detoxification and water disinfection systems.

.

Arbeitsfelder

2. Low-Emissions Mining

CHALLENGE 1: Energy sustainability and reduction of the carbon footprint in metal mining, with a circular economy approach

Reduction of emissions in the production of metals, so that they are inserted in the value chain of electromobility and green growth, among others. This challenge includes aspects such as:

- Technological development for energy efficiency; energy recovery and fossil fuel substitution.
- Focus on eco-efficiency in the production of copper and other minerals, valuing waste and generating valuable by-products, with a minimum carbon and water footprint.

CHALLENGE 2: New low emissions mining-metallurgical processes.

Increasing the value and/or producing new products with the minimum carbon footprint, through new approaches for mineral processing and disruptive innovations in the value chain ems.

.

Arbeitsfelder

2. Low-Emissions Mining

CHALLENGE 3: Innovations for the traceability of greenhouse gases emissions.
Providing verifiable evidence of emission reductions in the production of copper and other materials complementary to lithium in the electromobility industry and green growth.

.

CHALLENGE 4: Innovations for the sustainability of the non-metallic mining industry that operates in the "salares".
Supplying technologies for the extraction and processing of lithium and other relevant products from the salar, with low water consumption, low Greenhouse gases emissions and minimum environmental impacts

.

.

.

Arbeitsfelder

3. Advanced Materials of Lithium and other Minerals for Electromobility and Energy Storage

CHALLENGE 1: Innovations in advanced materials based on lithium, salts and other strategic minerals

Offering a competitive supply to the electromobility and energy storage industries, advancing in the value chain, with emphasis on the creation of opportunities for local productive investment, including aspects such as:

- Development of new compounds and alloys, based on lithium and/or other strategic minerals that reduce costs and extend the useful life of the components for electromobility, as well as for the storage and conduction of energy.
- Development of production methods and processing of advanced materials and products based on lithium and/or other strategic minerals, through the manufacture of new nanoparticles, laminates or other products.
- Development of materials based on salts and other products of the mining properties, which achieve greater efficiency for thermal storage of solar energy

CHALLENGE 2: Development of technologies to more efficiently extract and concentrate scarce products used in batteries and storage, such as cobalt.

Konsortien

Antragstellende Konsortien

ASDIT: Konsortium der führenden und bergbaurelevanten chilenischen Universitäten
Weitere Mitglieder: Industrievereinigung Antofagasta, MIT als “associate”, Europäisches Lithium Institut (mit Fraunhofer ISC Würzburg), TUBAF ggf. als “constituent”
Exklusivität

Fraunhofer Chile + CSIRO (Australien)
Weitere Mitglieder: u.a. KIT
Argument: TRL
Defizit: keine relevante chilenische Universität

Fundación Chile
Weitere Mitglieder: u.a. DLR
Keine eigene Forschung und Entwicklung, letztlich Mittelverteilung
Defizit: keine relevante chilenische Universität

Erwartung, dass durch Spezifikation der Bedingungen in RFP-Phase andere Konsortiums-Zusammensetzung

Anforderungen an Konsortien

- Chilenische gemeinnützige Einrichtung für Forschung und Entwicklung und Innovation
- Beteiligung von Universitäten oder staatlichen Einrichtungen Chiles
- Beteiligung von Institutionen aus der Region Antofagasta
- Internationale Kooperation
- 30% Selbstbeteiligung, davon 60% “pecuniary contribution”
- Orientierung auf die Lösung industrieller Probleme in technologischen Kerngebieten mit entsprechendem Humankapital

Chancen für Deutschland

Für Firmen:
- **Lieferanten von Ausrüstung für Bergbau und Energieanlagen**
- **Ingenieurdienstleister**
- **Produktion in Chile?**

Für Universitäten und Forschungseinrichtungen:
- **Fragestellungen, Forschungspartner**
- **Nachwuchs**
- **Bekanntheit, auch in Nachbarstaaten**
- **Chile als attraktives Partnerland**

Strategisch:
- **Sicherungvon Rohstoffquellen**
- **Sicherung von Absatzmärkten**
- **Lateinamerika als strategische Partnerregion**

Area: Solar Energy

Area: Solar Energy

Challenge 1: Solar Electricity

Topic: Reliability of High-Efficiency Solar Modules + Lifetime Energy Yield

Impact:
- Improved reliability of high-efficiency solar modules under high uv irradiance
- Optimization of high-efficiency solar modules under high irradiance conditions
- Lifetime energy yield and LCOE modeling considering reliability test results
- Focus on mining districts with storage systems in high irradiance areas and relaibility test under „Chilean“ conditions

Institution, group: TUBAF, Institute of Applied Physics, J. Heitmann, M. Müller

Rationale:
- Reliability testing of solar cells and modules, especially concerning UV resistance
- Design of series resistance and carrier injection optimized solar cells for high irradiance conditions
- Modeling of the influence of degradation mechanisms on the lifetime energy yield

Experience, prior work:
- Several projects on reliability testing of solar cells and modules
- Simulation and loss analyses of high-efficiency solar cells (PERC, Hetero-Junction)

TRL: Currently TRL 3-4, goal to be reached with partners at least TRL 6 or higher

German companies or other German partners involved:
- Hanwha Qcells GmbH

Chilean partner (if already identified): not yet identified

Area: Solar Energy

Challenge 1: Solar Electricity

Topic: Improved Efficieny, Life-time & Recycling of Mono- & Multicrystalline Silicon Solar Moduls

Impact:
- Higher output and improved cost performance of large and small scale solar electricity generation
- Involvement of Chilean research and industry in recycling of PV-moduls and electronic waste

Institution, group: TUBAF, Institute of Inorganic Chemistry (E. Kroke, A. Stapf)

Rationale:
- About 90% of PV installations world wide are based on mono- and multicrystalline silicon solar cells
- Innovative & improved cell processing, production, use & raw-material re-use have a large impact

Experience, prior work:
- Since 2005 several joint r&d projects in different areas have been successfully completed
- Patents, peer-reviewed publications and several completed PhD-theses

TRL: Currently TRL 4, TRL 6 to be reached in 2 years

German companies or other German partners involved:
- International Solar Energy Research Center Konstanz (ISC), to be confirmed
- RENA Technologies GmbH (Gütenbach), to be confirmed

Chilean partner (if already identified):
- To be identified

Area: Solar Energy
Challenge 2: Solar Fuels

Topic: Energy-Efficient Electrolysis of Water

Impact:
- Reduction of energy for production of H_2 by solar energy
- Possible storage form of energy for alternating renewable energy systems

Institution, group: TUBAF, Institute of Nonferrous Metallurgy and Purest Materials, M. Stelter
in cooperation with Fraunhofer Institute for Chemical Technology

Rationale:
- Use of efficient catalysts, which are not to costly and can be recycled

Experience, prior work:
- Long experience in development of catalysts for different application, e.g. water electrolysis or chloro-alkaline electrolysis

German companies or other German partners involved:
- Still open, but some companies interested

Chilean partner (if already identified):
- Not yet

Area: Solar Energy
Challenge 2: Solar Fuels

Topic: Hydrogen as a Fuel from Solar Energy

Impact:
- Use of almost emission-free renewable (solar-) energy, especially reduction of CO_2-emissions
- Hydrogen as a chemical can be stored and opens up completely different application possibilities

Institution, group: TUBAF, Chair of Gas- and Heat Technology, H. Krause

Rationale:
- Generation of so called „green hydrogen“ from solar energy (photovoltaics) by means of electrolysis (Power-To-Gas), use of hydrogen as a fuel: applications, such as fuel cells, engines, material use, etc.

Experience, prior work:
- Numerous projects on the topics of H_2 generation and H_2 use in fuel cells, such as: H2Home, FC-District, HyLPG, HyRef, WiBgE, …

German companies or other German partners involved:
- DBI-Gruppe (Freiberg und Leipzig)

Chilean partner (if already identified):
- …..

Area: Solar Energy
Challenge 2: Solar Fuels

Topic: Sensors for Fuel Cells

Needs application partner

Impact:
- Optimization of fuel cells to increase efficiency and lifetime
- Sensors, to monitor and control the operation on-line

Institution, group: TUBAF, Institute of Electronic and Sensor Materials, Y. Joseph

Rationale:
- Sensor system can monitor and adjust the operating parameters of fuel cell
- Sensors increase the reliability, service life and energy efficiency of the cell

Experience, prior work:
- Development and production of novel chemical sensors,
- Process monitoring with sensors
- …

German companies or other German partners involved:
- DLR - Deutsches Zentrum für Luft- und Raumfahrt e.V.,
- CiS - Forschungsinstitut für Mikrosensorik GmbH

Chilean partner (if already identified):
- …..
- …..

Area: Solar Energy
Challenge 3: Solar Heat

Topic: Process Heat from Solar Concentrators Using Salt Melts

Impact:
- Reducing fuel usage for heating processes
- Reduces fossil fuel dependency

Institution, group: TUBAF, Chair of Gas- and Heat Technology, H. Krause

Rationale:
- Using solar concentrators for heating salt melts up to 700°C. Can be used for energy storage, process heat or steam generation for electricity

Experience, prior work:
- Construction and operation of a parabolic solar concentrator
- Integration of solar heat into processes

German companies or other German partners involved:
- WÄTAS (still to be asked)

Chilean partner (if already identified):
- …..
- …..

Area: Solar Energy

Challenge 3: Solar Heat

Topic: Solar-Thermal Technologies for Low-Temperature Applications, e.g. Water Desalination

Impact:
- Use of almost emission-free renewable solar thermal technologies, reduction of climate change impacts

Institution, group: TUBAF, Chair of Gas- and Heat Technology, H. Krause

Rationale:
- Studies on solar-thermal technologies and collector design
- Application of solar-thermal technologies on desalination of water

Experience, prior work:
- Solar-thermal technologies and climate change impacts
- Simulation study of solar collector with a selectively coated polymeric double walled absorber plate

German companies or other German partners involved:
- Freiberg Institute (still to be asked)
- Timo Leukefeld (still to be asked)

Chilean partner (if already identified):
- …..
- …..

Area: Solar Energy

Challenge 4: Desalination and Water Treatment Using Technologies Based on Solar Energy

Topic: Durable Solar Distillery Made of Glass

Impact:
- Longer lifetime and economically advantageous compared to conventional solar distilleries made of plastic
- Recyclability of the glass distilleries

Institution, group: TUBAF, Institute of ceramic, glass and construction materials

Rationale:
- Using black foam glass as solar absorption, insulation and water-bearing material
- Production of distilled water and concentrated brine

Experience, prior work:
- Study of the sense of such a distillery
- Conceptual work for the construction of a distillery and a complete system
- Development of manufacturing technologies

TRL: Currently TRL 3-4, TRL 5 can be reached in 2-3 years

German companies or other German partners involved:
- Jörg Storz (Visionary of solar desalination)
- Further companies under negotiation

Area: Solar Energy

Challenge 4: Desalination and Water Treatment Using Technologies Based on Solar Energy

Topic: Sensors for Process Monitoring

Needs application partner

Impact:
- Process sensors can monitor adverse operating conditions and adjust the operating parameters
- Failure can thus be detected early or even avoided

Institution, group: TUBAF, Institute of Electronic and Sensor Materials, Y. Joseph

Rationale:
- By improving process diagnostics/monitoring, operating conditions can be adjusted to increase reliability, life and energy efficiency

Experience, prior work:
- Monitoring of desalination and nanofiltration processes
- Development of chemical and physical sensor networks

German companies or other German partners involved:
- UIT Michael Zauner
- Endress+Hauser

Chilean partner (if already identified):
- …..
- …..

Area: Solar Energy

Challenge 4: Desalination and Water Treatment Using Technologies Based on Solar Energy

Topic: Membrane Materials

Needs application partner

Impact:
- Support of solar desalination and water treatment with novel membrane materials

Institution, group: TUBAF, Institute of Electronic and Sensor Materials, Y. Joseph/P. Arki

Rationale:
- Energy savings and increased desalination efficiency through combined processes with new membrane materials

Experience, prior work:
- Development of membrane for desalination and nanofiltration
- Optimization and monitoring of desalination and nanofiltration prozesses

German companies or other German partners involved:
- UIT Michael Zauner
- Endress+Hauser

Chilean partner (if already identified):
- …..
- …..

Area: Low Emissions Mining

Area: Low Emissions Mining

Challenge 1: Energy Sustainability and Reduction of the Carbon Footprint in Metal Mining, with a Circular Economy Approach

Topic: Dry Comminution of Ores

Impact:
- Reduction of energy in comminution processes by elimination of SAG/ball mill processing
- Reduction of water consumption in ore processing
- Reduction of tailing pond requirements

Institution, group: TUBAF, Institute of Mineral Processing Machines, H. Lieberwirth

Rationale:
- Cone crushing/ HPGR milling instead of SAG/ball milling
  reduced recirculation loads for mills by sharp mechanical classification
- Innovative coarse ore bucket elevators for recirculation around HPGRs

Experience, prior work:
- Cone crushing tests with Kubria cone crusher for porphyry ores in Freiberg pilot plant
- Coarse ore bucket elevators test facility with Aumund in Rheinberg

TRL: Currently TRL 5, TRL 6 to be reached in 2 years

German companies or other German partners involved:
- Aumund (still to be asked)
- thyssenkrupp (still to be asked)

Chilean partner (if already identified):
- ……..

Area: Low Emissions Mining

Challenge 1: Energy Sustainability and Reduction of the Carbon Footprint in Metal Mining, with a Circular Economy Approach

Topic: Selective Comminution of Mo/Cu-Ores

Impact:
- Reduction of energy in comminution processes
- Increased recovery of Mo from Cu ores

Institution, group: TUBAF, Institute of Mineral Processing Machines, H. Lieberwirth

Rationale:
- Employing different strengths of molybdenite, chalcopyrite, bornite and host rock minerals
- Producing pre-concentrates by separating the finer fractions with increased metal mineral contents

Experience, prior work:
- Laboratory tests with various ores and rocks including chalcopyrite containing ores from Chile
- Pilot tests on industrial size crushers with skarn ores from a new

TRL: Currently TRL 5, TRL 7 to be reached in 2 years

German companies or other German partners involved:
- BHS (still to be asked)
- Köppern (still to be asked)

Chilean partner (if already identified):
- …..
- …..

Area: Low Emissions Mining

Challenge 1: Energy Sustainability and Reduction of the Carbon Footprint in Metal Mining, with a Circular Economy Approach

Topic: Pre-weakening of Cu Ores using High Voltage Impulses

Impact:
- Imcreased recovery + reduction of energy in comminution processes by high voltage impulses
- Liberation of ores at coarse grain sizes → increased yield of flotation

Institution, group: TUBAF, Institute of Mineral Processing Machines, H. Lieberwirth

Rationale:
- Pre-weakening of Cu-ores by high-voltage impulses, preferably along grain boundaries
- Improved liberation of metal minerals at coarse fractions → increased recovery at reduced energy

Experience, prior work:
- Laboratory tests with various ores and rocks
- Pilot tests on continuously operating patented system with no moving mechanical parts

TRL: Currently TRL 5, TRL 7 to be reached in 2 years

German companies or other German partners involved:
- HEM Haver Engineering, Werner Industrielle Electronic (ready to participate)
- Technical University Dresden (ready to participate)

Chilean partner (if already identified):
- …..
- …..

Area: Low Emissions Mining

Challenge 1: Energy Sustainability and Reduction of the Carbon Footprint in Metal Mining, with a Circular Economy Approach

Topic: Sulfidic Ore Leaching Assited by Advanced Electrochemical Methods

Impact:
- Reduce the of use of resources and carbon emission for metal extraction processes
- High leaching rates of copper and other sulphide ores by hydrometallurgical processes

Institution, group: TUBAF, Institute of chemical technology, M. Bertau, Institute of inorganic Chemisrty, G. Frisch

Rationale:
- Use advanced electrochemical technology to leach copper and other sulphide ores, substitute for pyrometallurgy
- Regeneration of leaching agents to significantly reduce chemical consumption and CO_2 footprint.

Experience, prior work:
- Successful leaching of chalcopyrite ore with yields up to 80 % copper in 3 hours
- Selective leaching of complex ores through judicious choice of leaching agent
- Methods to prevent passivation

German companies or other German partners involved:
- Condias (still to be ask)
- EUT (still to be asked)

Chilean partner (if already identified):
- Codelcotech (still to be asked)

Area: Low Emissions Mining

Challenge 1: Energy Sustainability and Reduction of the Carbon Footprint in Metal Mining, with a Circular Economy Approach

Topic: In-Situ Bioleaching

Impact:
- Less energy consumption by avoidance of transport of ore to the surface
- Avoidance of landscape changes

Institution, group: TUBAF, Institute of Mining, H. Mischo, and Institute of Biosciences, M. Schlömann

Rationale:
- System of boreholes with hydrodynamic fracturing byy
- Pumping of bacteria through the fractured ore, collection of leachates in corresponding boreholes

Experience, prior work:
- Test site of the Biohydrometallurgical Center Freiberg in the mine Reiche Zeche in Freiberg, Germany
- Winning of zinc from sphalerite-containing ore

German companies or other German partners involved:
- …
- …

Chilean partner (if already identified):
- …..
- …..

Area: Low Emissions Mining

Challenge 1: Energy Sustainability and Reduction of the Carbon Footprint in Metal Mining, with a Circular Economy Approach

Topic: Winning of Strategic Metals from Tailings, Slags, Residuals & Solutions

Impact:
- Maximising revenues from mining activities through enhancing metal winning effectivity
- Reduction of tailings, and improving CO_2-footprint

Institution, group: TUBAF, Institute of Chemical Technology Prof. M. Bertau,
Institute of Inorganic Chemistry, Prof. G. Frisch

Rationale:
- Low waste concept
- Effective combination of novel hydrometallurgical methods

Experience, prior work:
- TRL 6, Extraction of indium and other valuable metals from polymetallic solutions
- TRL 5, Winning of indium, gallium, germanium and tin from different secondary sources

German companies or other German partners involved:
- RMF GmbH
- FNE GmbH

Chilean partner (if already identified):
- Reingenieria Minera
- Chilenian universities

Area: Low Emissions Mining

Challenge 1: Energy Sustainability and Reduction of the Carbon Footprint in Metal Mining, with a Circular Economy Approach

Topic: Reduction in Energy Consumption & CO_2 in Mining Using LNG

Impact:
- Energy consumption is a major factor in cost and CO_2 footprint of mining & ore processing. – Substituting Diesel by LNG-Trigeneration + Cooling with recovered cold energy from LNG regasification

Institution, group: LNGcold solutions GmbH, U. Becher

Rationale:
- Clean production of electricity, heat (cogeneration) and cold energy (trigeneration) with LNG (trendy energy also in Chile), **direct CO2-free recovery of deep cold from LNG-regasification**

Experience, prior work:
- Commercial use in warehouse application proved
- Different temperature levels down to -50°C realized, container based modules for diferent needs

German companies or other German partners involved:
- CHP plant providers with track record in Chile, e.g. 2G, Sokratherm, Siemens (to be defined)

Chilean partner (if already identified):
- Several Chilean engineering and maintenance companies
- Several Chilean LNG distributors

Area: Low Emissions Mining

Challenge 1 and 2: Energy Sustainability and Reduction of the Carbon Footprint in Metal Mining, with a Circular Economy Approach / New Low Emissions Mining-Metallurgical Processes

Topic: Membrane technology for in-situ Treatment of Bioleaching Solutions

Impact:
- Reduction of energy and carbon emission for metal extraction processes
- Reduction of water consumption in ore processing

Institution, group: TUBAF, Institute of Thermal-, Environmental- and Resources Process Engineering

Rationale:
- PLS is treated in the underground mine immediately by using selective membrane technology in terms of microfiltration (MF) and nanofiltration (NF).

Experience, prior work:
- Selective separation of In, Ge, Re, Mo and different other strategic elements by membrane treatment
- In-situ application in pilot scale in underground mine
- More than 20 years research projects in selective membrane separation technology

TRL: Currently TRL 6

German companies or other German partners involved:
- Andreas Junghans - Anlagenbau und Edelstahlbearbeitung GmbH & Co. KG (under negotiation)
- G.E.O.S. (under negotiation)

Chilean partner (if already identified):

Area: Low Emissions Mining

Challenge 2: New Low Emissions Mining-Metallurgical Processes

Topic: Bioleaching in Presence of Chloride

Impact:
- Lower consumption of drinking water
- Higher yields of Cu from chalcopyrite

Institution, group: TUBAF, Institute of Biosciences, M. Schlömann

Rationale:
- Combining leaching effect of chloride with bioleaching
- Use of cultures that in contrast to usual cultures tolerate high levels of chloride

Experience, prior work:
- Availability of cultures leaching chalcopyrite at 400 mM NaCl in bioreactors
- Studies in continuous bioreactors

TRL: Currently TRL 3-4, TRL 5 to be reached in 2 years

German companies or other German partners involved:
- G.E.O.S. (under negotiation)
- Ekato (still to be asked)

Chilean partner (if already identified):
- Universidad de Santiago, G. Levicán
- Minera Coynacura (in proposed related project)

Area: Low Emissions Mining

Challenge 2:New Low Emissions Mining-Metallurgical Processes

Topic: Alternative Slag Utilisation

Impact:
-Use of previously waste copper slag materials
-Preparation of glass- or stone wool-like new insulation materials

Institution, group: TUBAF, Institute for Mineralogy, Prof. Heide/IKGB, Dr. Kilo; optionally: Fraunhofer ISC

Rationale:
-Direct use of molten slag for preparation of fibers
-Tuning of composition of slags

Experience, prior work:
-Knowledge on slag compositions and technology of fiber preparation
-Studies on composition-properties correlations and fiber stability

TRL: Currently TRL 3, TRL 5 to be reached in 3 years

German companies or other German partners involved:
-P-D (under negotiation)
-Ursa, Knauf (to be asked)

Chilean partner (if already identified):
-Universidad de Conception, Conception, U. Kelm
-Anglo American Chile

Area: Low Emissions Mining

Challenge 3: Innovations for the Traceability of Greenhouse Gases Emissions

Topic: Reduction in Energy Consumption in Copper Production

Impact:
- Specific energy consumption is a major factor in cost and CO_2 footprint of copper production. This project targets the reduction in copper electrowinning and electrorefining for the future

Institution, group: TUBAF, Institute for Nonferrous Metallurgy and Purest Materials, M. Stelter

Rationale:
- Reduction of oxygen-overvoltage in electrowinning
- In electrolytic refining increase of energy efficiency and copper quality by various optimizations

Experience, prior work:
- Since decades expertise in copper electrolysis, reduction of energy and optimisation of quality
- More than 9 years research projects for the Sponsor Group Copper Electrorefining

German companies or other German partners involved:
- Not necessary, but Aurubis would be possible

Chilean partner (if already identified):
- Still open, but Codelco and BHP might be interested

Area: Low Emissions Mining

Challenge 3: Innovations for the Traceability of Greenhouse Gases Emissions

Topic: Quantitative Greenhouse-Gas Monitoring along the Process Chain

Impact:
- Precise and accurate monitoring data (CO_2, CH_4, N_2O) along the entire process chain
- Very high uptime, robustness and ease of use permits reliable data acquisition to improve processes
- Deliver and guide GHG emission monitoring, train personnel and evaluate output data

Institution, group: TUBAF, Interdisc. Environ. Res. Centre, Group Geochemistry and Earth Sys. Sci.

Rationale:
- High-quality GHG fluxes and concentrations data providing governmental administration, companies and academia with the necessary data quality in both space and time.

Experience, prior work:
- 10 years of highly successful experience with key publications in the field
- Development of low-cost, highly robust and precise chamber systems

German companies or other German partners involved:
- Various options, e.g., BEAK Consultants Freiberg, Prof. Yvonne Joseph (still to be asked)
- Max-Planck-Institute for Biogeochemistry, Jena (still to be asked)

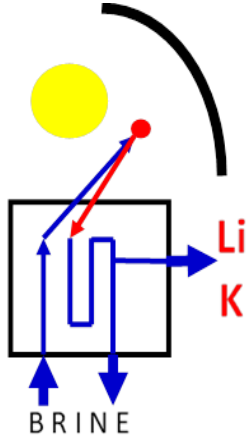
Chilean partner (if already identified):
- Univ. Concepcion and/or Univ. de Chile in Santiago
- Fundación Chile

Area: Advanced Materials of Lithium and other Minerals for Electromobility and Energy Storage

Area: Advanced Materials of Lithium and other Minerals for Electromobility and Energy Storage

Challenge 1: Innovations in Advanced Minerals Based on Lithium, Salts or other Strategic Minerals

Topic: Zero Water Consumption Zero Waste Generation in Lithium / Potash Recovery from Salar Brines (related also to Challenges 2, 3, 4)



Impact:
- No use of any external water resource, No generation of solid wastes, No tailings
- Consequent use of solar energy in form of heat and electricity
- Rising of added value

Institution, group: TUBAF, Institute of Inorganic Chemistry; Inst. Heat Technology; Inst. Analytical Chemistry, ITUN

Rationale:
- Re-Design process of the lithium/potash recovery for use of solar energy in multiple-effect evaporator-crystallizer technology and all subsequent process steps;
- Preventing of groundwater lowering during brine extraction;
- Utilisation of biological activity.

Experience, prior work:
- Lithium center Freiberg; Patents in lithium recovery; several lithium projects world-wide
- More than 50 international papers (Voigt et al.) in salt research

German companies or other German partners involved:
- K-UTEC Salt Technology AG Sondershausen + University of Bremen, Energy storage and conversion systems
- Protarget AG – solar power systems
- LNGcold solutions GmbH

Chilean partner (if already identified):
- Grupo Errázuriz, ACF Minera S.A.

Area: Advanced Materials of Lithium and other Minerals for Electromobility and Energy Storage

Challenge 2: Innovations in Advanced Minerals Based on Lithium, Salts or other Strategic Minerals

Topic: Strategies to Minimize the Effect on Natural Ressources

Impact:
- Lower impact of extraction and infiltration on water flow
- Higher yield of safe water

Institution, group: TUBAF, Institute of Hydrogeology and Hydrochemistry, T. Scheytt

Rationale:
- Hydrochemical processes and density-driven flow during extraction and re-infiltration of brines
- New Methods to reduce the impact of high-salinity high density brines during extraction and injection

Experience, prior work:
- Determination of groundwater flow and groundwater modelling
- Studies in laboratory experiments on transport processes of metals

TRL: Currently TRL 5, TRL 6 will be reached in 2 years

German companies or other German partners involved:
- GUB (under negotiation)
- Plejades GmbH (to be asked)

Chilean partner (if already identified):

Area: Advanced Materials of Lithium and other Minerals for Electromobility and Energy Storage

Challenge 2: Development of Technologies to more Efficiently Extract and Concentrate Scarce Products Used in Batteries and Storage, such as Cobalt

Topic: Lithium Battery Recycling, Lithium Winning from Unconventional Ores

Impact:
- Li-battery recycling yielding Li, Co, Ni, Cu in primary product quality
- Lithium winning from so far inappropriate Li-ores

Institution, group: TUBAF, Institute of Chemical Technology, Institute of Inorganic Chemistry

Rationale:
- Holistic approch to Li-battery recycling
- Utilisation of less common Li-ores such as amblygonite or montebrasite
- Selective recovery of pure Li, Co and Ni compounds based on thermodynamic and kinetic control of precipitation reactions

Experience, prior work:
- TRL 7, proven on the 20 L-scale
- Commercialisation of technology to industry as of 1st July 2019 within a government funded project

German companies or other German partners involved:
- RMF GmbH, PARFORCE Engineering & Consulting GmbH
- FNE Entsorgungsdienste GmbH
- K-UTEC Salt Technology AG Sondershausen

Chilean partner (if already identified):
- Chilean universities, …..

Area: Advanced Materials of Lithium and other Minerals for Electromobility and Energy Storage

Challenge 2: Development of Technologies to more Efficiently Extract and Concentrate Scarce Products Used in Batteries and Storage, such as Cobalt

Topic: Bioleaching of Cobalt-Containing Arsenides

Impact:
- Benefication of cobalt arsenide containing ores with avoidance of arsenic in smelters
- Chance to deposit arsenic as stable scorodite

Institution, group: TUBAF, Institute of Biosciences, M. Schlömann

Rationale:
- Oxidation of the arsenides by arsenic-tolerating acidophilic iron-oxidizing bacteria
- Oxidation of the arsenic to the arsenate state, immobilization intended as scorodite

Experience, prior work:
- Culture available that bioleaches cobalt and nickel from BiCoNi ores from the ore mountain area in Germany and from safflorite ($CoAs_2$) in bioreactors

German companies or other German partners involved:
- Sachsenerz Bergbau (still to be asked)

Chilean partner (if already identified):
- …..
- …..