scale

SCANDIUM ALUMINIUM EUROPE

what is scandium?

RARE EARTH

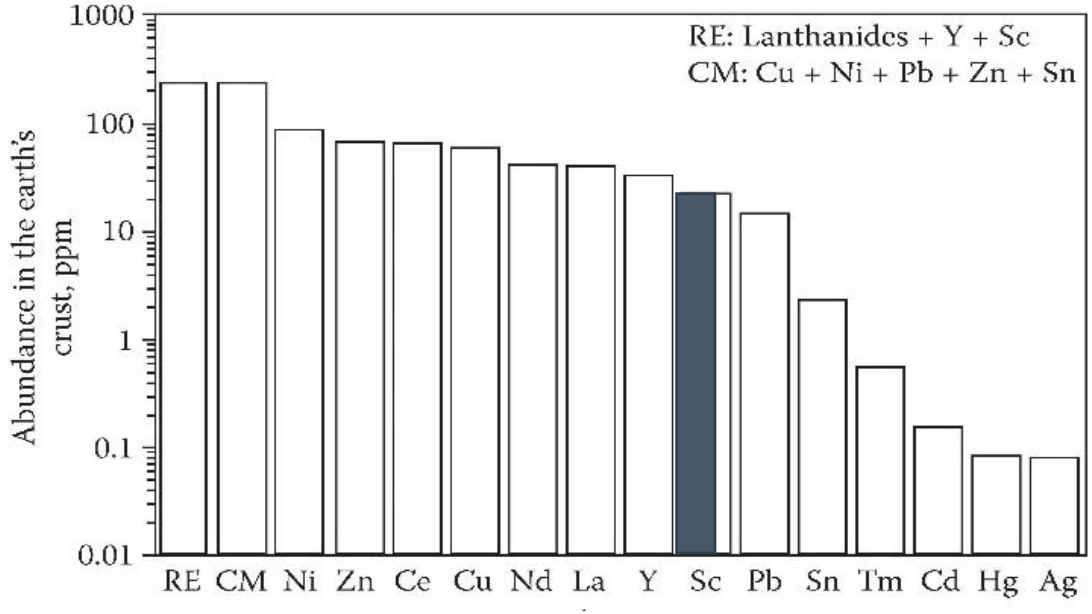
scandium

21

Sc

44.956

Occurrence of Scandium



- Sc is the 36th most abudent element in the crust
- Earth's crust abundance of 22 mg/kg, the occurrence of scandium is comparable with that of lead (14 mg/kg) and cobalt (25 mg/kg)
- However, scandium is rarely concentrated in nature and remains widely dispersed in the lithosphere as it lacks affinity to combine with the common ore-forming anions

Sc is 'more rare' than all other REEs

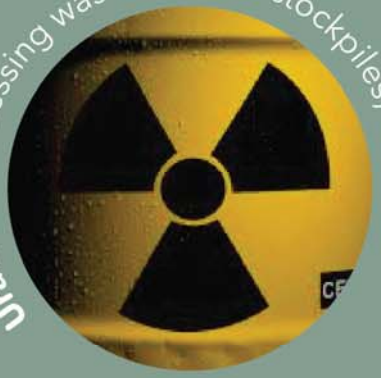
scandium 21 Sc 44.956	yttrium 39 Y 88.906													
lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.05	lutetium 71 Lu 174.97

WHERE IS **Sc** FOUND?

Viable sources of **Sc** today

TiO2 pigment product acid wastes streams

Uranium processing wastes (Soviet stockpiles)



Nickel-Cobalt Laterites (Australia/Turkey/USA)

Bauxite Residues (RUSAL, AoG)

Bauxides and nickel laterite ores are proposed as the most promising **Sc** resources for future large scale production; **Parnassos/Greece could well be a worldwide resource for Sc!**

Supply of Scandium today

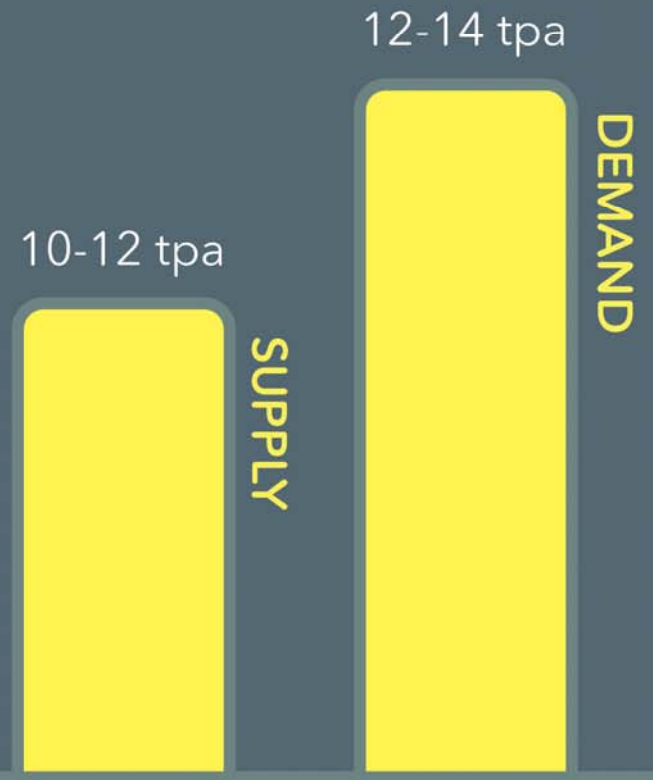
- A major source for scandium deposits was the now flooded Ashurst mine in Zhovti Vody outside Kiev, Ukraine, that was once a major harvesting ground for iron ore and uranium for the Soviet military.
- Today there is an active mine for Sc is in Kazahkstan
- Other Sc sources include REE byproducts in Kola Peninsula in Russia and Bayan Obo in China and there are several Acid Waste facilities (TiO_2 production) in China, USA, Philippines and Japan

The current Sc world production is estimated at 10 – 12 tpy of scandium oxide

Main producers

- **China (66%)**
- **Russia (26%)**
- **Ukraine (7%)**

THE ECONOMY OF Sc



Al - Sc 2%

100-150 $/g




Sc VALUE CHAIN: **0.9 $/g**

2013 Data

Sc_2O_3 99%

5 $/g

Sc_2O_3 99,99%

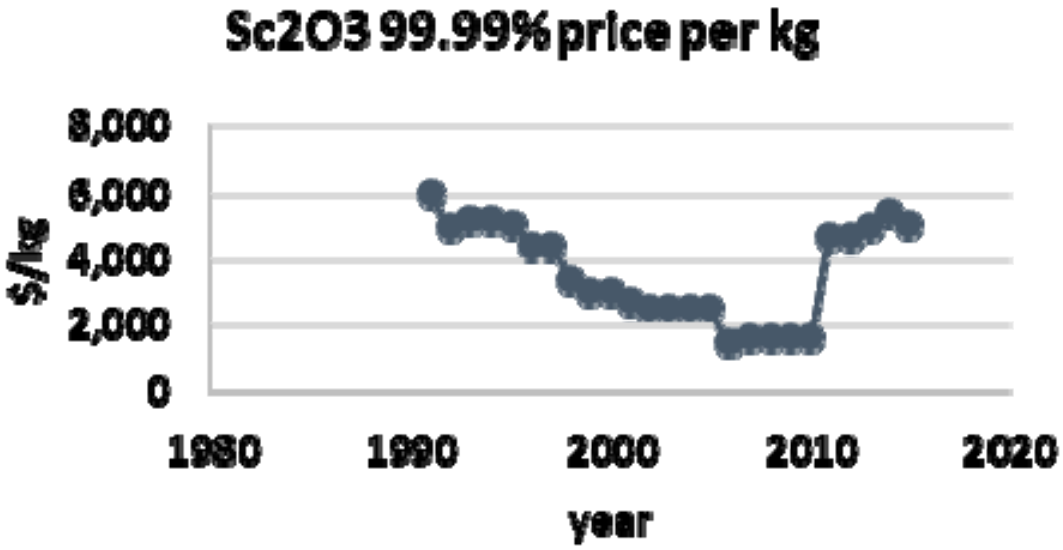
253 $/g

ScF3 99,99%

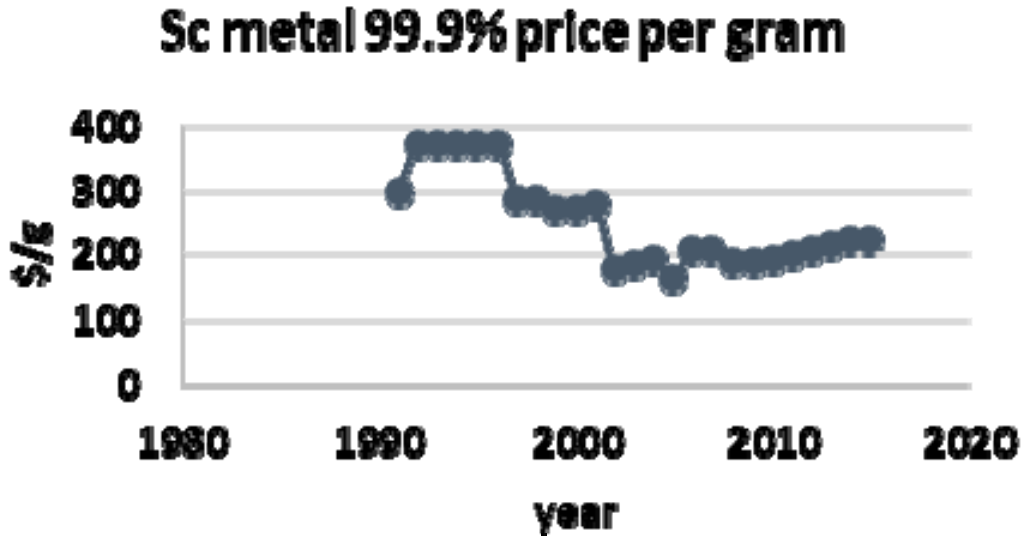
206 $/g

Sc Metal

Scandium Market



On 24 February 2010, BLOOMENERGY announced that their devices (SOFC) were making electricity for $0.08–.010/kWh using natural gas (using Sc_2O_3 in the solid electrolyte)



Sc HAS SUPERPOWERS!

Sc achieves superior results than Y in material applications

SOLID OXIDE FUEL CELLS

Sc-stabilized Zirconia has **lowered operational temperatures** facilitating the **commercialization** of the technology

LASERS WITH Sc GARNETS

have **3 times higher efficiency** than Y garnets

NATURAL LIGHT

Sc compound is used as phosphors for **high intensity 'natural' light** - close to solar optical spectrum

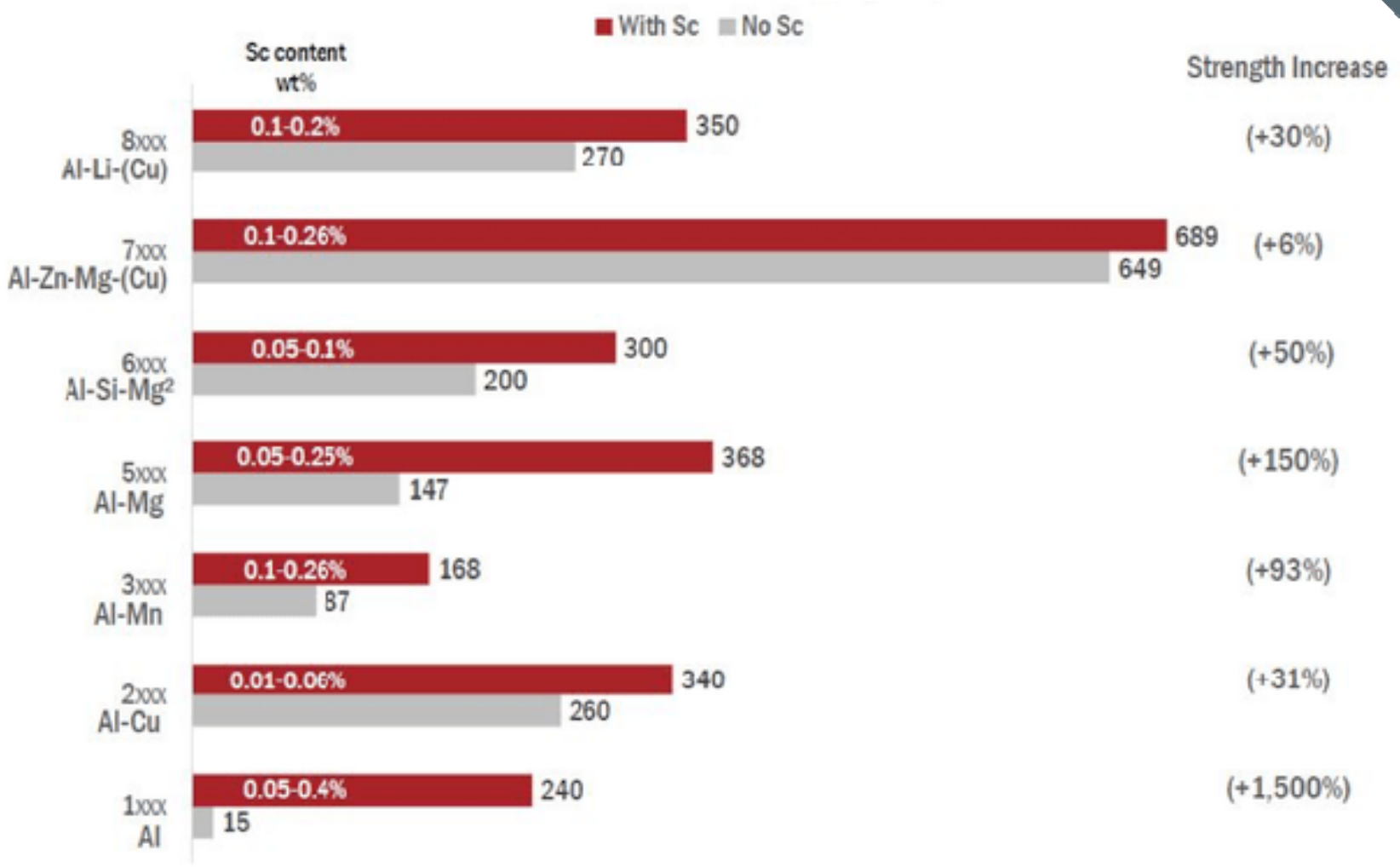
Lazer Garnet by II-VI (gadolinium-scandium-gallium)

BLOOMENERGY Sc-SOFCs deployed at NASA building

Scandium Aluminium Alloys

- Scandium –Aluminium alloys were first used in the 1980s for structural purposes in Soviet aircrafts and missiles.
- The strength that Scandium alloys brought to weldable alloys, allowed Soviet to built aircrafts (MIG-29) and utilize welded structures. This gave these planes tremendous weight, maneuverability and range advantages.

Scandium Aluminium Alloys



Sc offers the highest increment of strengthening per atomic percent of any alloying element *when added to Al*

Sc reduces ***hot cracking during welding*** *of Al-alloys*

Sc Applications

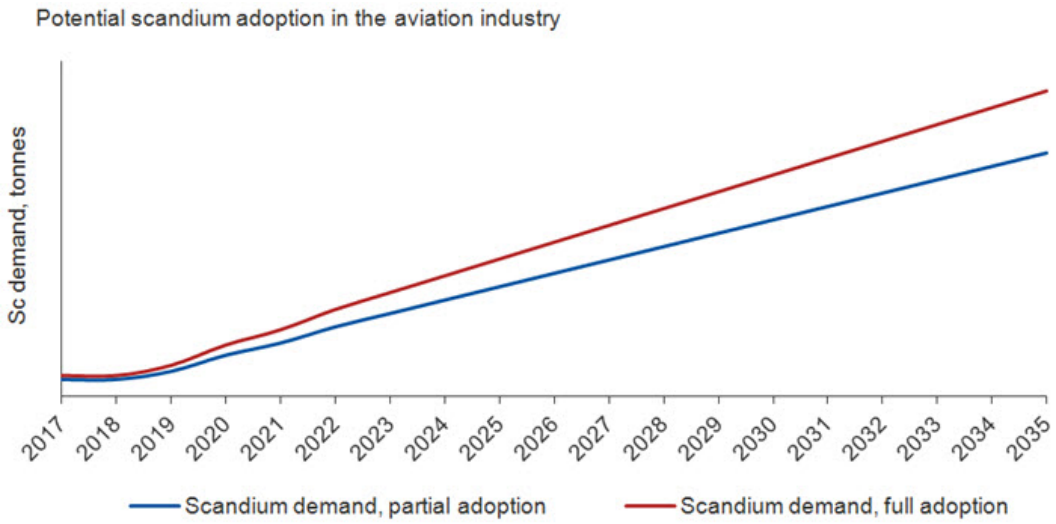
Sc Compound	Application	Today	Future
Sc_2O_3	SOFC – SSZ solid electrolyte	in market by Bloomenergy	Household use
Sc_2O_3	Er: YSGG garnets (**$Er:Y_3Sc_2Ga_30_{12}$**) for optics in lazer application		Er:YSGG has 3 higher efficiency then Nd,Er:YAG in solid-state lasers radiating in the 3 µm
Sc-Al alloy	High resistance Al alloy used in welding or casting – best Al alloy available	High End sporting equipment	Aerospace, Automotive
Al-Mg-Sc (Scalmalloy®)	3D Printing –licensed by Airbus to Apworks		Aerospace, Automotive
ScF_3	Material with negative thermal expansion coefficient		Advanced material composites
20% Sc-80% Ti Carbide	doubling of the hardness TiC, to about 50 GPa, second only to diamonds in hardness.		Advanced materials
Phosporous / Lighting	Scandium has a broad emission spectrum that generates a 'daylight' effect. Sc2O3 and ScVO4 are typical host materials for phosphorus in monitors	Stadium / studio lighting	Household lighting

The future is limited by high prices and unreliable value chain

Scandium Emerging Applications

- In SOFC Sc-stabilized Zirconia has lowered operational temperatures leading to commercialization of the technology
- The Al-Sc-Mg alloy powder is used in 3D printing by AIRBUS

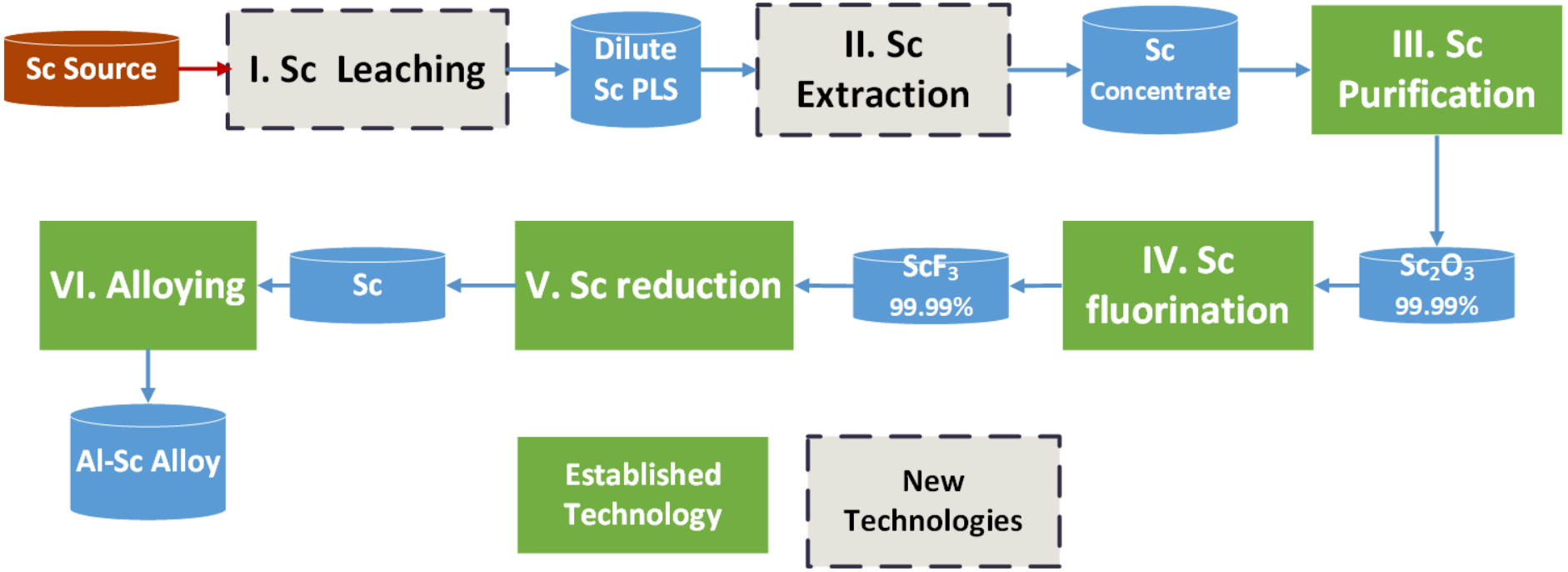
Sc demand expected to increase 30 fold in the next decade



APWorks. 2 December 2015

"We did produce 122 out of the 162 parts on our M400 out of SCALMALLOY®.
The partition weights a massive 45% less than current Airbus A320 partition designs"

Scandium Production today



- Scandium Production does not happen in large scale
- Specially Metallic Sc is produced only through calcio thermic reduction of ScF3 – a very expensive and small scale process

Sc VALUE CHAIN: 2013 Data

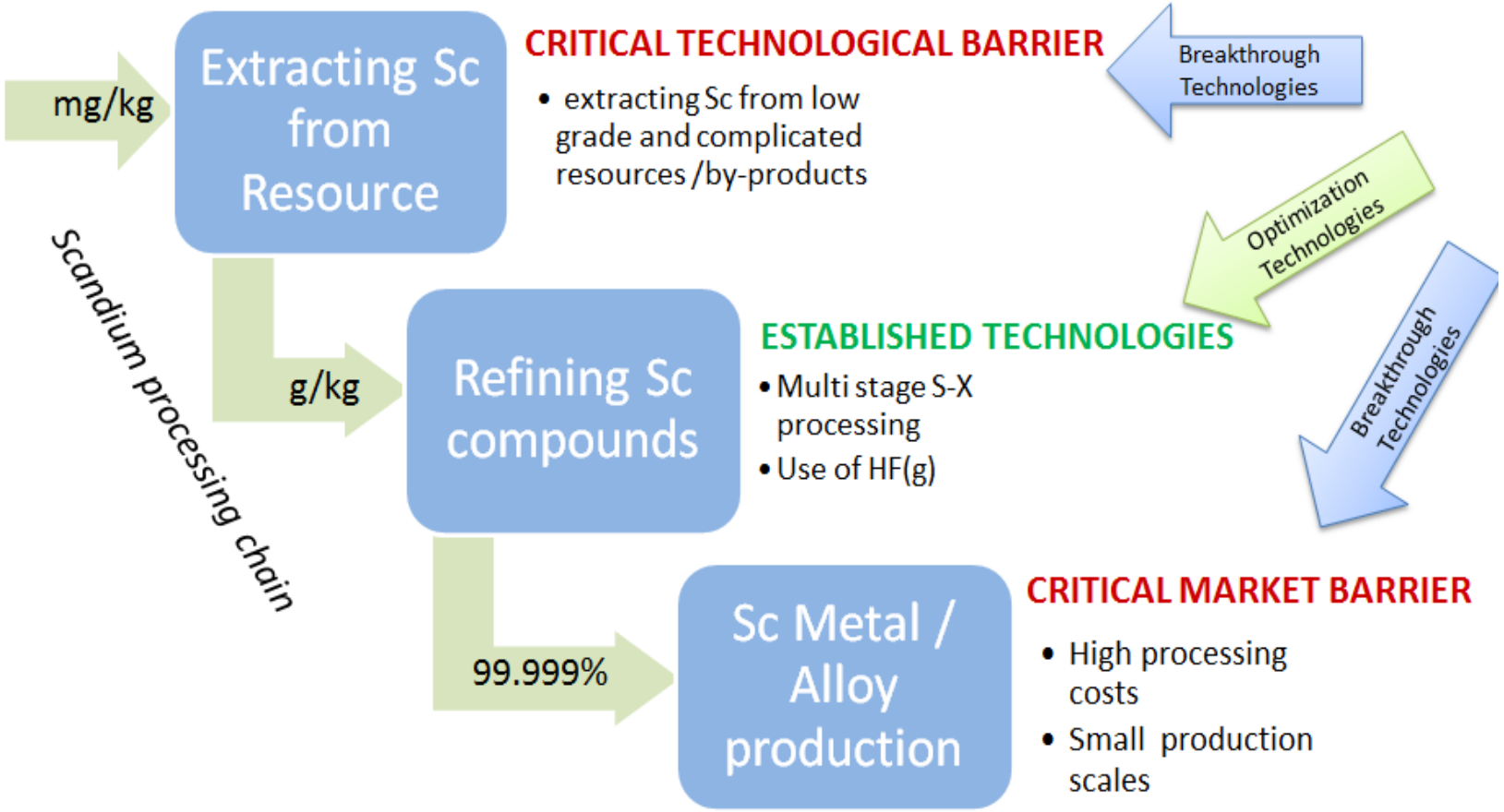
0.9 $/g Sc_2O_3 99%

5 $/g Sc_2O_3 99,99%

253 $/g ScF3 99,99%

206 $/g Sc Metal

Scandium Production today



SCALE: AN RTD PROJECT DEDICATED IN DEVELOPING A NOVEL Sc SUPPLY CHAIN

Horizon 2020 | 4 year project | € 7,000,000.00 | AoG demo plant

EU MARKET POTENTIAL

- **Alumina Sector:**
  up to 500 t/y of Sc
- **Titania Sector:**
  up to 140 t/y of Sc

Newsflash: Sc now included on the 2017 list of Critical Raw Materials for the EU

SCALE RAW MATERIAL SOURCES

AoG Bauxite Residue:
130 g/t Sc; 750,000 t/y

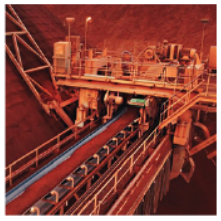
AOS Bauxite Residue:
93 g/t Sc; 900,000 t/y

TRONOX acid waste filter cake:
150 g/t Sc; 50,000 t/y

The research leading to these results has been performed within the SCALE project and received funding from the European Community's Horizon 2020 Programme (H2020/2014-2020) under grant agreement n° 730105.

ALUMINIUM OF GREECE · II-VI · TRONOX · io·li·tec Ionic Liquids Technologies · KTH · RWTH AACHEN UNIVERSITY · MŰEGYETEM 1782 · n|w University of Applied Sciences and Arts Northwestern Switzerland · BAM

aluminiumoxid · LCM less common metals · ITRB CONSULTING · Kurt Salmon · KBM AFFILIPS MASTER ALLOYS · MEAB · Fraunhofer · SINTEF



Bauxite Residues TiO_2 Pigment Acid Wastes

mg/kg

EXTRACTING

Sc from waste

g/kg

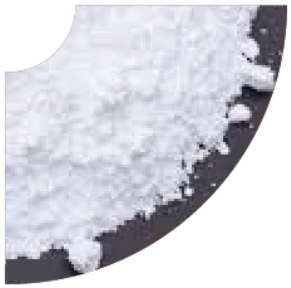
REFINING

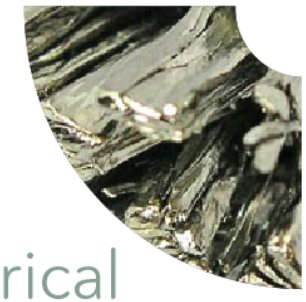
Sc concentrates

PRODUCING

Sc Metal

Sc_2O_3





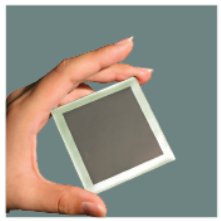
SCALE:

Production of Sc compounds & Sc-Al alloys from European metallugrical by-products

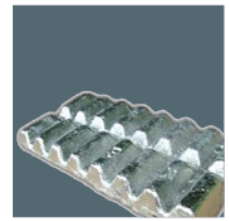
LASERS: YSG GARNETS

II-VI

SSZ LAYER SOLID OXIDE FUEL CELLS

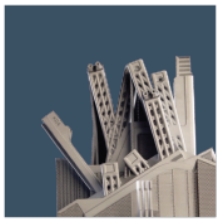


AL-SC ALLOY



IKBM AFFILIPS MASTER ALLOYS

SCALMALLOY 3D PRINTING



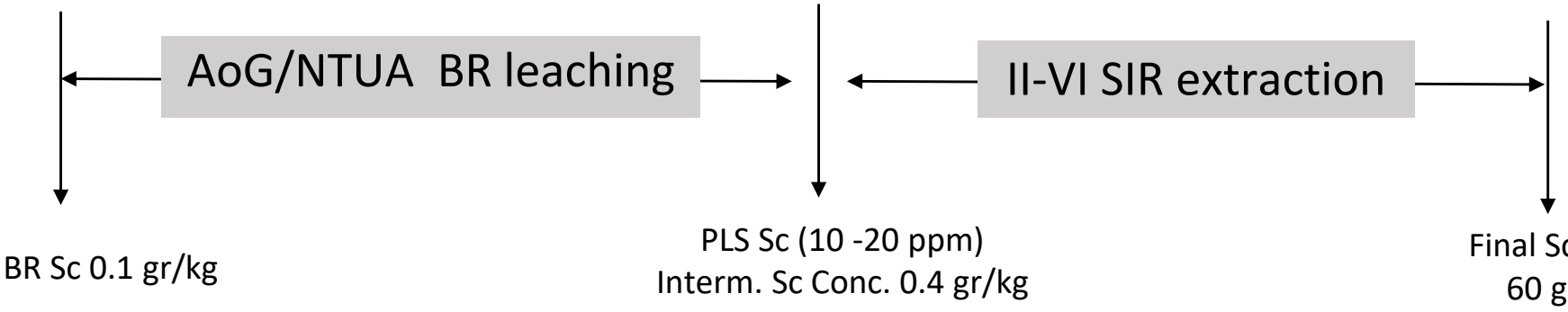
AIRBUS

scale

SCANDIUM ALUMINIUM EUROPE

Our results so far -10 months in

- Leaching of up to 90% of Sc from Greek Bauxite Residue
- Positive resutls from SIR ion-exchange resin to extract Sc from dilute solutions produced



- Positive results in producing ScF_3 without use of HF gas
- Direct molten salt electrolytic production of Al-Sc Alloy from $Sc_2O_3 – Al_2O_3$ mixtures
- Room temperature electrowining of Sc in ionic liquids from $ScCl_3$

http://scale-project.eu

http://www.circulary.eu/project/scale/

Thymis Balomenos
Mytilineos S.A.
Metallurgy Business Unit

The research leading to these results has been performed within the SCALE project (http://scale-project.eu/) and received funding from the European Community's Horizon 2020 Programme (H2020/2014-2020) under grant agreement n° 730105.

Thank you for your attention. Questions?