Current State of the Sc Recovery Possibilities during Hydrometallurgical Treatment of Lateritic Ni-Co Ores

By

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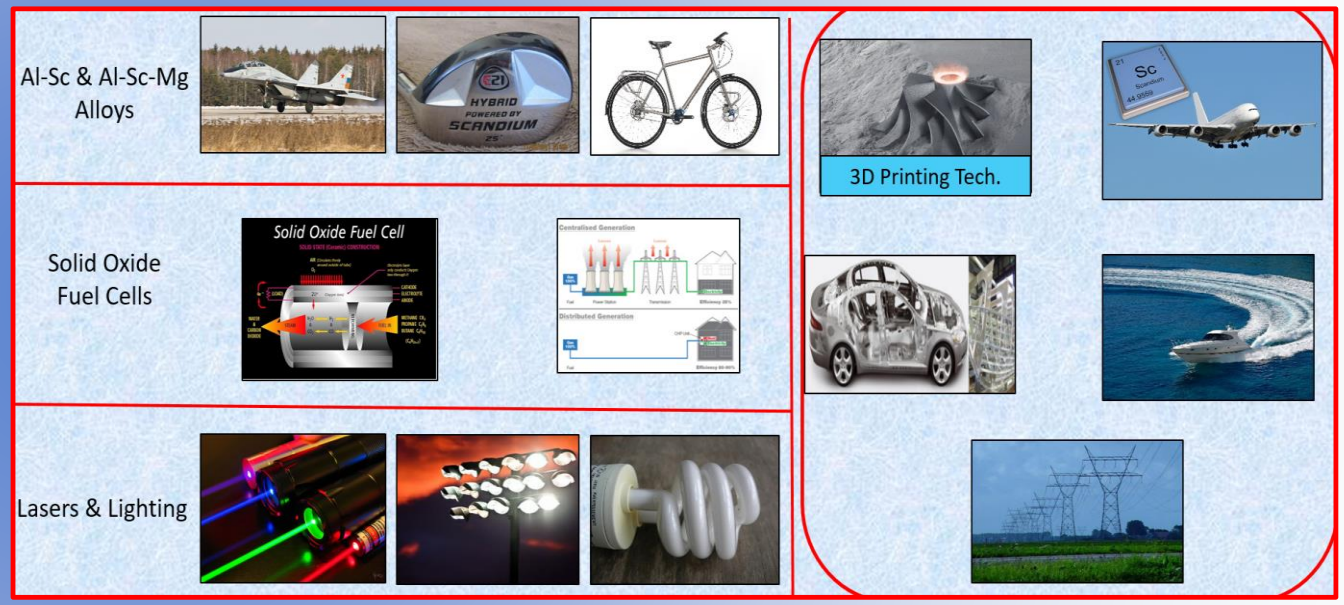
OUTLINE

- Current Sc Sources and Supply/Demand Issues:
- Laterite Reserve/Production Information:
- Companies Developing New Sc Projects:
- Scandium Recovery from Lateritic Ni-Co Ores:
- Sc Distribution in META HPAL Plant
- References:



Current Sc Sources and Supply/Demand Issues

No primary Sc mine production yet!

- As a by product during Iron-Uranium Production,
- As a by product during Tungsten Production,
- As a by product during Titanium Production,
- As a by product during Zirconium Production,
- As a by product during REE's Production, **[1,2]**

→

- Supply is only ~5-12 tons/year in the form of Sc_2O_3 and the price is too high (2000-4500 $/kg 99.9 Sc_2O_3) for commercial applications. **[3]**
- Currently, only used in appliations where performance is much more important than the price (military/sporting goods, space appl. etc.)

- However; when consistent, abundant, reliable and low cost scandium supply is achieved, commercial applications will certainly boom!

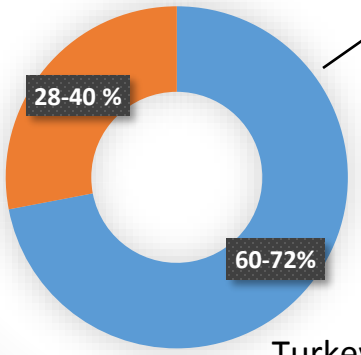
The solution for the short term promising source of the huge and urgent scandium need of the industry:

↓

LATERITES

World Laterite Reserves

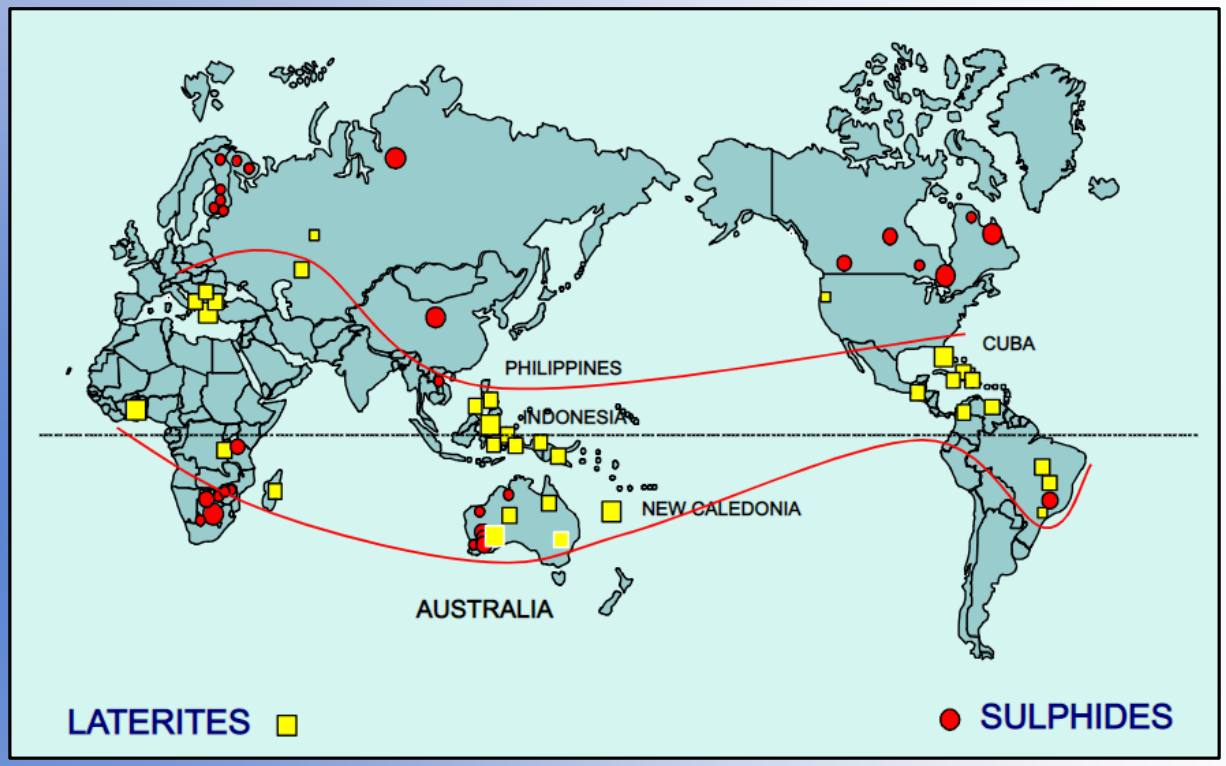
Sulfides:
Russia,
Canada,
South Africa,
Australia.



Laterites :
Indonesia,
Philippines,
New Caledonia,
Colombia,
Madagascar, Cuba,
Papua New Guinea, Brazil,
Venezuela,
Dominican Republic,
Australia,
Turkey, Greece, Albenia, Serbia, etc.

Trend in Nickel Production from Laterites

- In 1950's <10% of primary Ni was produced from lateritic ores,
- In 2003 ~42% of primary Ni was produced from lateritic ores,
- In 2012 ~50% of primary Ni was produced from lateritic ores,
- In 2020's It is expected that 55-60% of Ni will be produced from lateritic sources.



[4-8]

Companies Developing New Sc Recovery Projects

Company & Project/Deposit Name	Location	Head Grade (mg/kg)	Cut-off Grade (mg/kg)	Contained Sc_2O_3 (tons)	By-products	Production Route	Current Status
Clean TeQ Syerston/Sunrise Ni-Co-Sc Project (Previously Ivanhoe Mines)	Australia	583	300	18,000	Ni, Co	HPAL Sc IX (Resin in Pulp) IX-SX for Ni&Co sulphate	DFS completed in 2018 Construction is planned in 2019.
Scandium Int.& Scandium Inv. LLC. Nyngan Scandium Project	Australia	409	100	3,135	None	HPAL SX	DFS completed in Waiting financing
Platina Resources Ltd. (Owendale Sc-Pt Project)	Australia	384	300	16,500	Ni, Co, Pt	HPAL SX	PFS
Metallica/Australian Mines SCONI Project	Australia	208	120	3,000	Ni, Co	HPAL SX	DFS
Jervois/Australian Mines Flemington Deposit	Australia	450	300	2,085	Ni, Co	HPAL SX	PFS
Imperial Mining Crater Lake	Canada	-	-	-	Nb, Ti, Zr	-	-
Niocorp Niobium Project Elk Creek	USA	72	-	3,400	Nb	-	-
RUSAL Al Corp. – From Red Mud by carbonate/bicarbonate leaching	Russia	-	-	-	-	Carbonate Leaching IX	Currently producing Sc_2O_3 in its pilot plant facilities.

[9-10 and corporate webpages]

Sc from Lateritic Ni-Co Ores and Residues

- When compared to NaOH leaching of Bauxite ores in Al production, Sc does not dissolve during leaching and remain in the Leach Residue-Red Mud.
- Depending on the ore mineralogy 80-95 % of Sc in lateritic ores dissolves during HPAL. **[11,12]**
- At META-Gördes HPAL Plant, Sc leach recovery is ~80%.

Main Ni-Co Recovery Options

1-MSP (Mixed Ni-Co Sulfide Ppt.)

- Coral Bay (Philippines)
- Taganito (Philippines)
- Ambatovy (Madagascar)
- Moa Nickel (Cuba)
- Murrin Murrin (Australia)

2-MHP (Mixed Ni-Co Hydroxide Ppt.)

- Ramu Nickel (Papua New Guinea)
- Ravensthorpe (Australia)
- Cawse (Australia)
- META Nikel-Kobalt A.Ş. (Turkey)

3-Direct Solvent Extraction

- Bulong (Australia)
- Goro Nickel (New Caledonia)

Sc from Lateritic Ni-Co Ores and Residues

Companies Developing New Sc Projects

Companies Already Operating HPAL Plants for Ni-Co Production

Sumitomo Metal Mining Co.

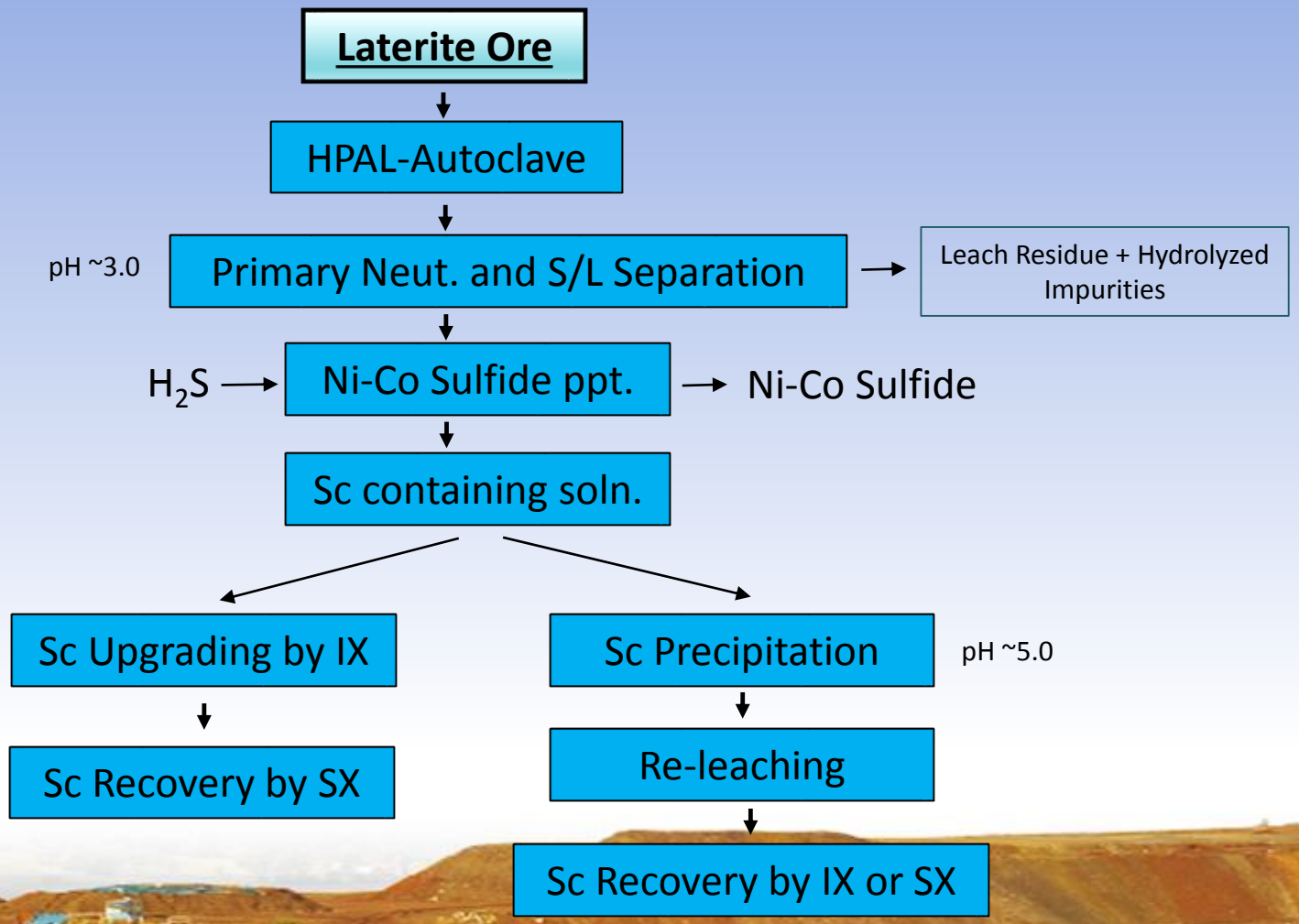
- Coral Bay & Taganito MSP HPAL Plants (Philipinnes)
- In 2013, Pilot Plant constructed in Coral Bay 10 kg/month Sc_2O_3 capacity, and the industrial plant in Taganito HPAL and Harima Refinery (Japan) having 7.5 ton/year Sc_2O_3 capacity was completed in 2017.
- Sc concentration by IX and purification by SX.
- Product Portfolio: **Sc_2O_3**

META Nikel-Kobalt A.Ş.

- Gördes MHP HPAL Plant-Eskişehir Yunusemre Deposit (40-120 g/ton Sc)
- Patent Applications for IP.
- Scandium fluoride chemicals are targetted **[13, 14].**
- Lab. scale process chemistry was proved in bench and semi-pilot scale.
- Product Portfolio: **$(NH_4)_2NaScF_6$, $(NH_4)_2KScF_6$,**
- **$(NH_4)_3ScF_6$, ScF_3** and mixture of **($NaScF_4$ - Na_3ScF_6), (K_3ScF_6 – KSc_2F_7)**

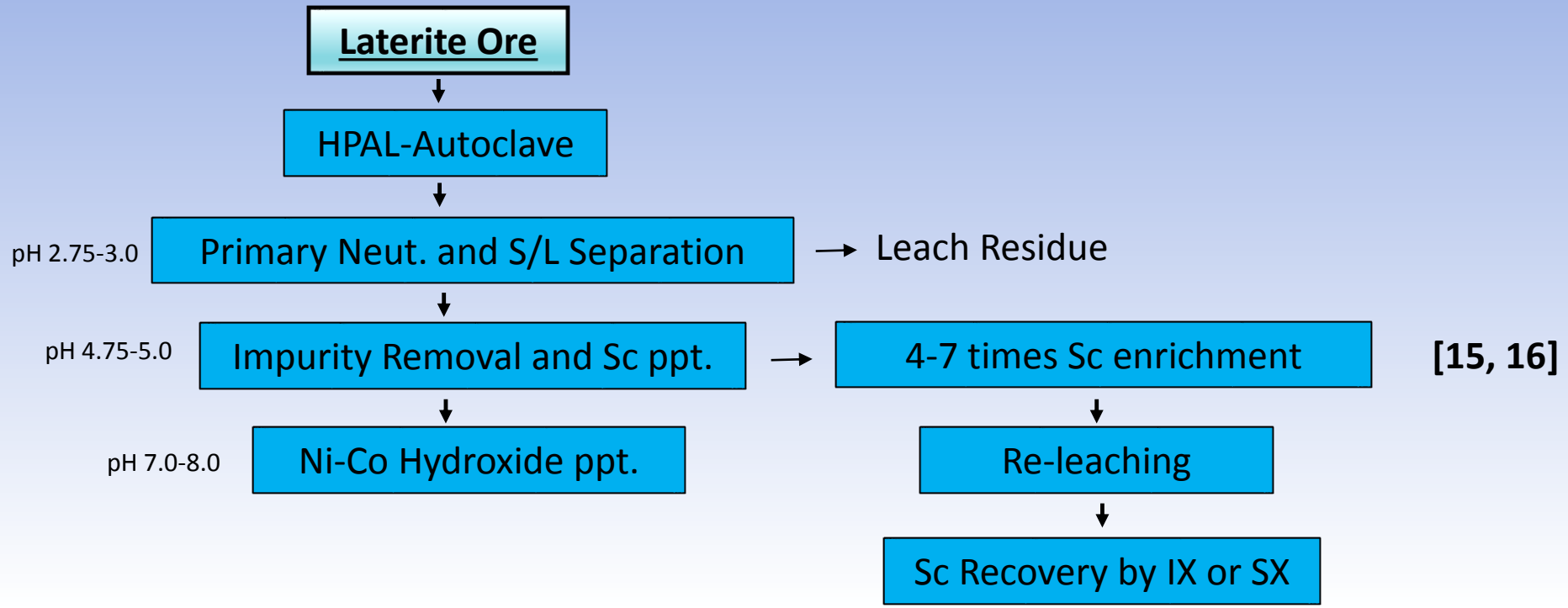
Sc from Lateritic Ni-Co Ores and Residues

1-MSP (Mixed Ni-Co Sulfide Ppt.) Method



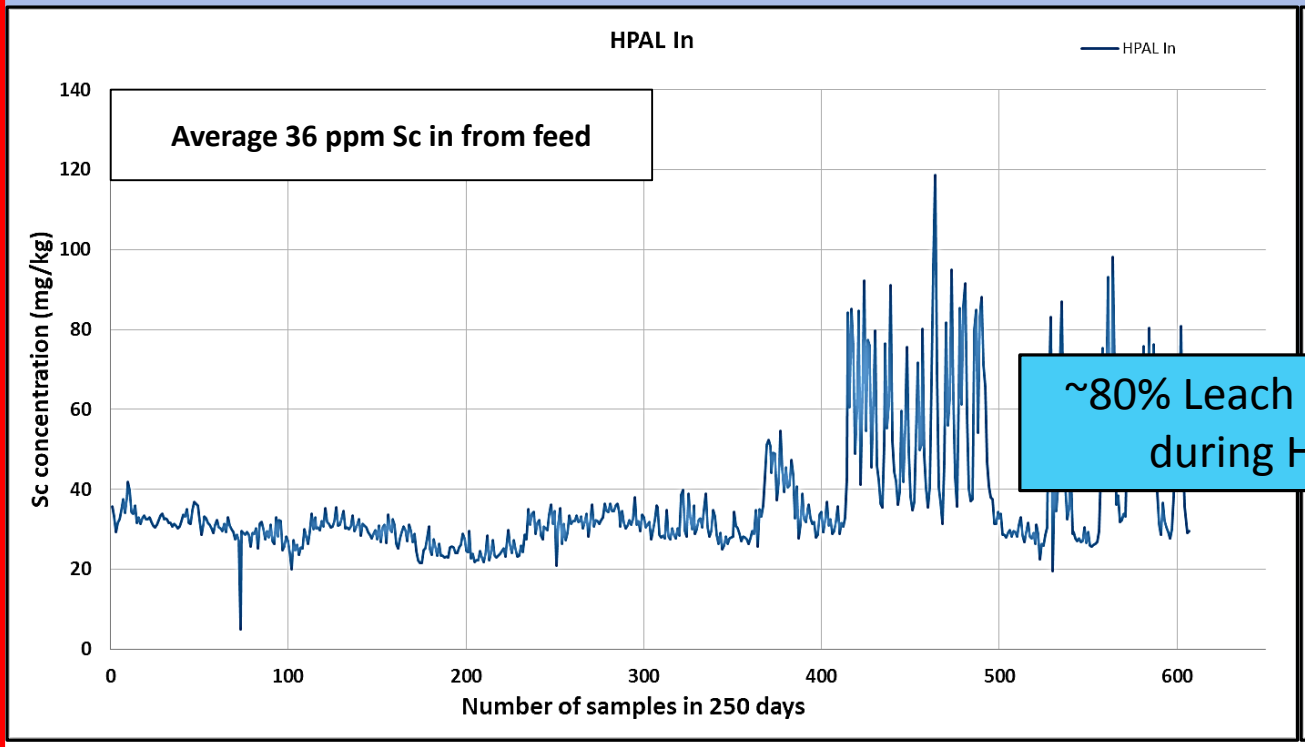
Sc from Lateritic Ni-Co Ores and Residues

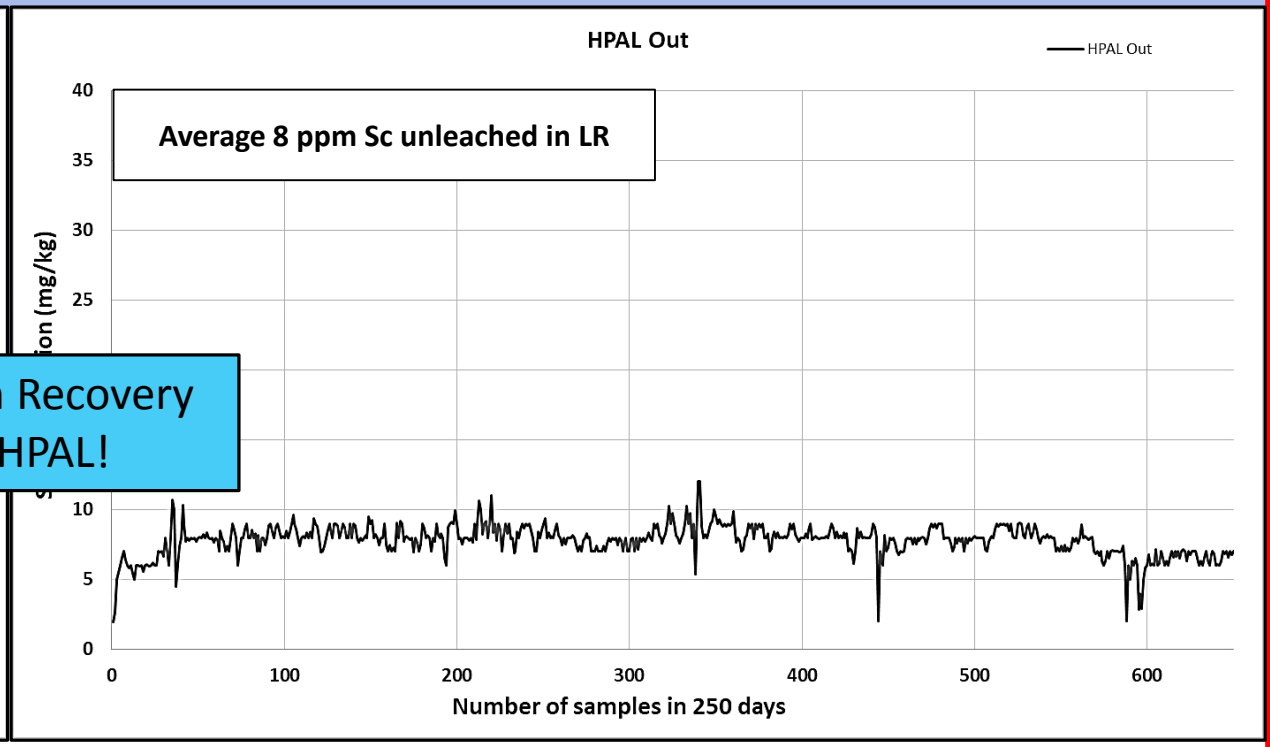
2-MHP (Mixed Ni-Co Hydroxide Ppt.) Method



Sc from Lateritic Ni-Co Ores and Residues

Behaviour of Sc in Gördes HPAL Plant during HPAL during 250 days of operation

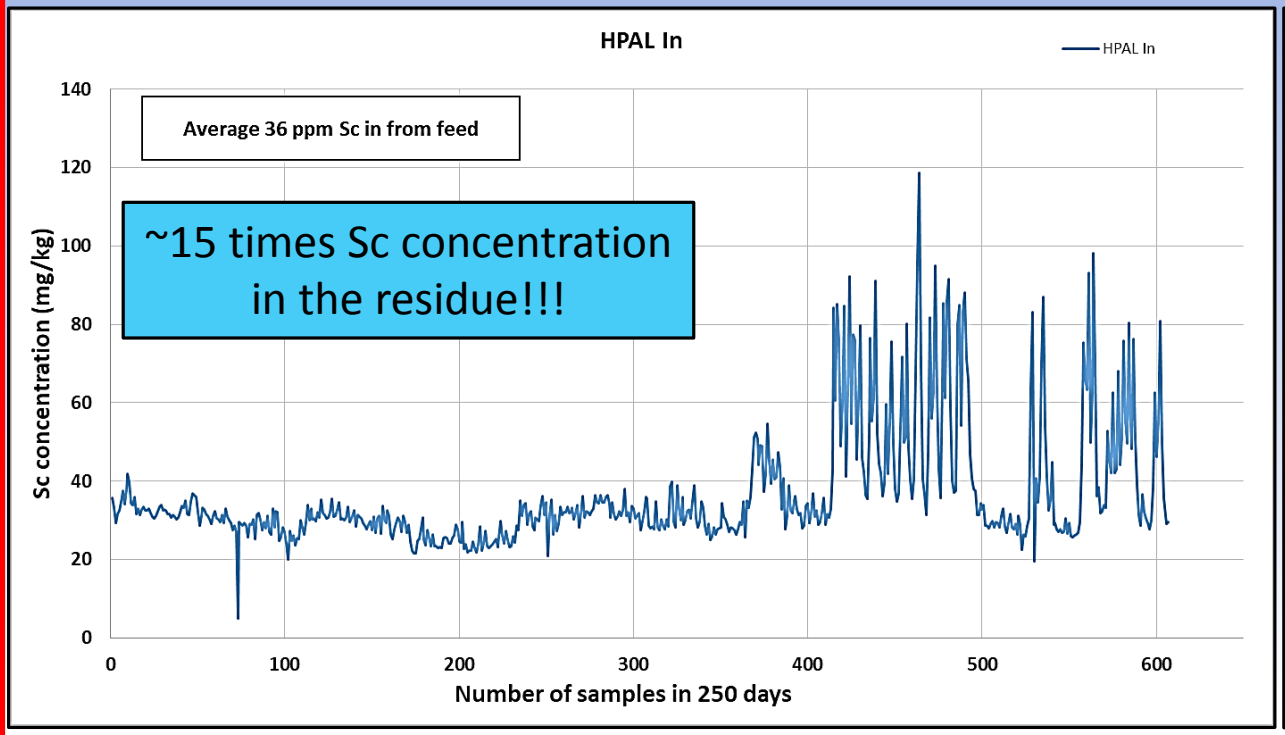


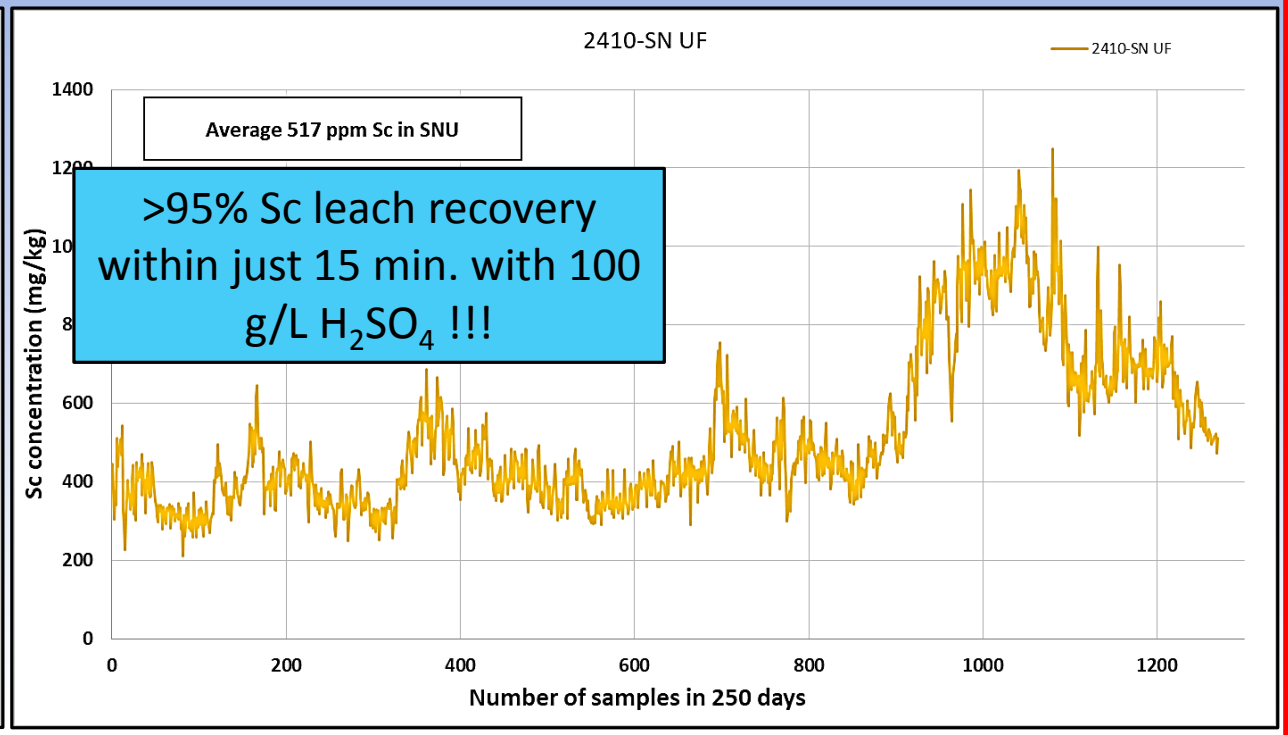


~80% Leach Recovery during HPAL!

Sc from Lateritic Ni-Co Ores and Residues

Behaviour of Sc in Gördes HPAL Plant during HPAL during 250 days of operation





PLS		Strip Liquor	
Ag ppm	0	Ag ppm	0
Al ppm	17771	Al ppm	2
As ppm	4	As ppm	0
Ca ppm	513	Ca ppm	0
Cd ppm	0	Cd ppm	0
Co ppm	46	Co ppm	1
Cr ppm	348	Cr ppm	0
Cu ppm	221	Cu ppm	0
Fe ppm	1205	Fe ppm	7
Mg ppm	2980	Mg ppm	3
Mn ppm	260	Mn ppm	0
Ni ppm	1344	Ni ppm	0
Pb ppm	0	Pb ppm	0
Sc ppm	**147**	**Sc ppm**	**2969**
Zn ppm	64	Zn ppm	0

High Purity $(NH_4)_3ScF_6$ Product
High purity ScF_3 can be obtained after calcination.

Sc Recovery Possibility from Laterites-Worst Case Scenario!

- 1-) Coral Bay – MSP ……. 24 000 ton Ni,
- 2-) Taganito – MSP …….. 36 000 ton Ni,
- 3-) Murrin Murrin – MSP ……. 40 000 ton Ni ,
- 4-) Ambatovy – MSP …… 40 000 ton Ni,
- 5-) Moa Bay – MSP …….. 30 000 ton Ni,
- 6-) Ramu – MHP …….. 35 000 ton Ni,
- 7-) Ravensthorpe – MHP ……. 40 000 ton Ni,
- 8-) META Nikel-Kobalt – MHP … 10 000 ton Ni,

USGS, 2018 Price Data	Purity (%)	Sample Size	2013	2014	2015	2016	2017
Scandium Acetate, US$/per gram	99.9	5 gr	51.90	43.00	43.00	44.00	44.00
Scandium Chloride, US$/per gram	99.9	5 gr	148.00	123.00	123.00	126.00	124.00
Scandium Iodide, US$/per gram	99.999	5 gr	228.00	187.00	187.00	149.00	183.00
Scandium Oxide, US$/per gram	99.99	5000 gr	5.00	5.00	5.10	4.60	4.60
Scandium Fluoride, US$/per gram	99.9	5 gr	253.00	263.00	263.00	270.00	277.00
Scandium Ingot, US$/per gram	-	5 gr	175.00	134.00	134.00	107.00	132.00

Approximately: ~250 000 ton Ni/year comes from laterites

If ores contain ~1% Ni → ~25 million tons of lateritic ore processed annually!

If lateritic ores contain ~40 g/ton Sc (worst case) ~(25 million tons * 40 g/ton = 1000 tons Sc) enter into the HPAL process annually.

If ~50% of Sc recovered overall during HPAL → ~500 tons Sc production (worst case) is possible with the current scenario.

By taking long term (2000 $/ton for Sc_2O_3) and (3000 $/ton for ScF_3)

500 tons Sc → 750 tons Sc_2O_3, Economic Value: (750 tons * 1000 $/kg) = 0.75 Billion USD/year

500 tons Sc → 1100 tons ScF_3, Economic Value: (1100 tons * 1500 $/kg) = 1.65 Billion USD/year

QUESTIONS & ANSWERS

For the widening of Sc market and applications in a sustainable manner;

- **Reliable,**
- **Secure,**
- **Long-term,**
- **Open to collaborations,**

As META, we are ready and confident about producing;

- ✓ **$(NH_4)_2NaScF_6$, $(NH_4)_2KScF_6$,**
- ✓ **Mixture of ($NaScF_4$ - Na_3ScF_6) or (K_3ScF_6 – KSc_2F_7)**
- ✓ **$(NH_4)_3ScF_6$,**
- ✓ **And, ScF_3 if collaborated with serious partners.**

ZORLU

THANK YOU FOR YOUR ATTENTION

meta NİKEL KOBALT A.Ş.

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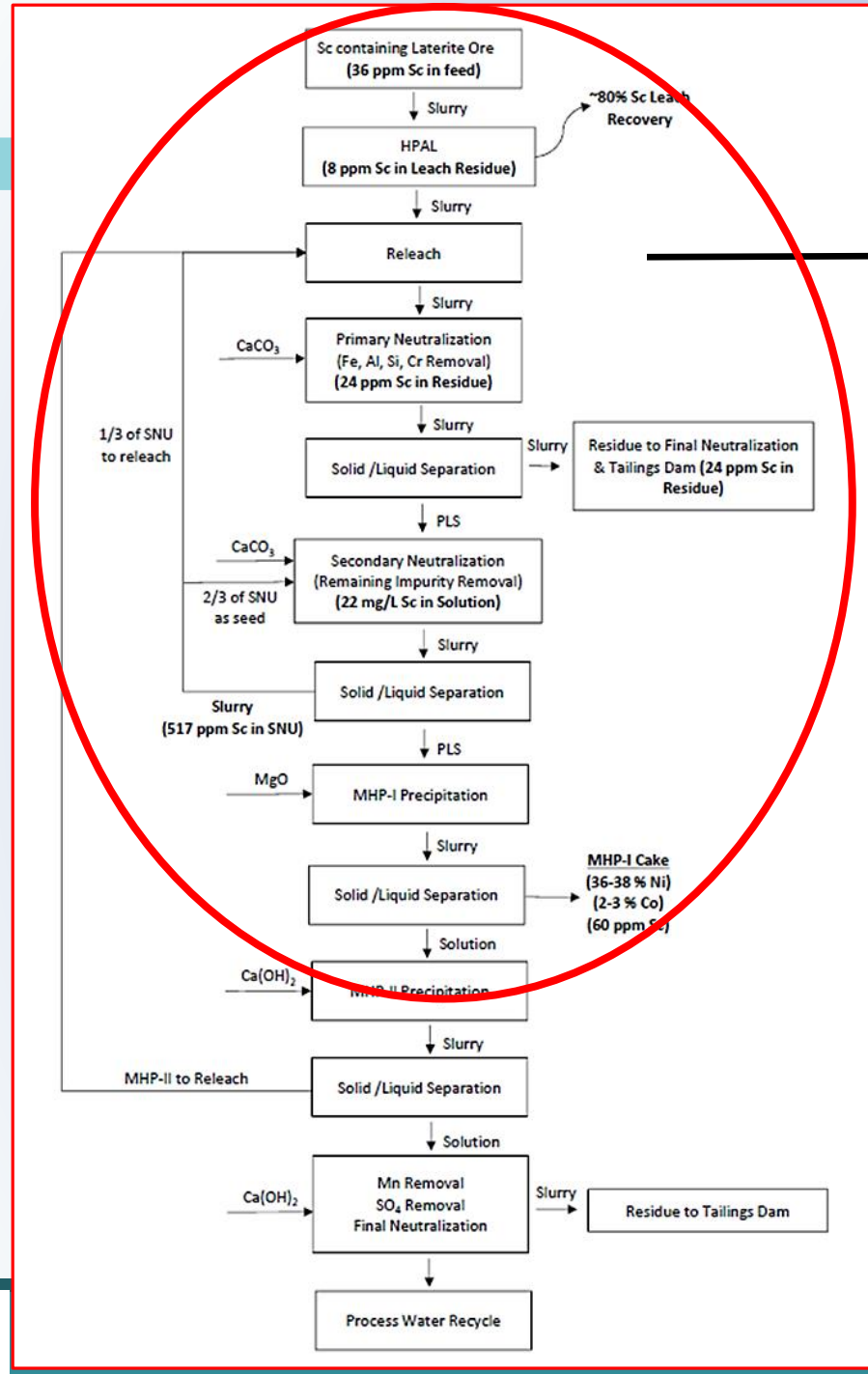
Additional Slides



Sc containing Laterite Ore
(36 ppm Sc in feed)
Slurry
~80% Sc Leach Recovery
HPAL
(8 ppm Sc in Leach Residue)
Slurry
Releach
Slurry
CaCO3
Primary Neutralization
(Fe, Al, Si, Cr Removal)
(24 ppm Sc in Residue)
Slurry
1/3 of SNU to releach
Solid /Liquid Separation
Slurry
Residue to Final Neutralization & Tailings Dam
(24 ppm Sc in Residue)
PLS
CaCO3
Secondary Neutralization
(Remaining Impurity Removal)
(22 mg/L Sc in Solution)
2/3 of SNU as seed
Slurry
Solid /Liquid Separation
Slurry
(517 ppm Sc in SNU)
PLS
MgO
MHP-I Precipitation
Slurry
Solid /Liquid Separation
MHP-I Cake
(36-38 % Ni)
(2-3 % Co)
(60 ppm Sc)

World Laterite Reserves

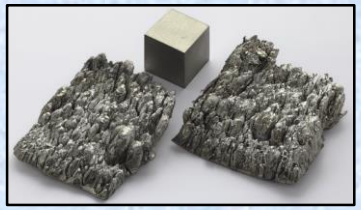
Details of Lateritic Deposits

Laterites are mainly composed of:

- Fe rich, Mg, Si poor **Limonitic (Fe oxide dominant)**, and (more amenable to HPAL)
- Fe poor, Mg, Si, rick **Saprolitic (Mg silicate dominant)** zones (more amenable to FeNi and NPI)

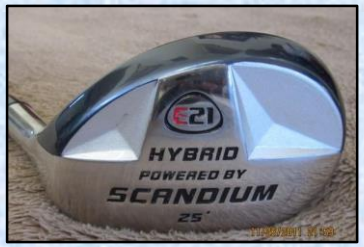
[5]

APPLICATIONS of Sc

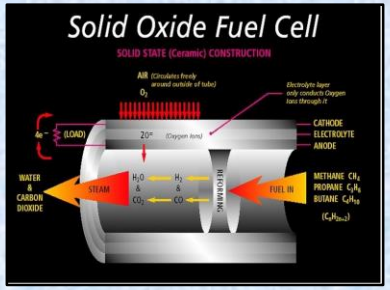


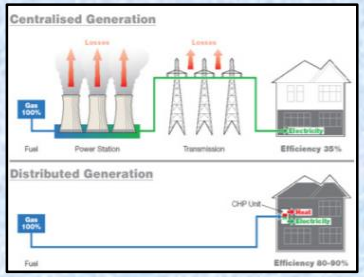
In the Near Future

Al-Sc & Al-Sc-Mg Alloys



Solid Oxide Fuel Cells

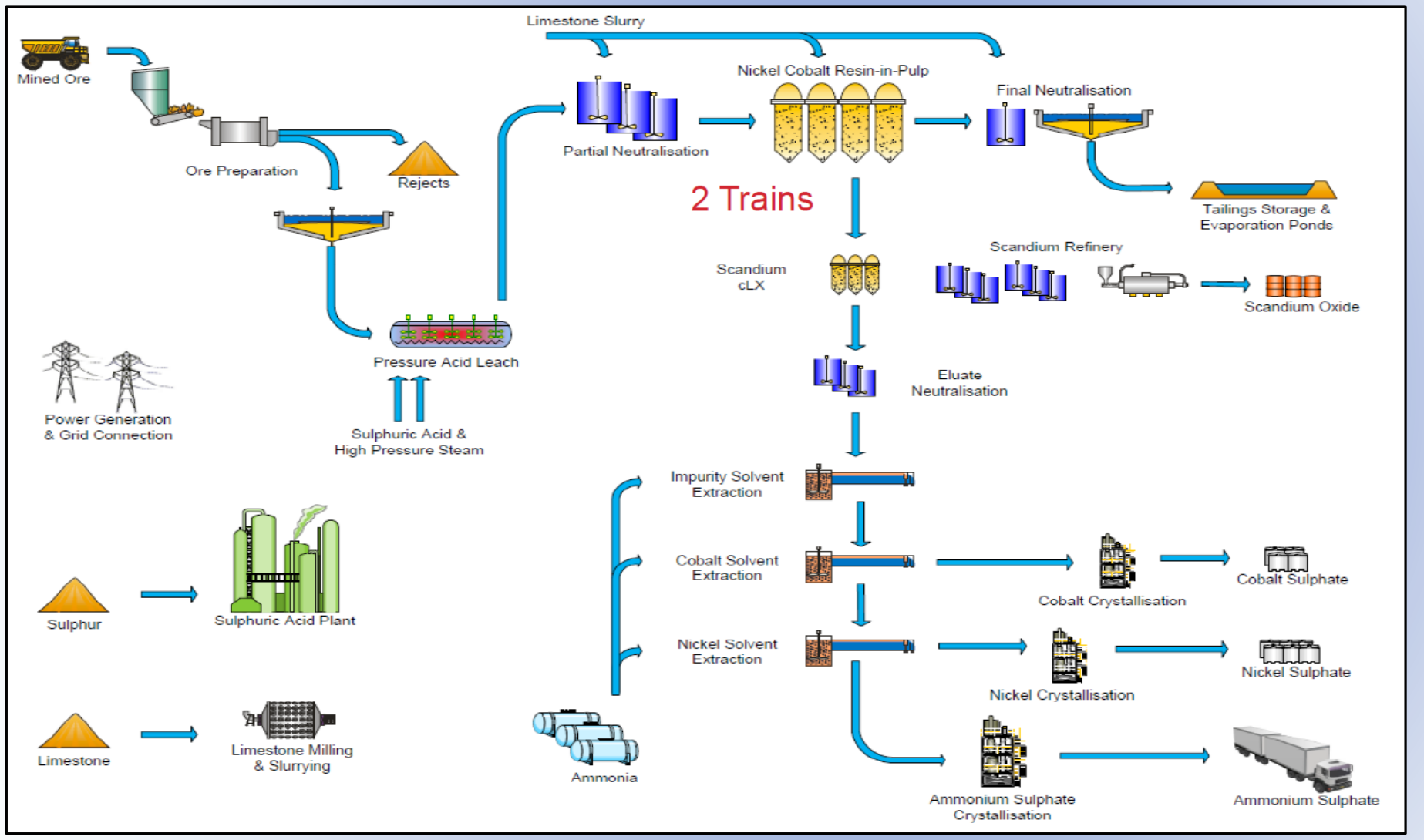




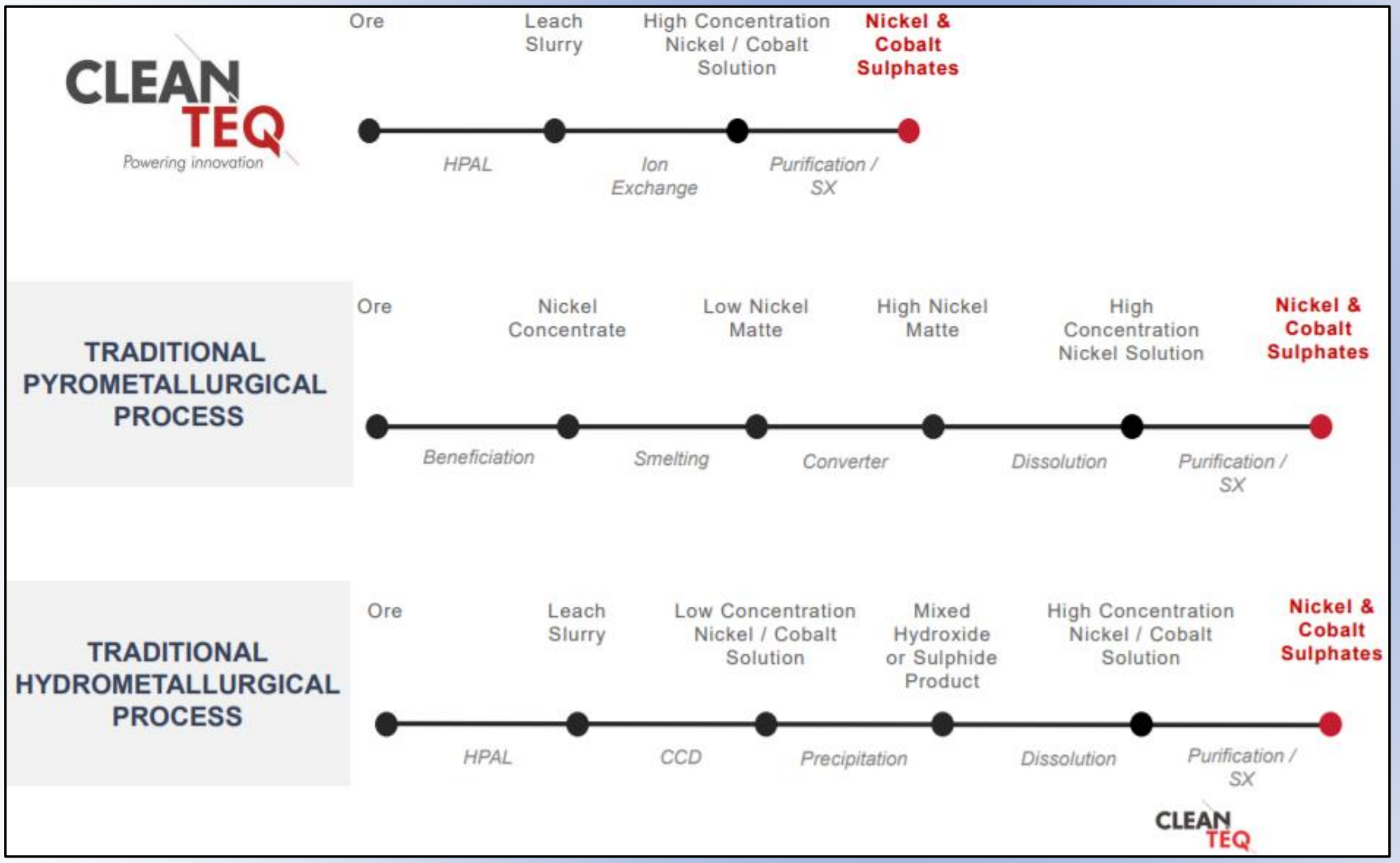
Lasers & Lighting

3D Printing Tech.

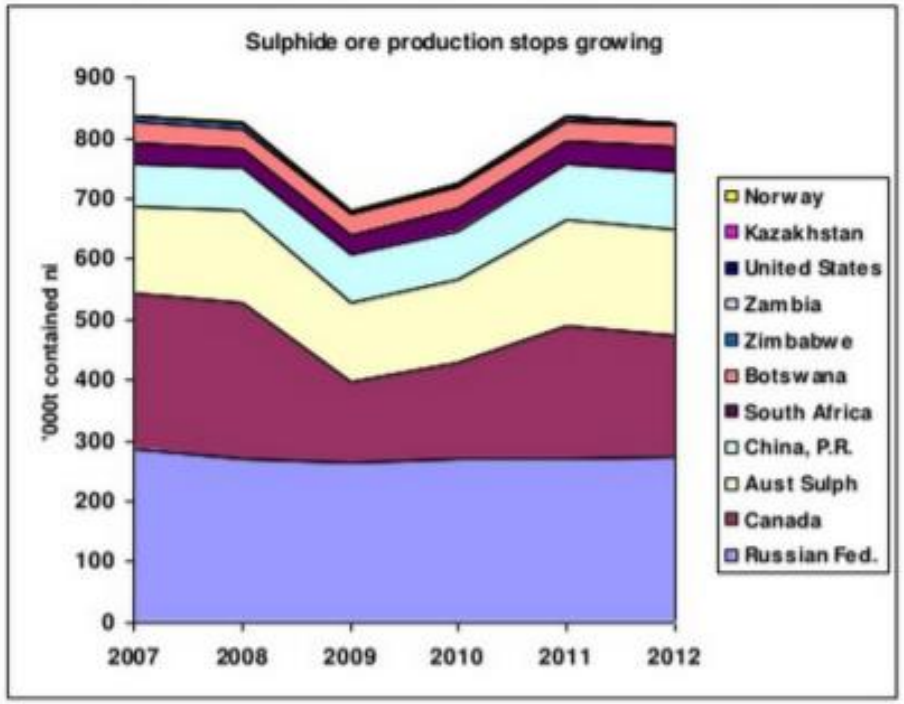
Clean TeQ Sc Recovery Circuit

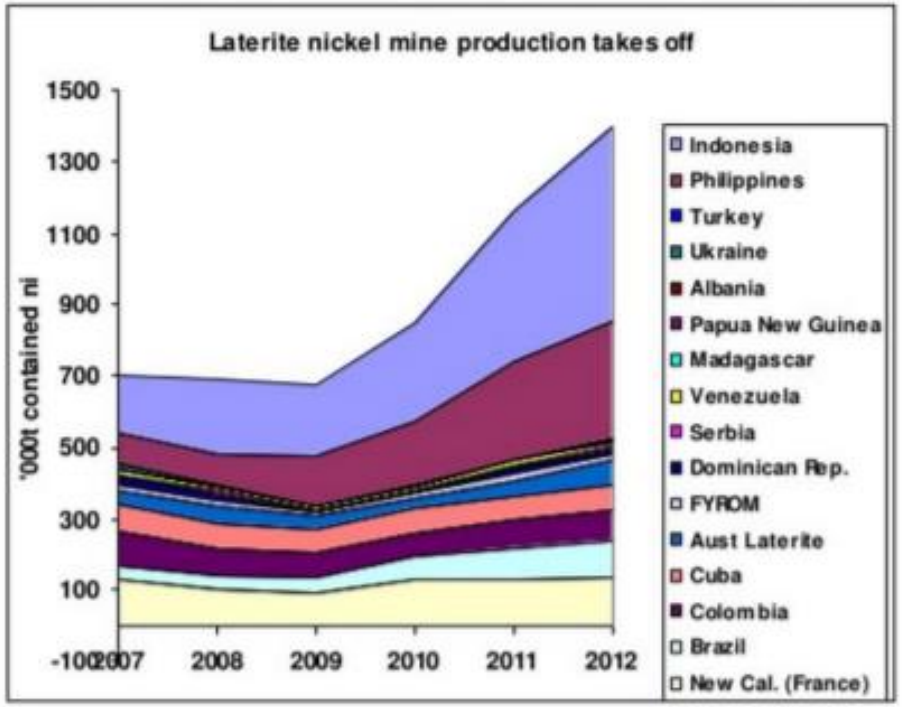


Clean TeQ Sc Recovery Circuit



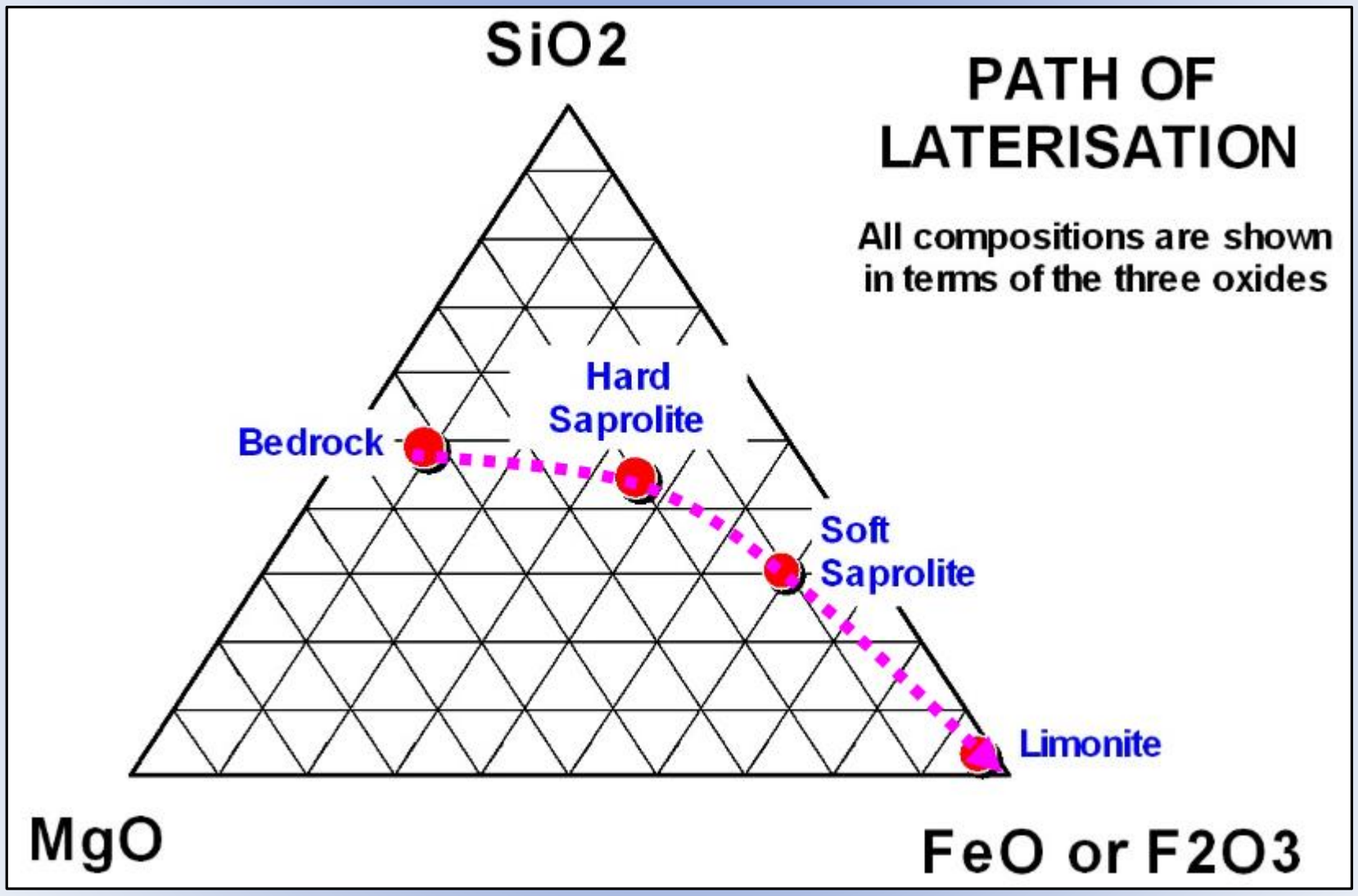
The changing face of nickel – stagnation in sulphide production as laterites take off – mine production basis





Source: INSG, Macquarie Research, July 2013

New Caledonia has not participated in the laterite ore surge


SiO2
PATH OF LATERISATION
All compositions are shown in terms of the three oxides
Hard Saprolite
Bedrock
Soft Saprolite
Limonite
MgO
FeO or F2O3

Sc from Bauxite Residues (Red Mud)

Environmental concerns and huge economic potential, force the exploitation of Red Mud for Sc recovery.

Hydrometallurgical Approaches

- Selective Leaching

✓ (mineral acids: H_2SO_4, HCl, HNO_3),

✓ (carbonate leaching),

✓ (Ionic liquids),

- IX - Solvent Extraction (Recovery & Purification)

Pyro-Hydrometallurgical Approach

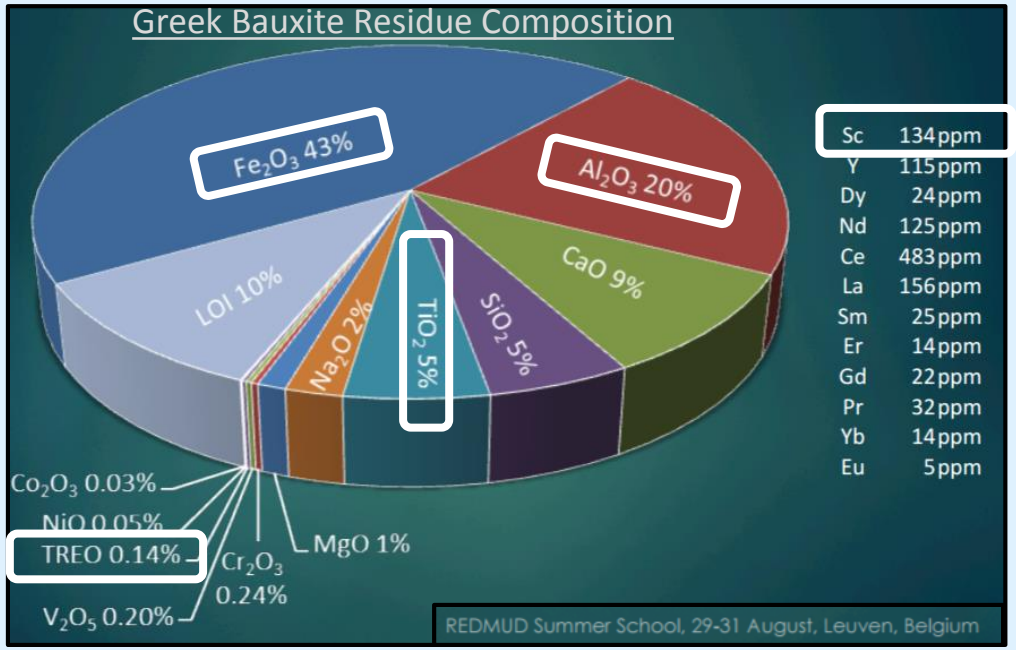
- Reductive Roasting & Magn. Separation
- Reductive Smelting of BR for Fe rec. (Pig Iron)

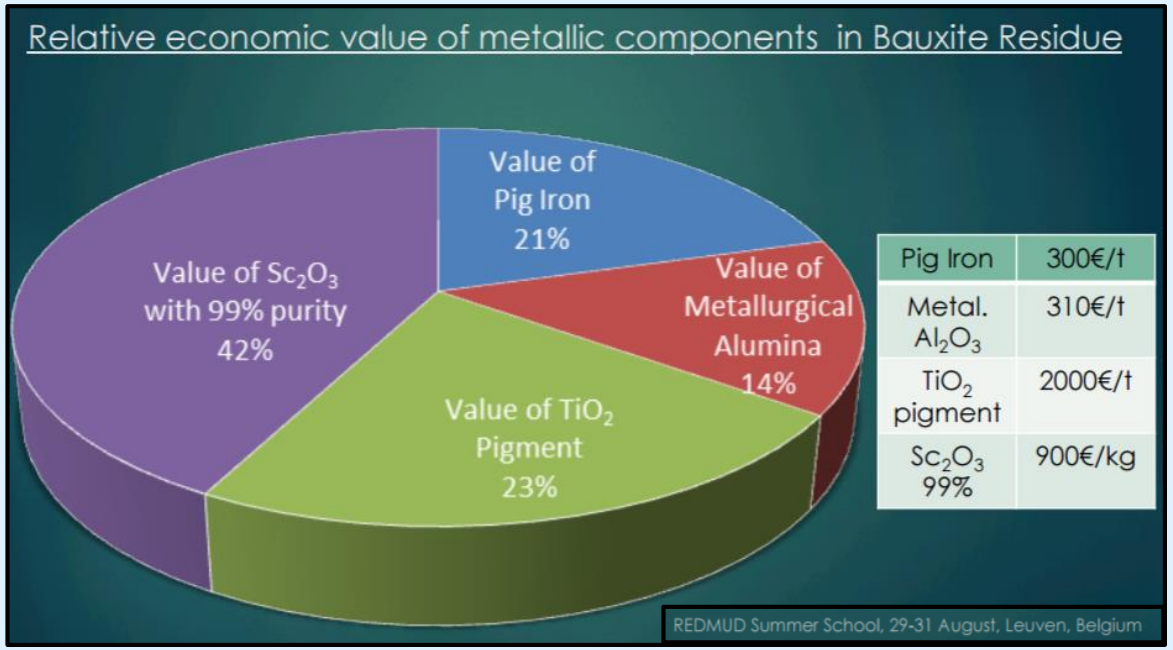
✓ > 98% Sc reported in the slag

- Leaching & Recovery by IX-SX

Sc from Bauxite Residues (Red Mud)

- Worldwide there is an annual bauxite residue production of 120 million tonnes (dry matter) and a total inventory of 3 billion tonnes, stored in huge tailing ponds. Sc is enriched ~2 times in the BR and represents >95% of the economic value of rare earth elements in red mud.

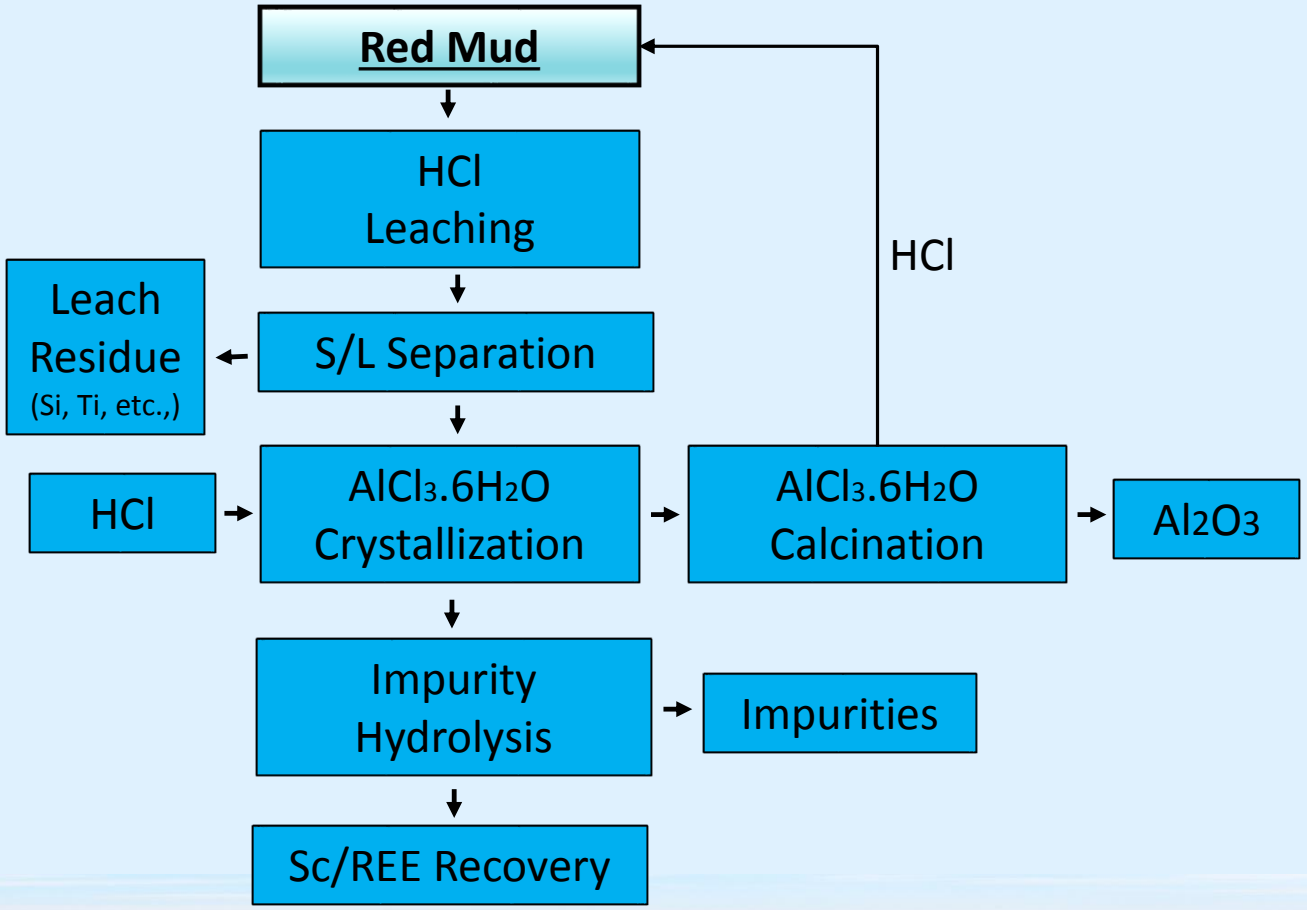




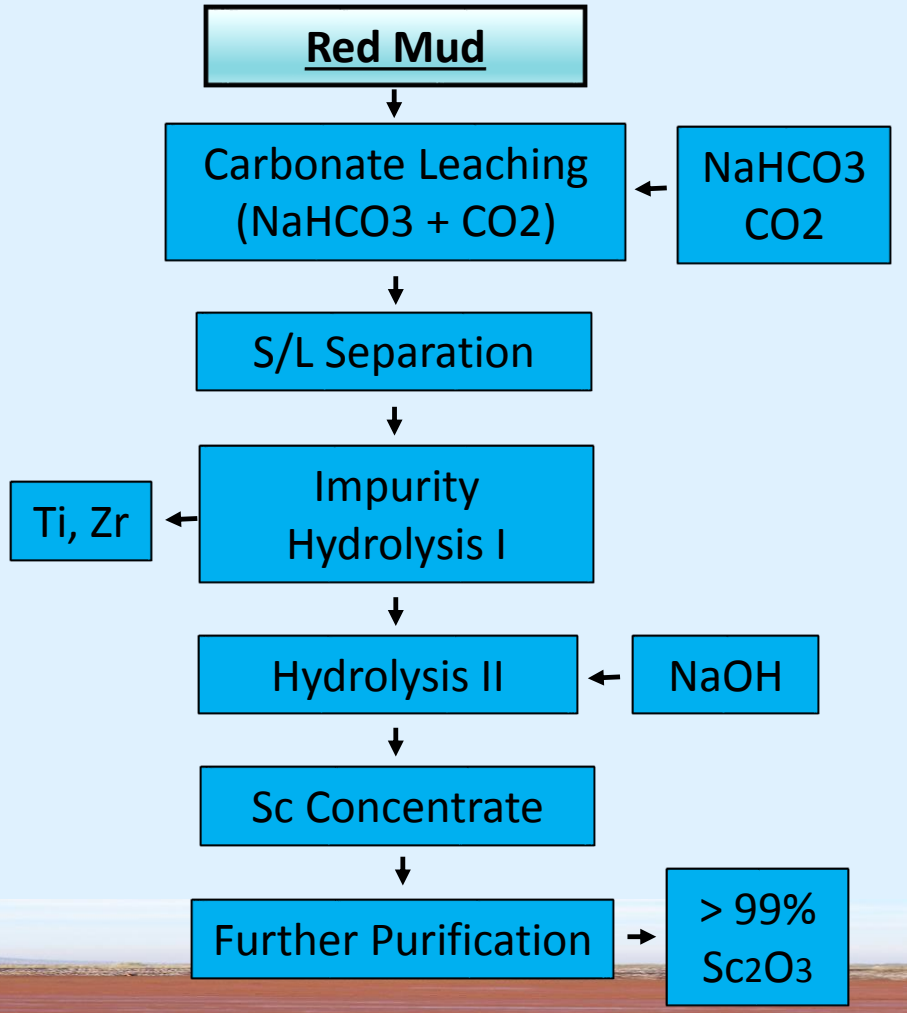
Environmental concerns and huge economic potential, force the exploitation of Red Mud for Sc recovery.

Sc from Bauxite Residues (Red Mud)

ORBITE Alumina Flowsheet [6]



RUSAL Flowsheet [7]



Pilot Plant in Urals Al Smelter

~95 kg Sc_2O_3 per year

Sc from Lateritic Ni-Co Ores and Residues

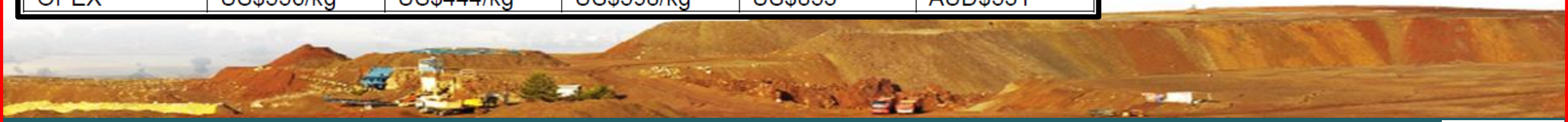
Companies Developing New Sc Projects

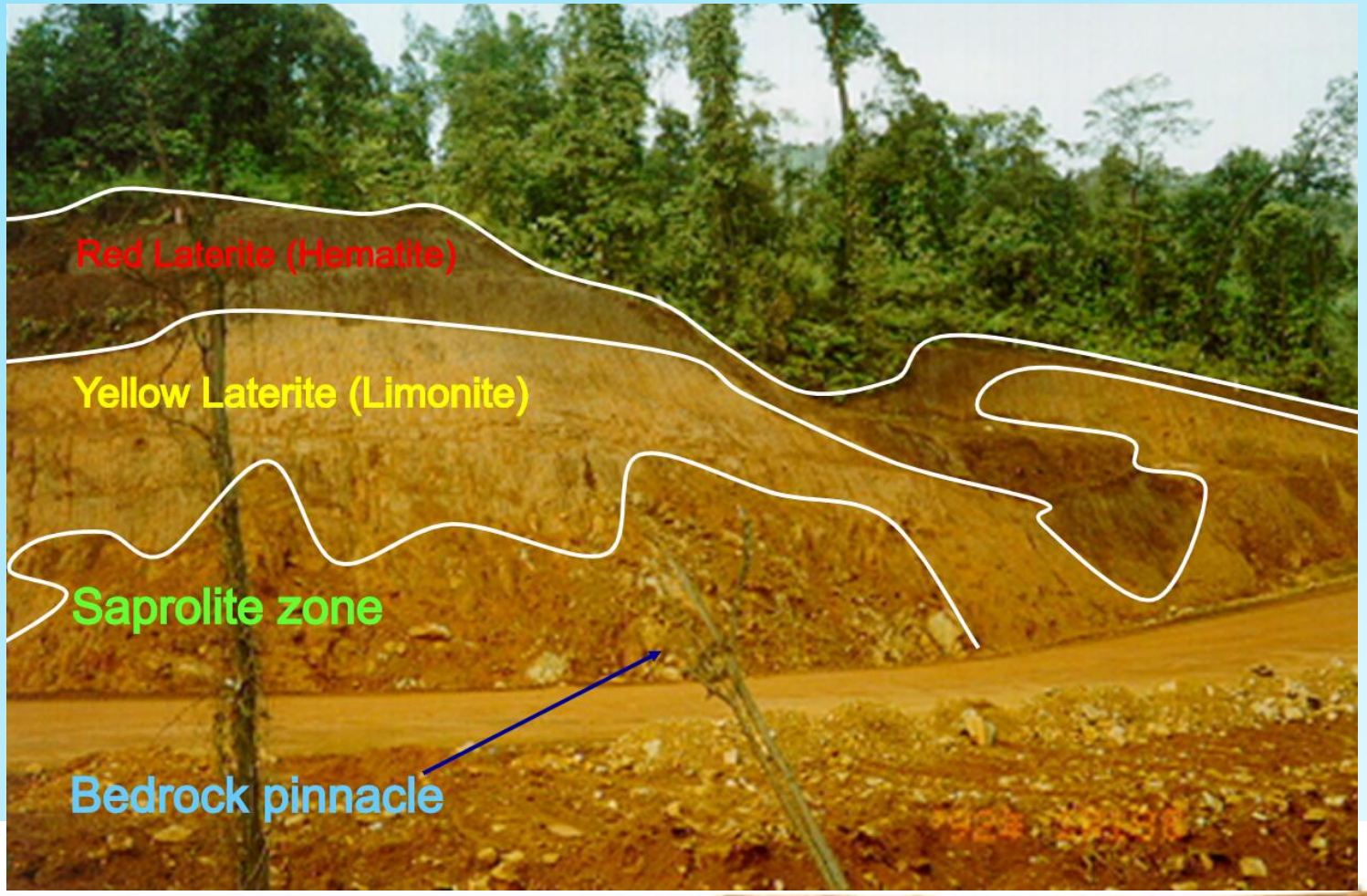
Project Characteristic	Project Name				
	Nyngan	**Syerston**	**Owendale**	**ScONi**	**Flemington**
Proponent	Scandium International Mining Corp	Clean TeQ	Platina Resources	Metallica/ Australian Mines	Jervois/ Australian Mines
Study Status	DFS Completed	PFS (Sc only) PFS (+Co,Ni)	Scoping/ PFS underway	PFS by Metallica/ DFS by AUZ	Scoping Completed by AUZ
Next Steps	Financing	DFS	PFS	DFS	PFS
Cut-off Grade	100 ppm	300 ppm	300 ppm	120 ppm	300 ppm
Head Grade	409 ppm	583 ppm	384 ppm	208 ppm	450 ppm
By-products	None	Co, Ni	Co, Ni, Pt	Co, Ni	Co, Ni
Resource (t Sc_2O_3)	3,135	11,819	16,500	1,950	2,085
Recovery	83.7%	88%	86%	81.5%	76.2%
Product %	99.8%	99.9%	99.9%	99.99%	99.9%
Capacity (tpa)	38	49.2	30	68	50
Process	HPAL/SX	HPAL/RIP IX	HPAL/SX	HPAL/SX	HPAL/SX
CAPEX	US$77.8M	US$75M	US$73.5M	US$178	AUD$74
OPEX	US$556/kg	US$444/kg	US$598/kg	US$853	AUD$531

Lateritic Ni-Co resources seem highly advantageous;

- Urgent,
- Reliable/secure,
- Sufficient,
- Long-term/stable,
- Reasonaly priced,
- Sustainable,

Sc Production in the near future!




Red Laterite (Hematite)
Yellow Laterite (Limonite)
Saprolite zone
Bedrock pinnacle