INTERNATIONAL NICKEL STUDY GROUP

INSG Meetings, Lisbon, Portugal, April 2024

Industry Advisory Panel – *Tuesday 23 April 2024*

“Low Carbon Production of Nickel and Other Metals: A Review of Potential New Technological Approaches and the Role of Hydrogen”

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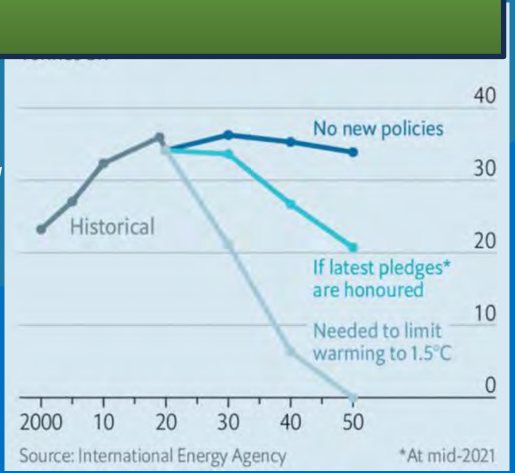
Topics covered

Nickel will play an indispensable role in the global energy transition – Ni has to have a low CO_2 footprint

1. **Introduction & background/energy transition**
2. **Nickel- world production by country/ore types development of present Ni technology**
3. **New developments in iron and steel technology (for lower CO_2) - and link to Ni**
4. **Potential new technologies for nickel**
5. **Concluding comments**

Appendix slides

The "Big Nickel", Sudbury, Ontario, Canada, opened in 1964.
It is a large replica of the 1951 Canadian nickel coin (in 1951, Canada produced 74% of the world's nickel)
It also celebrated the 200th anniversary of the isolation of Ni by Cronstedt in 1751



Source: The Economist, 2021

Note: 1. Some tonnages approximate. Annual tonnages are generally for 2020 or 2022 as indicated
2. Slides in Appendix provide back-up details

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Stop Press

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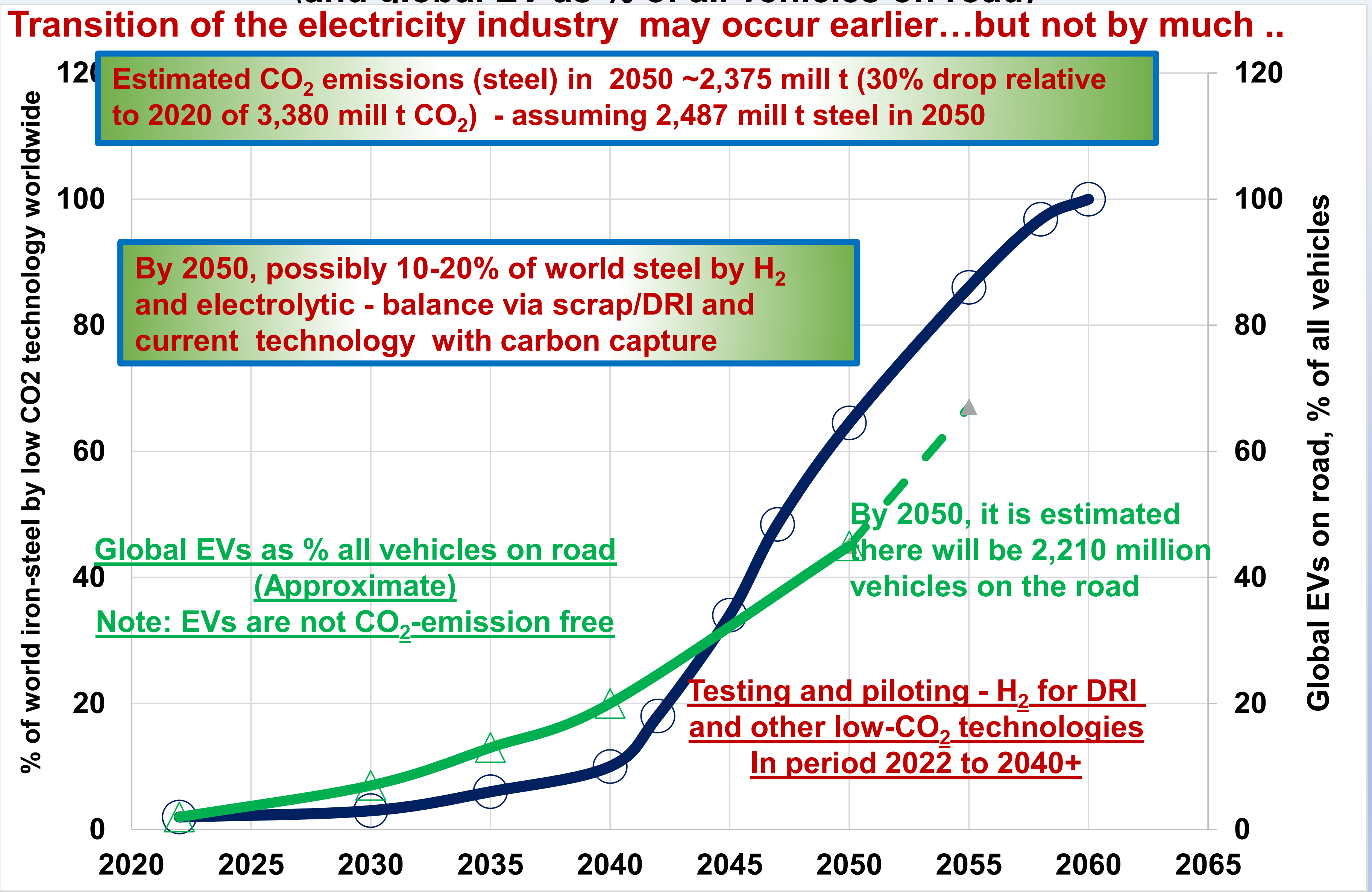
Technology& the way it is used can play a major role in keeping plant costs low*

***Refers to the whole technology package encompassing: excellent safety and environmental record, high on-line time, low maintenance, long equipment/refractory life, good level of automation/labour saving**

Projected rate of world-wide take-up of low carbon technology in iron and steelmaking

(and global EV as % of all vehicles on road)



Note: Low carbon steel is <200 kg CO_2/t steel

P.J. Mackey © 2024 Source: P.J. Mackey, 2022

2. Nickel- firstly, review of world production

- Overview
- By country
- By ore type and technology

It is noted that today, there are about 100 nickel smelters and refineries worldwide (half in Indonesia)

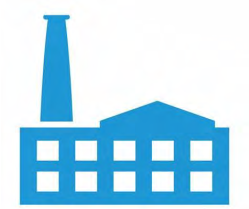
Nickel- 1

Overview of Ni - production by ore type and technology

While the world economy is expected to grow at less than about 3 to 3.3 % in the period 2025-2030 - down from 3.4% in 2021, growth in metal demand - such as for Ni- is expected to be somewhat higher- and stainless steel will continue to be important

Nickel (3.12 million t in 2022) is the 8th metal in terms of world metal tonnage after steel, aluminum, chromium, copper, manganese, lead and zinc; world steel tonnage is some 800 times larger than that of nickel

The six largest primary nickel producing countries (2022 smelter data) are: Indonesia, China, Russian Federation, Canada, Australia and New Caledonia



About 75% of current world primary nickel (2.34 million t) is produced from oxidic ores called laterites, the balance (25%) from sulphidic nickel ores (0.78 million t).

Of the amount produced from laterites - approximately 87% is by pyrometallurgy – saprolite (mainly RKEF), the balance (13%) is produced by hydrometallurgy by high pressure leaching of limonite (HPAL)

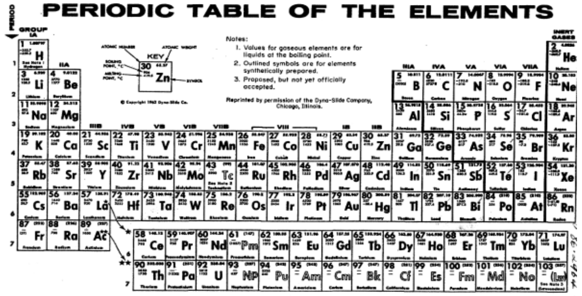
Source: refer to P. Mackey

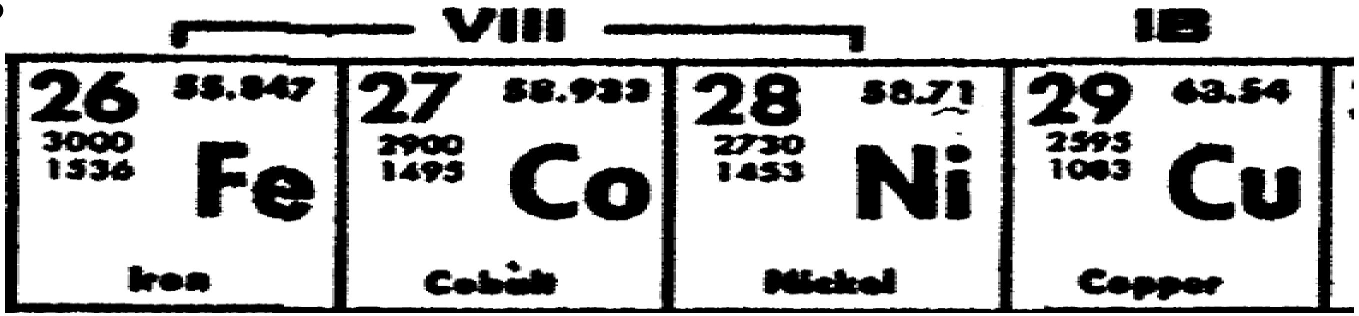
RKEF-Rotary Kiln Electric Furnace; HPAL-High Pressure Acid Leach

Nickel will play an indispensable role in the global transition to a low-carbon economy

Nickel- 2

In general, iron, cobalt and nickel share similar characteristics. These elements are adjacent to each other in Group 8 of the periodic table – also note, copper is next to nickel. This helps us understand technology processes





Copper and iron stretch back to antiquity- the Bronze Age (prior to 1200 BC) and the Iron Age (1200 BC to 500 BC).

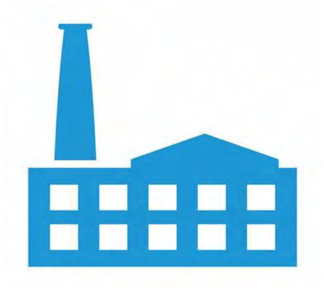
Nickel however was only isolated in 1751 by A.F. Cronstedt by experimenting with cobalt ores from Helsingland, Sweden

Nickel- 3

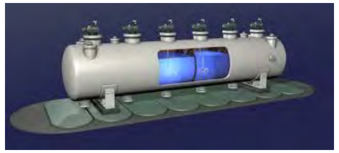
Extraction processes for nickel have traditionally followed the technology in place for copper (for Ni sulphides) and iron (for Ni laterites):


Early converter for Ni

► **When nickel sulphide deposits were discovered in Europe in the 1800s (Germany & Norway), miners turned to copper metallurgy for processing (blast, later reverberatory/electric furnaces, converters)**



► **Similarly, when large nickel laterite deposits (oxidic Ni) were discovered in New Caledonia in the 1880s, miners turned to iron metallurgy for processing (blast furnace, electric furnace, rotary kiln, etc.)**



► **This adaptation has generally followed to the present day**

Note: HPAL for leaching limonite - based on early pressure leaching of U ore & sulphides in Canada - began at Moa Bay, Cuba in 1959

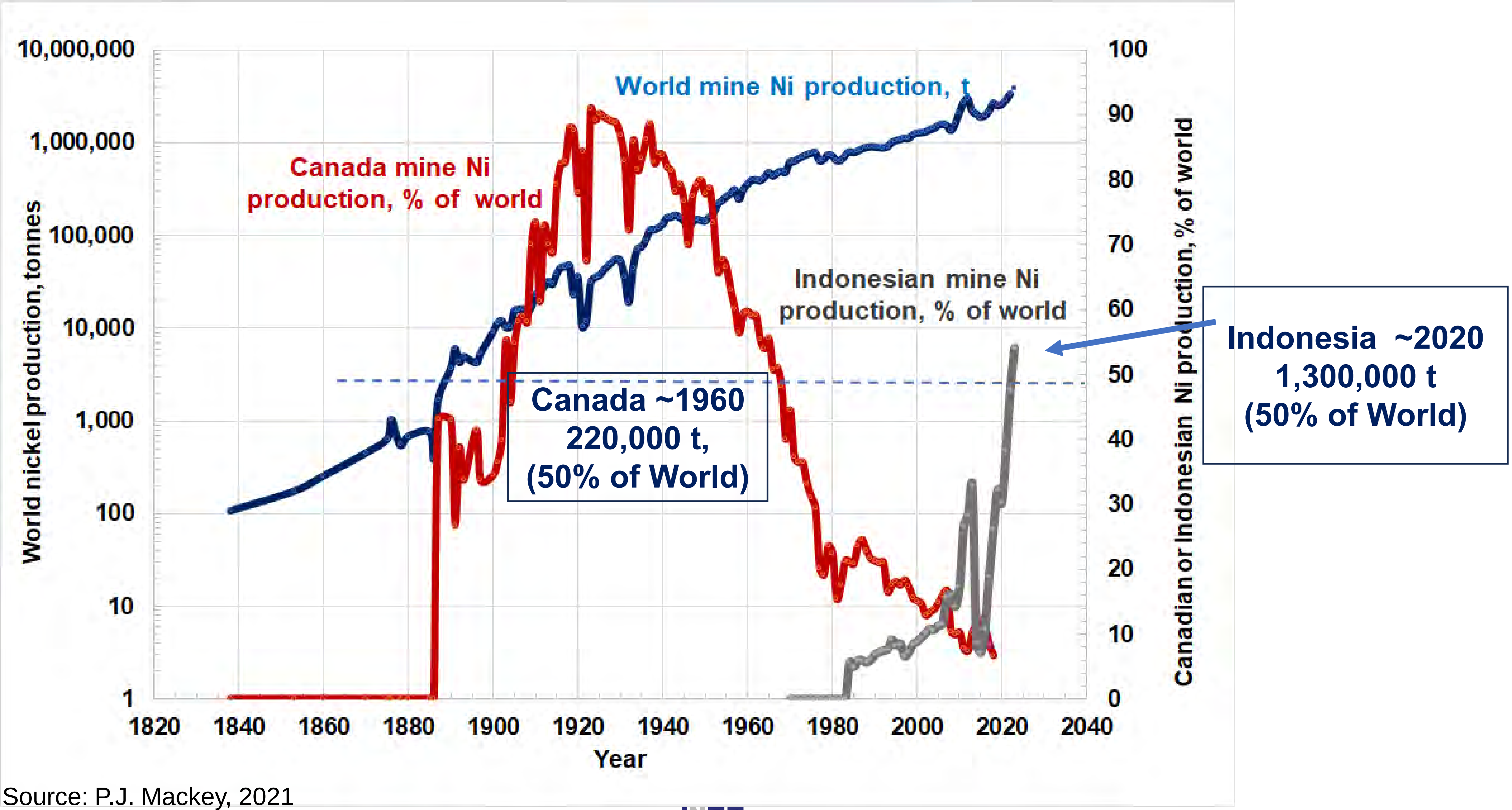
Note: The production of pure Ni metal also required the development of new, specialized metallurgical processes – Hybinette electrolytic process, Orford process, etc

World nickel tonnages/ores

- Total by year since 1840
- Growth to 2030
- Split by ore type (saprolite/limonite)
- Major producing countries compared - Canada (historical) & Indonesia (current)
- Production and total CO_2 emissions- major metals

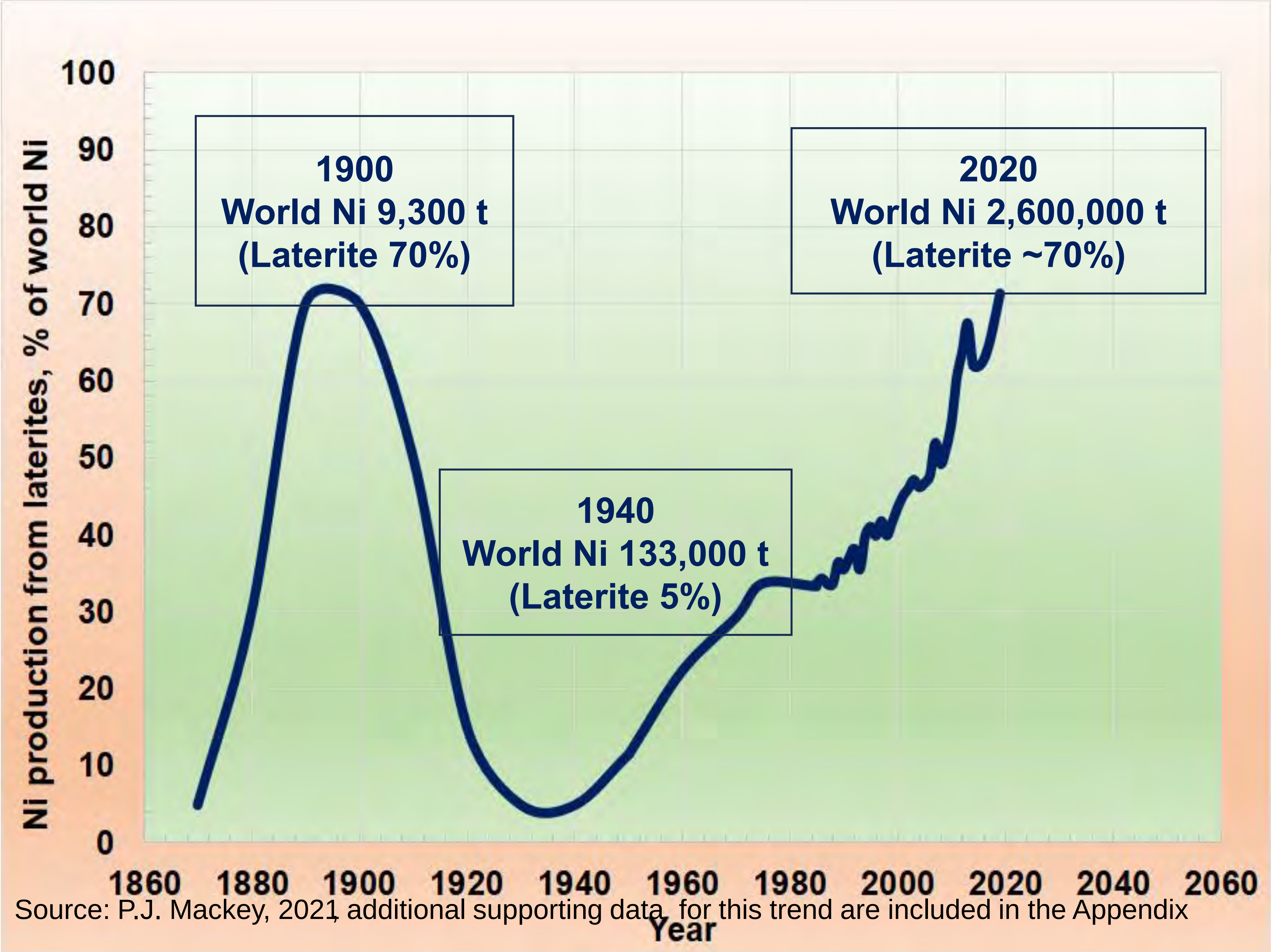
Canada Ni as % of world Ni - 1880 to present and rise of Indonesian Ni

(Canada dominated Ni for over 70 years from about 1900)



Source: P.J. Mackey, 2021

Changes in % of world Ni from laterite, 1860 to present day



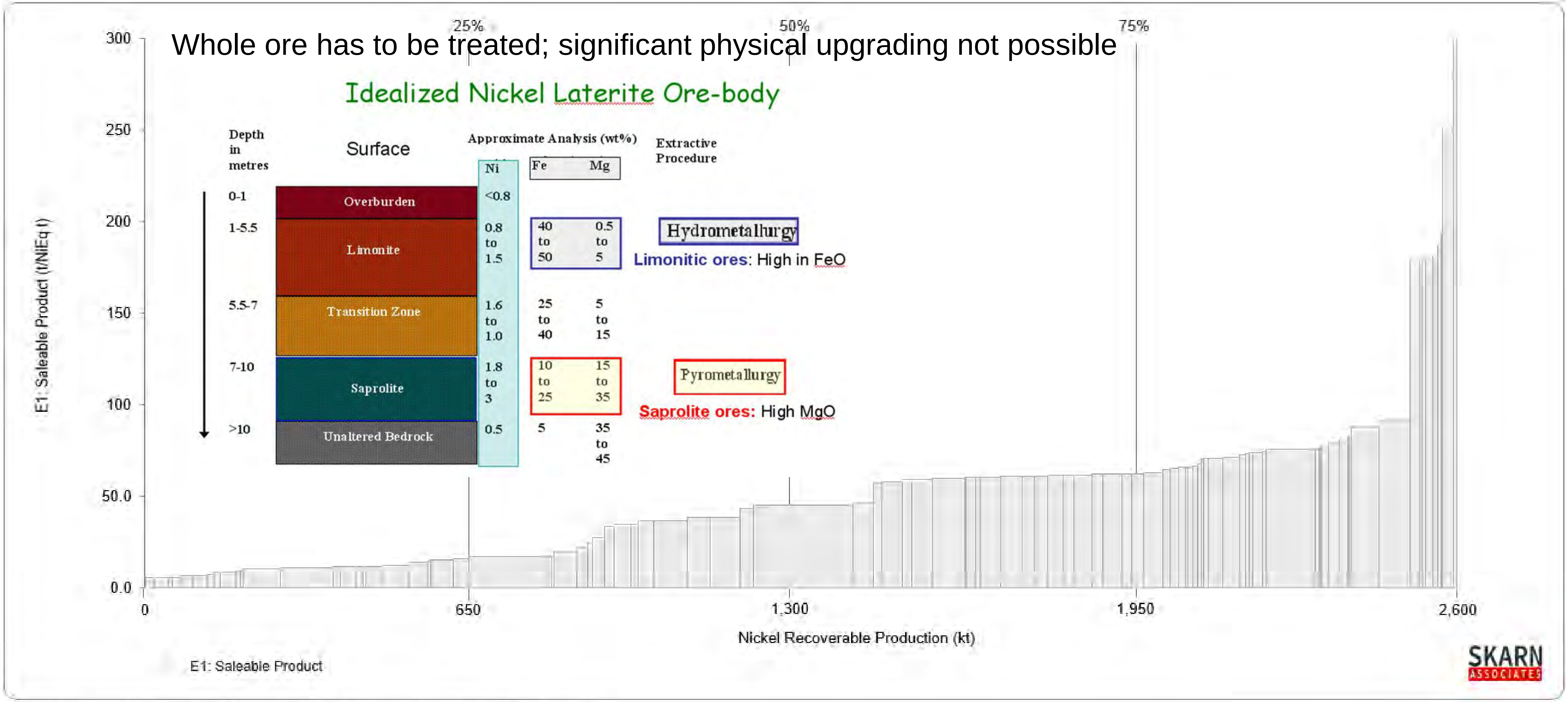
Source: P.J. Mackey, 2021 additional supporting data, for this trend are included in the Appendix

Projected growth in nickel demand

There are a number of published projections for annual nickel growth, ranging from 3 to over 7%.

In the median term, growth is expected to be quite modest

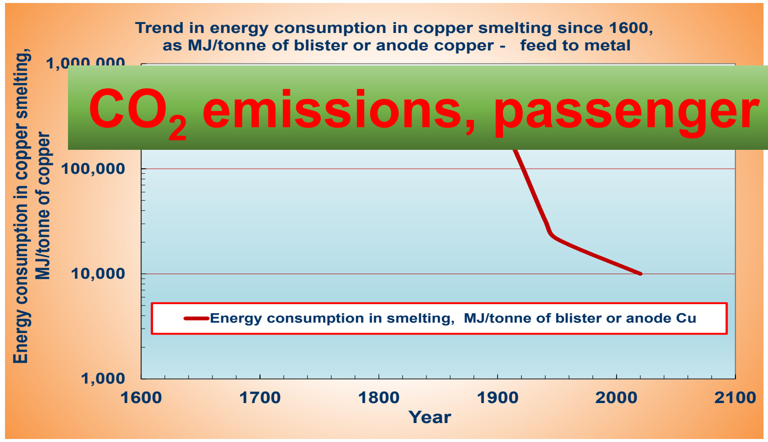
CO_2 emissions for world nickel production (and ore types)
(World average ~32 tonnes CO_2/t nickel - present author)



Source (Main graph): Skarn Associates Limited, UK, 2024; Insert: Utigard, CIM 2009

Global metal production and global CO_2 emissions for each metal

Metal (average global ore grade, %)	Production (2020), mill t	~ Value US$ million	Global CO_2 Mill t CO_2	Proportion of total global CO_2, %	CO_2 for metal t CO_2/t metal
Steel (57-62%Fe-Aust, US ~lower)	1,870	4,138,000	3,380	9.70	1.8 (Mine0.01t/t)
Aluminum (~ 40%)	64	169,000	1,000	2.90	15.7
Copper (Global avg 0.62% Cu)	21	190,000	82	0.24	4.5
Zinc (Range 2-6% Zn)	14	41,000	52	0.15	3.8
Nickel (1.6%Ni-L, 1-2% Ni-S)	2.4	42,000	76.9	0.22	32.0
Lithium (0.5-2% Li- hard rock)	0.0825	4,000	~2	<0.01	4 – 30 (Varies)
Ammonia (NH_3)	230	230,000	550	1.6	2-3
Present world mining truck fleet	>5,000	-	71	0.21	0.01-0.02 (/t ore)
Cement	4,100	510,000	2,870	8.3	0.70



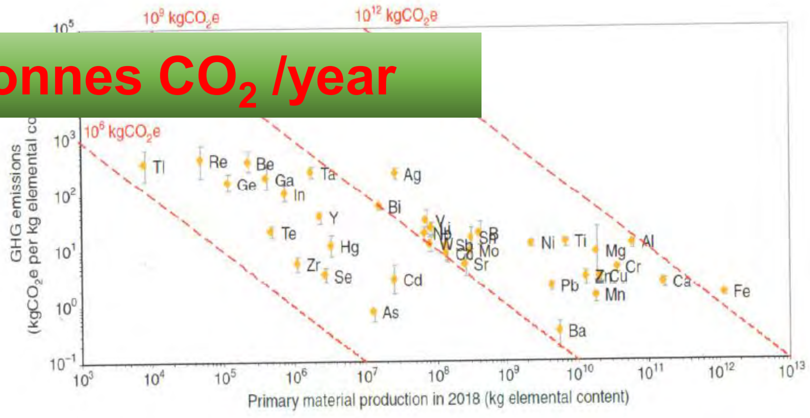
Smelting energy – 1700 to present

CO₂ emissions, passenger cars globally — **3,000 mill tonnes CO_2 /year**

Note: Data are typical global

individual plants, countries varies widely.

Depending, the CO_2 footprint of some metals produced in Canada could be lower than the above global average



Energy consumption- all metals

P.J. Mackey © 2024

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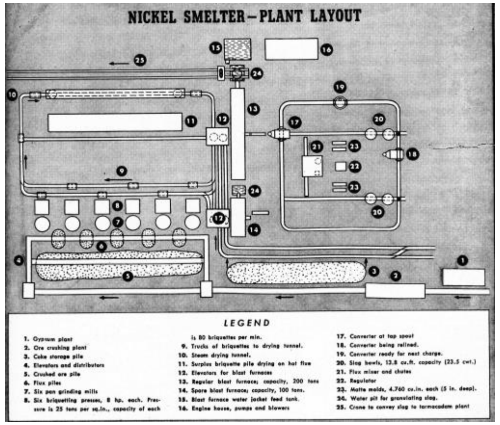
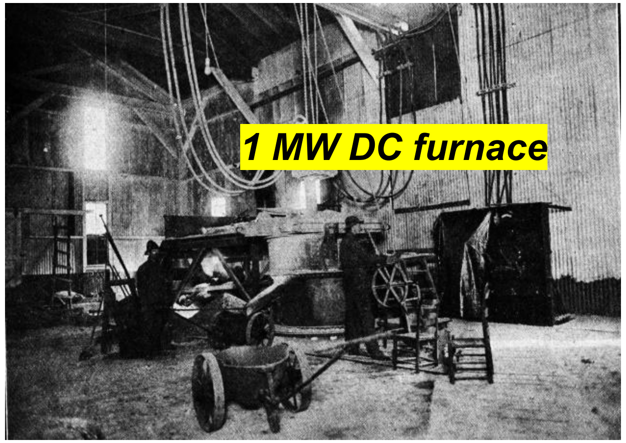
Nickel - Technology development

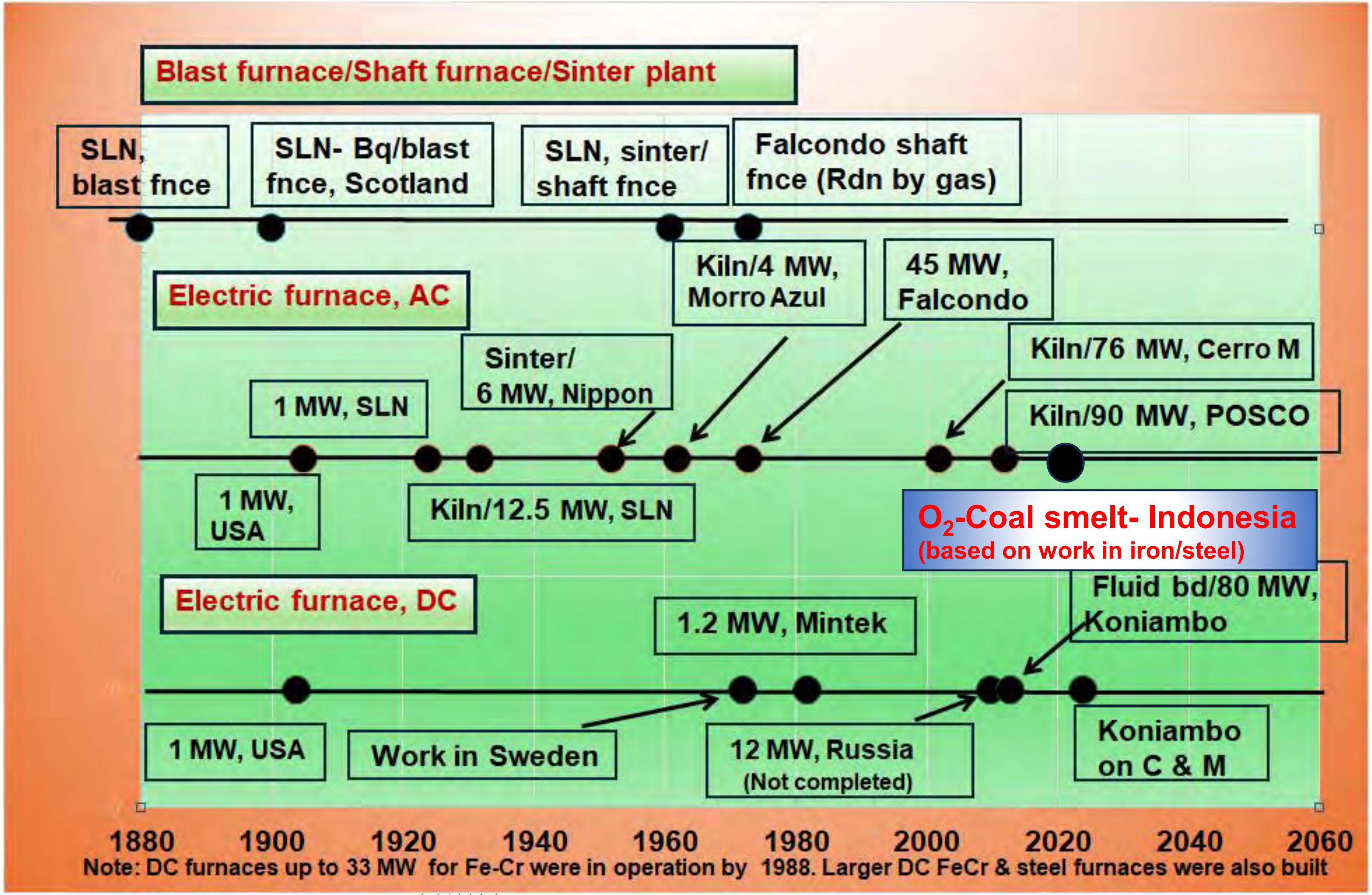
Details of nickel technology development, 1880 to 2024
Laterite ore - pyrometallurgy



Layout of large laterite blast furnace/converter plant, Glasgow,1900

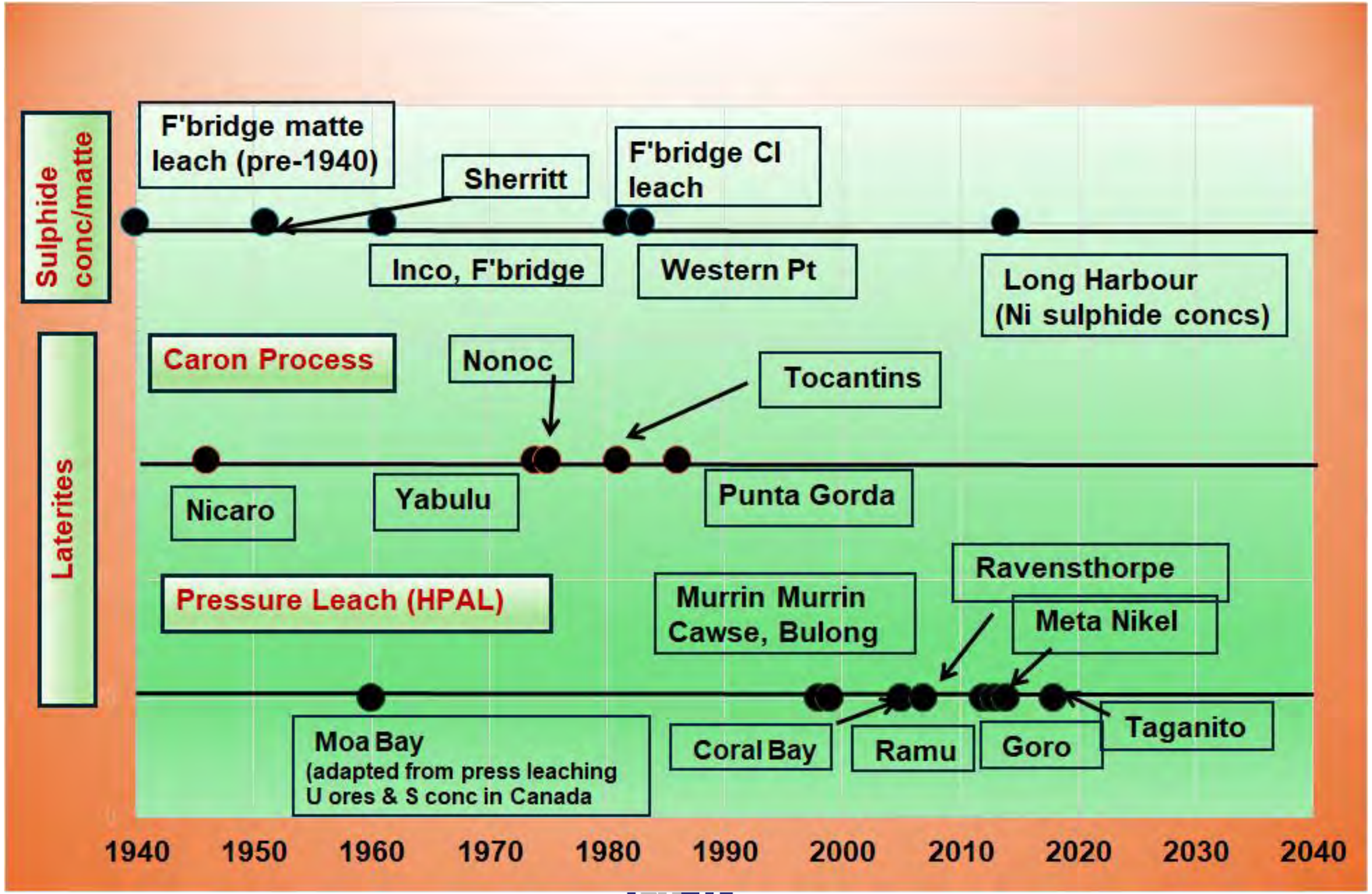


First DC furnace testing of laterite ore, USA, 1904



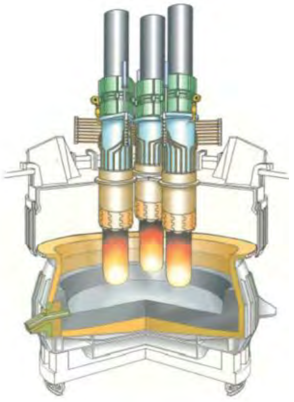
Source: P.J. Mackey, 2024

Development of nickel technology- Hydrometallurgy
(for sulphide concentrates, matte and laterites)



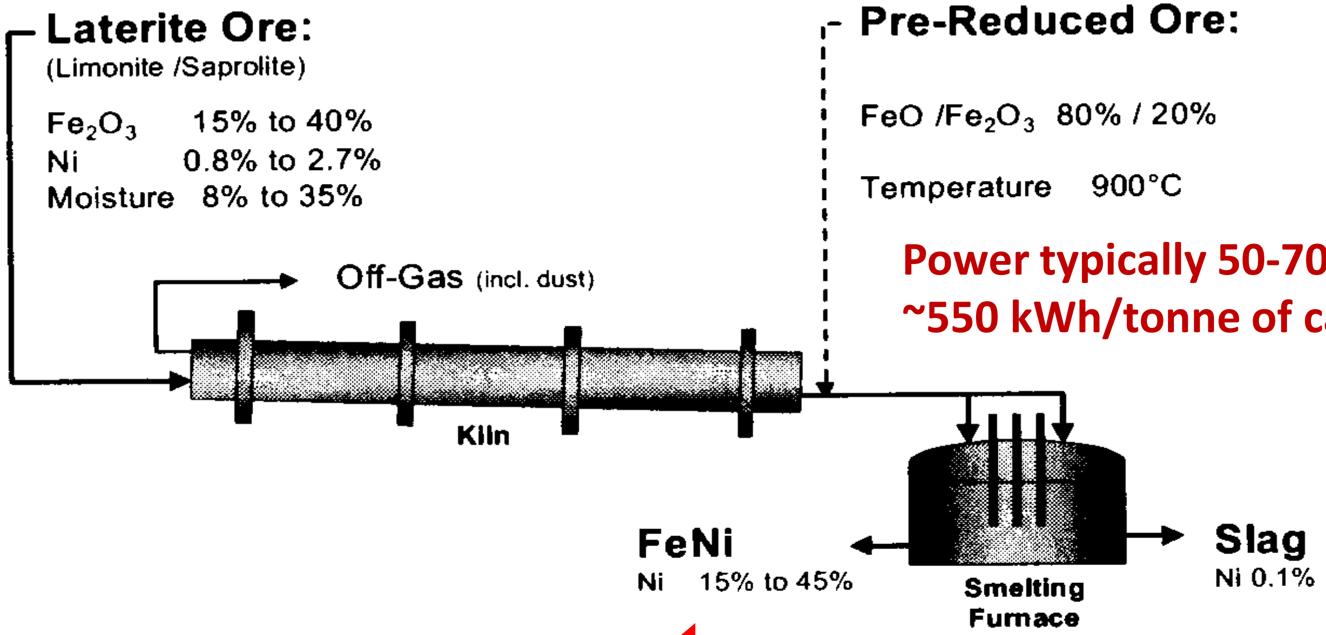
 Source: P. J. Mackey, 2024

Nickel production processes - 1



Nickel from saprolite/transition laterite ore – Rotary Kiln-Electric Furnace (RKEF) - 65% of primary Ni today

Calcine ~ 80-120 t/h



Power typically 50-70 MW, ~550 kWh/tonne of calcine

Slag at 1550 °C contains most of the energy input
Ni content ~0.1 to 0.2 %

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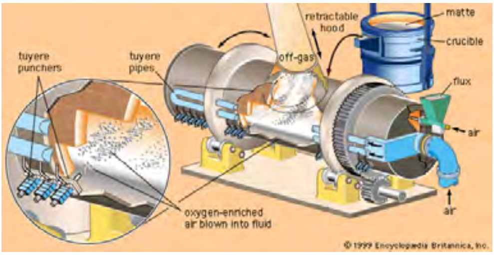
Nickel production processes - 2

Nickel from limonite laterite ore – High Pressure Acid Leaching (HPAL) - 10% of primary Ni today (there is a trend now in Indonesia to build more HPAL plants)

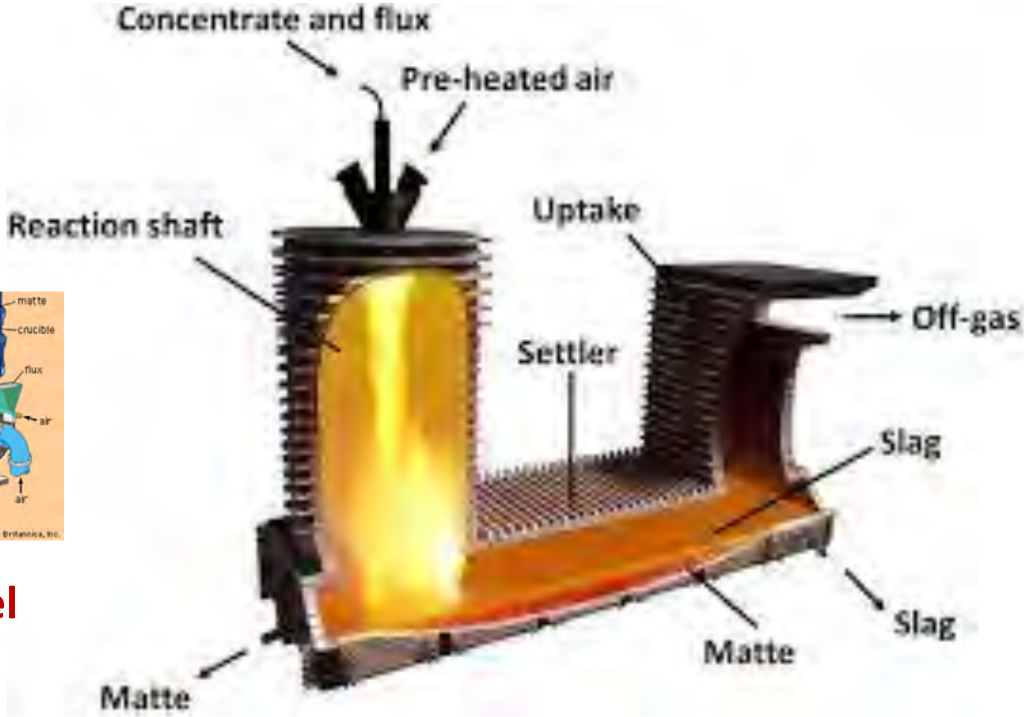
Large autoclave for Ni laterite leaching

Nickel production processes - 3

Nickel from nickel sulphide concentrates - 25% of primary Ni



Converters for nickel matte converting

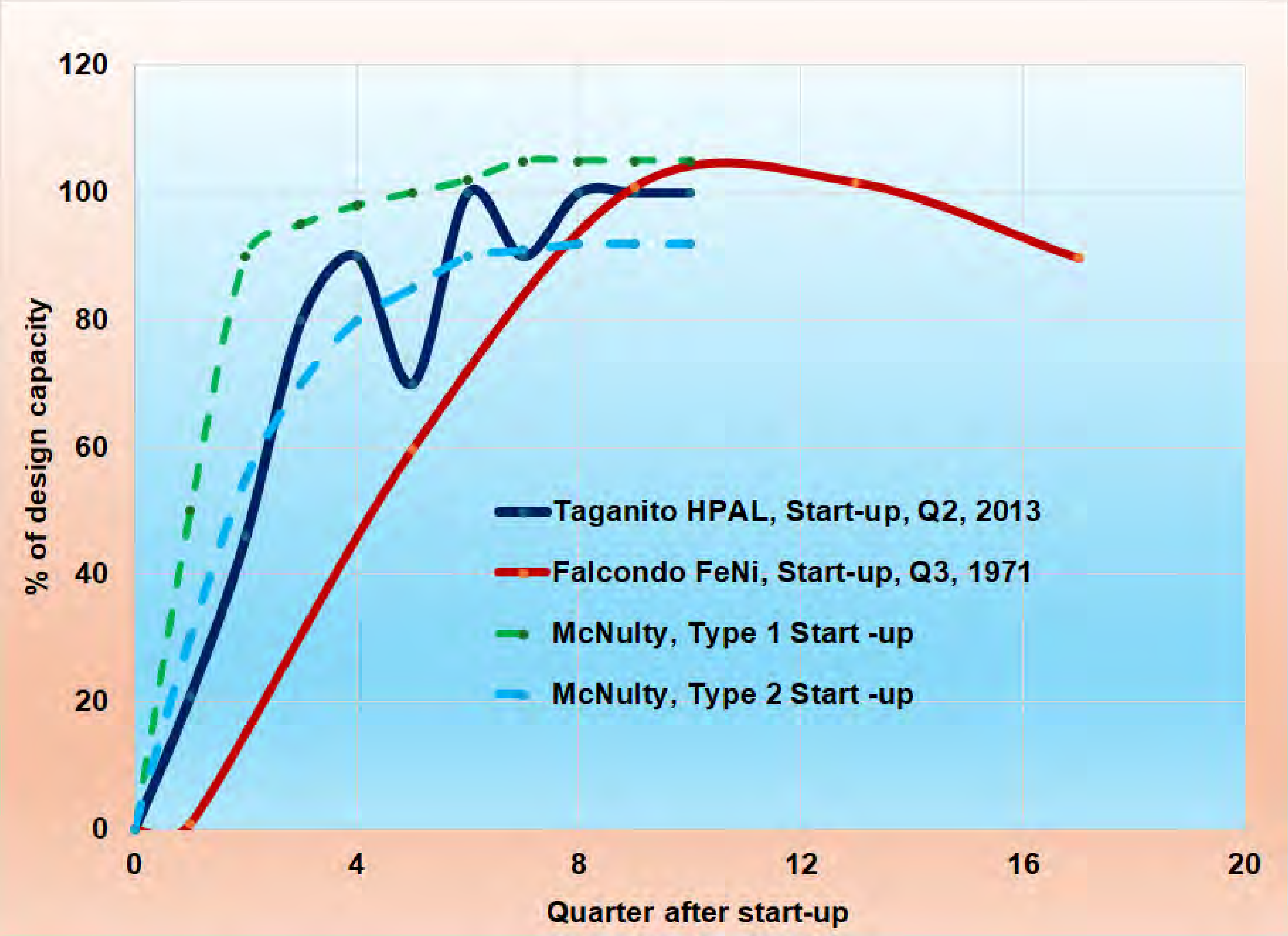


Flash furnace for smelting nickel sulphide concentrates

The electric furnace is also used for smelting nickel sulphide concentrates

Well piloted new Ni plants can have a good start-up

Evidence: Falcondo - red curve pyro (1970s) and Taganito – dark blue curve hydro HPAL(2013)



Good start-up = follow rules for metallurgical plant development and project implementation

Source: P.J. Mackey, 2023

New technology (for lower CO_2)

3. New developments in iron and steel technology (for lower CO_2)

New developments in iron and steel technology.

Mackey Technology Inc.

Important to understand that technologies developed for iron & steel have generally been adapted for nickel (along with specialized Ni refining processes)

In other words, emerging developments that we see today for iron and steel, will eventually be adapted for nickel

Summary- production and CO_2 data- iron and steel and non-ferrous metals

Metal	CO_2 emissions, % of global	CO_2 emissions, t CO_2/t metal
Iron and steel (1870 mill t, 2020)	9.7	~ 2
Four non-ferrous metals (Cu, Zn, Ni & Li) (102 mill t, 2020)	0.6	~ 5.6

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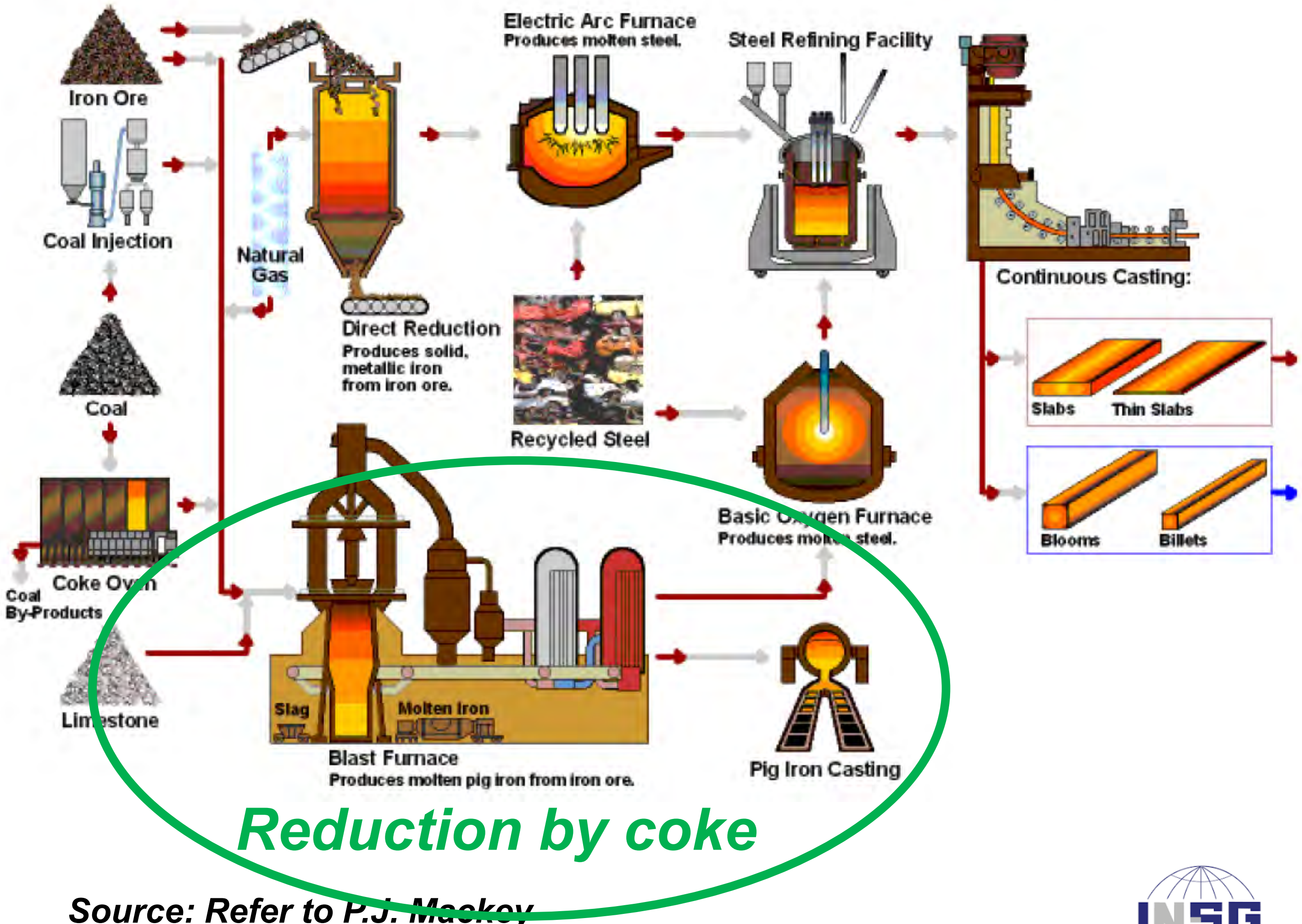
About 70% of world steel is produced via the iron blast furnace (Balance of steel by scrap and Direct Reduced Iron (DRI) (The iron blast furnace is a major source of CO_2 emissions)



The iron blast furnace dates back centuries. Early laterite smelting utilized the blast furnace (Insert below- Closed BFs- Bethlehem, USA, now outdoor museum)

It is recognised that the technology needs to change if CO_2 emissions are to be reduced

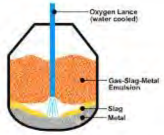
We will look at these new and emerging technologies

Source: Refer to P.J. Mackey

How long does it take to develop and commercialize a successful new metallurgical technology

Steps of: Lab testing-piloting-commercialization

Let us take a look at how processes in use today started – what level of piloting and scale-up was successful (simplified review)



Source: AKI Steelworks website & article titled: "The Basic Oxygen Steel Making Processes".

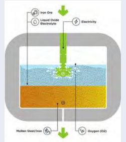
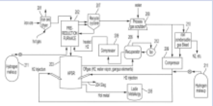
Data are given for the Basic Oxygen Furnace (BOF) for steel, the Midrex Process for Direct Reduced Iron and later, the Falcondo FeNi process

2 t Pilot BOF

Summary- Development Time and Scale-up Factors (BOF, Midrex – iron/steel and Falcondo FeNI processes)

Process	Development Time, years	Scale-up factor. Pilot to commercial	
		Shaft furnace	Furnace
BOF	13	-	36 (in 3 stages)
Midrex	15	98	-
Falcondo (FeNi)	16	18	34 (Electric furnace

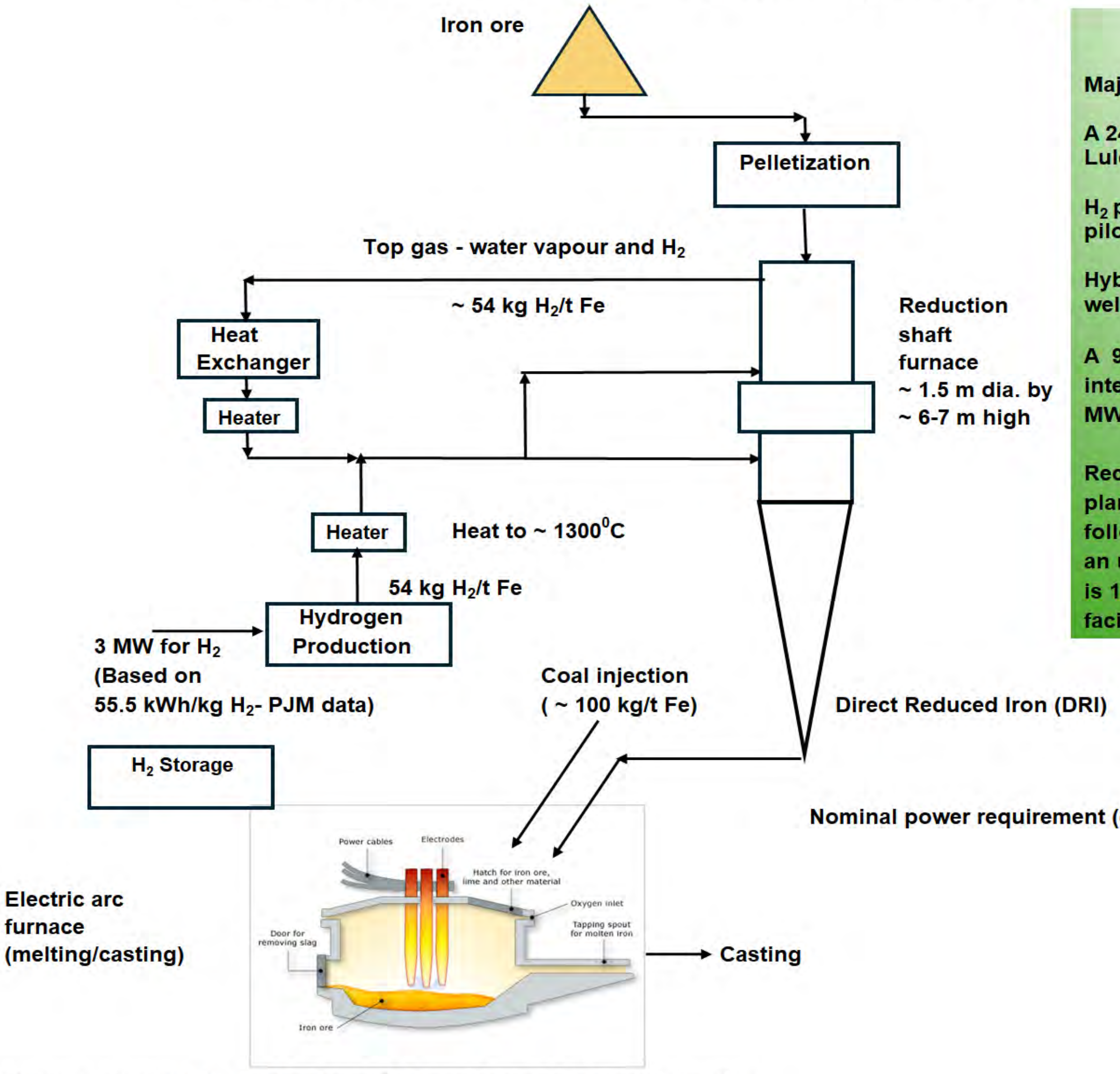
8 selected low-CO_2 iron-making technologies under development in 2024

No	Process/Developer	Country	Current Status
1	H_2/DRI (Midrex, (Energiron, Greeniron) 	USA/ Germany/Sweden	300 t/d demo plant, ~4 m shaft furnace. Is a pilot for H2 Green Steel, Boden, 2.5 mill t/yr
2*	H_2/DRI (Hybrit) 	Sweden	24 t/d pilot plant (1,000 kg/h) with ~2 m shaft furnace, and accompanying electric furnace
3	H_2/DRI (MS&T)	USA/Intnl.	0.2 t/d lab/pilot scale (8 kg/h), ~0.25 m unit
4*	Hi Temp Electrolytic (Boston Metals) 	USA	3 t/d pilot plant operating at 200 kA (3 to 4 individual cells)
5	Lo Temp Electrolytic (McGill/Mittal)	Canada/India	Small-scale laboratory experiments currently underway
6	H_2/DRI (Calix) "Zesty" 	Australia	Testing at a small pilot scale now underway - 60 kg/h (a 0.2 m electrically-heated shaft)
7*	H_2 reduction (Breakthrough Energy). H_2 version of coal technologies 	USA	Bath smelting process using injected H_2 for reduction of iron ore. A 2 MW pre-pilot unit is under construction near Houston, Texas.
8	CO recycling to BF (Univ. Birmingham)	UK	Theoretical study- Uses a perovskite crystal structure to convert CO_2 to CO for the BF

* *Described in following slides*

Source: Refer P.J. Mackey

Hybrit Process (Sweden)- Schematic Process Flowsheet (2024)



Nominal power requirement (excluding EF): 3.4 to 4 MWh/t iron

Major development in Sweden past ~8 years

A 24 t Fe/day, 1.5-2 m dia. shaft pilot plant at Lulea, Sweden commenced 2021 (~8,000 t/yr)

H_2 produced by electrolysis (hydro power) - for pilot plant ~3 MW for H_2

Hybrit has allowed 4-5 years for piloting, it may well take longer

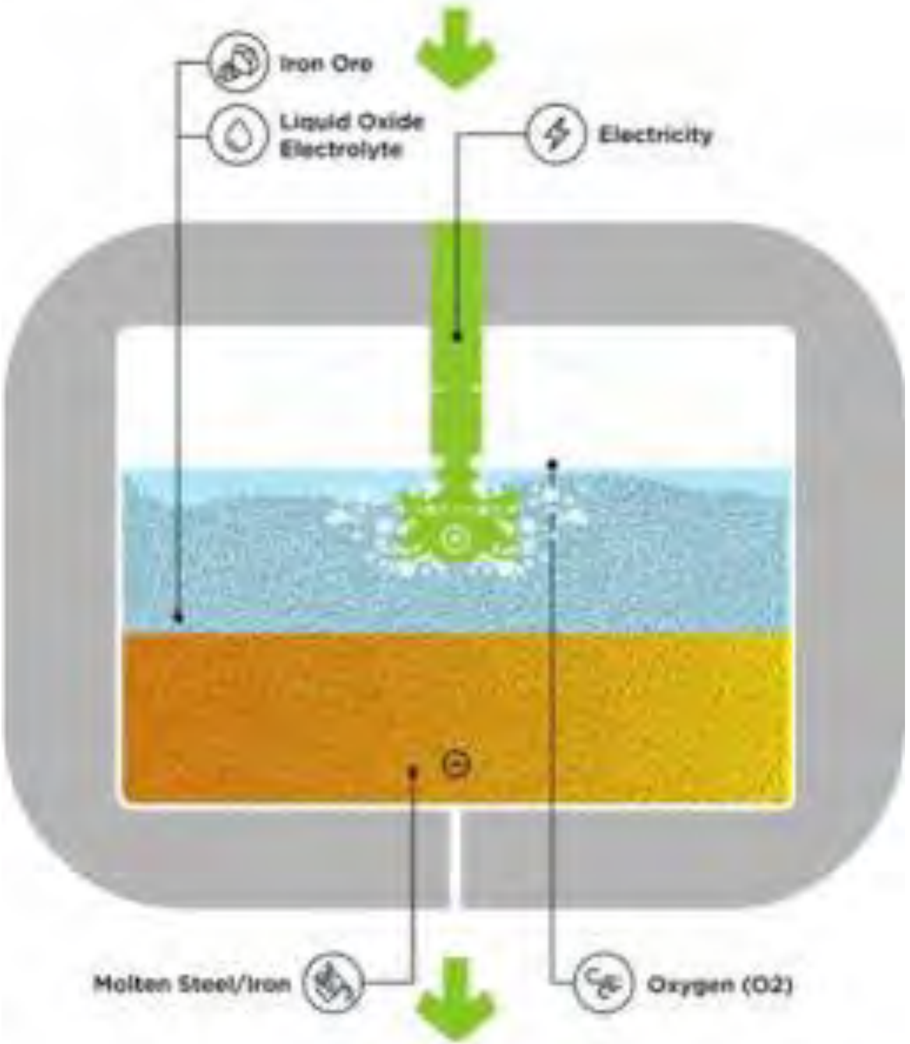
A 900 t/d demonstration plant was originally intended following piloting (~300,000 t/yr, 120 MW for H_2).

Recent announcements suggest a commercial plant rated at 1.35 million t Fe/hr may be built following completion of piloting (this involves an unusually high scale-up factor of 170 - this is 1.7 times that of the first commercial Midrex facility)

Diagram prepared by P.J.Mackey 2024 based on published information

Hybrit: Hydrogen Breakthrough Ironmaking Technology

4. Electrolytic Production of Iron- Boston Metals



Direct production of iron from iron ore by molten salt electrolysis (akin to the Al production in the Hall-Herault cell)

Pilot plant was scaled-up from initial laboratory tests carried out at MIT using inert Cr-Fe electrodes operating at ~5 V.

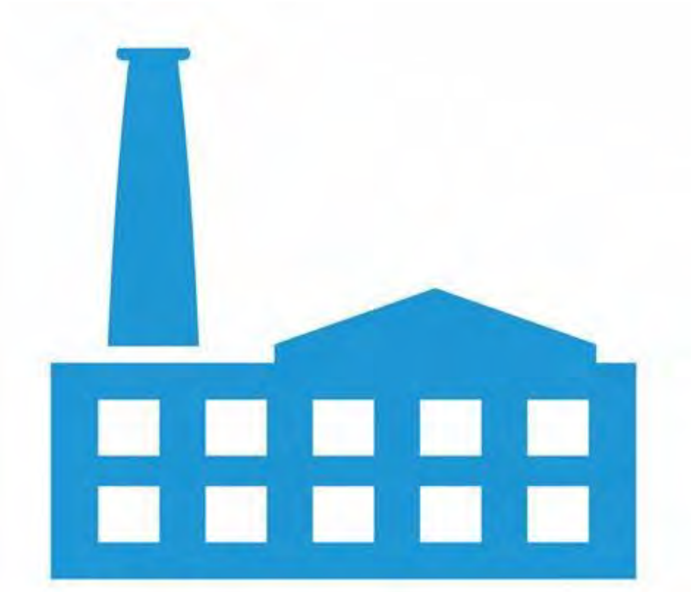
Current plans include a pilot or demonstration plant rated at 3 t Fe/day and operating at ~200 kA. Plans beyond this not published

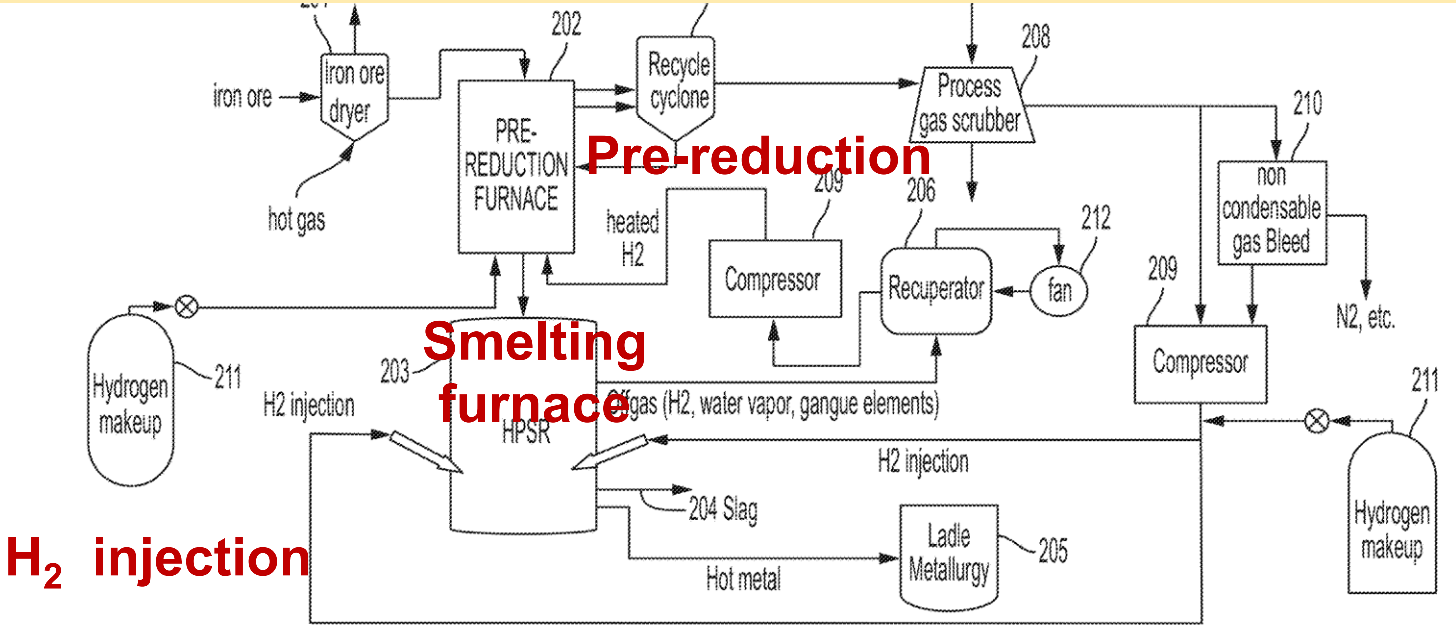
Nominal power requirement: 3.5 to 4 MWh/t iron

Ref. Boston Metals, Allanore et al, 2013, Wang and Sadoway, 2011

Reduction of molten iron ore using H_2

For more than 80 years, the reduction of solid iron ore with H_2 has been tested and piloted- but not commercialized (Past unsuccessful processes include: H-iron, NU-Iron, Gas-solid ironmaking). Bath smelting with coal/O_2 also tested.
A new development is the use of H_2 instead of coal in a bath smelting furnace (below). A 1-2 MW pilot furnace (~200-400 kg/hr) is presently under construction, Texas, USA





Flowsheet taken from a recent US patent application

If successful, the concept could be adapted to process Ni laterite using H_2

Source: US patent application, US2024/00264476 A1 (2024)

Potential new technologies for nickel

Laterites

1. H_2 reduction using a shaft furnace (the Ni equivalent of the direct reduction of iron ore by H_2, except the degree of reduction is far less)

2. Bath smelting with coal and tonnage oxygen (possibly eventually by H_2)

Sulphides

1. H_2 reduction of sulphides

The next set of slides summarize potential new technologies for nickel, followed by a timeline in nickel process development (Falcondo process)

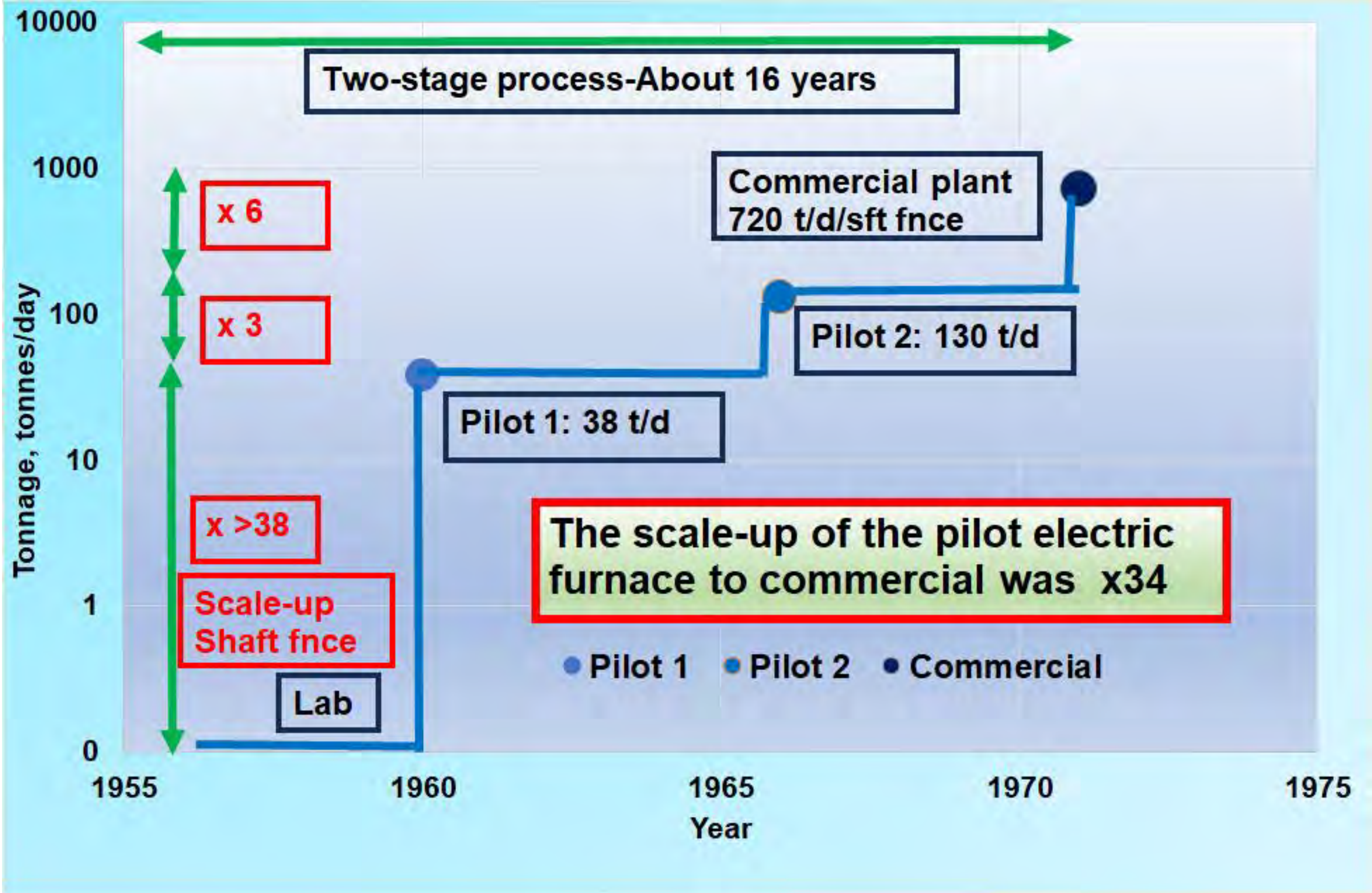
Potential new technologies for nickel - Paths to decarbonization

Item		% reduction in CO_2
Nickel Laterites (75% of Ni production today)		
Mine	Electric (or H_2) vehicles	6%
Process	Upgrade RKEF Technology (partial use electricity, use of bio-mass etc.) Heat recovery from molten tapped slag	Up to 20-30% To be determined
	H_2 Shaft furnace (P. Mackey – small-scale lab/pilot tests in 2024) Coal-O_2 bath smelting (Commenced in Indonesia- 2022 (Ni kilns will adapt new ideas tested for cement kilns)	63-76% 20-30% (Relative to coal-fired power)
Nickel Sulphides (25% of Ni production today)		
Mine	Electric (or H_2) vehicles	8%
Mill	Ore sorting, improved comminution	10%+
Process	H_2 reduction of sulphides P. Mackey-lab testing in 2024-25)	To be determined
	Solid state conversion to FeNi	To be determined

Source: P.J. Mackey, 2024

Development time - Falcondo- FeNi (2-stages)-1957-1973

The Falcondo Ni process was developed by Falconbridge, Canada in the 1960s at about the same time that the Midrex shaft furnace process was developed for iron ore (Independent developments)

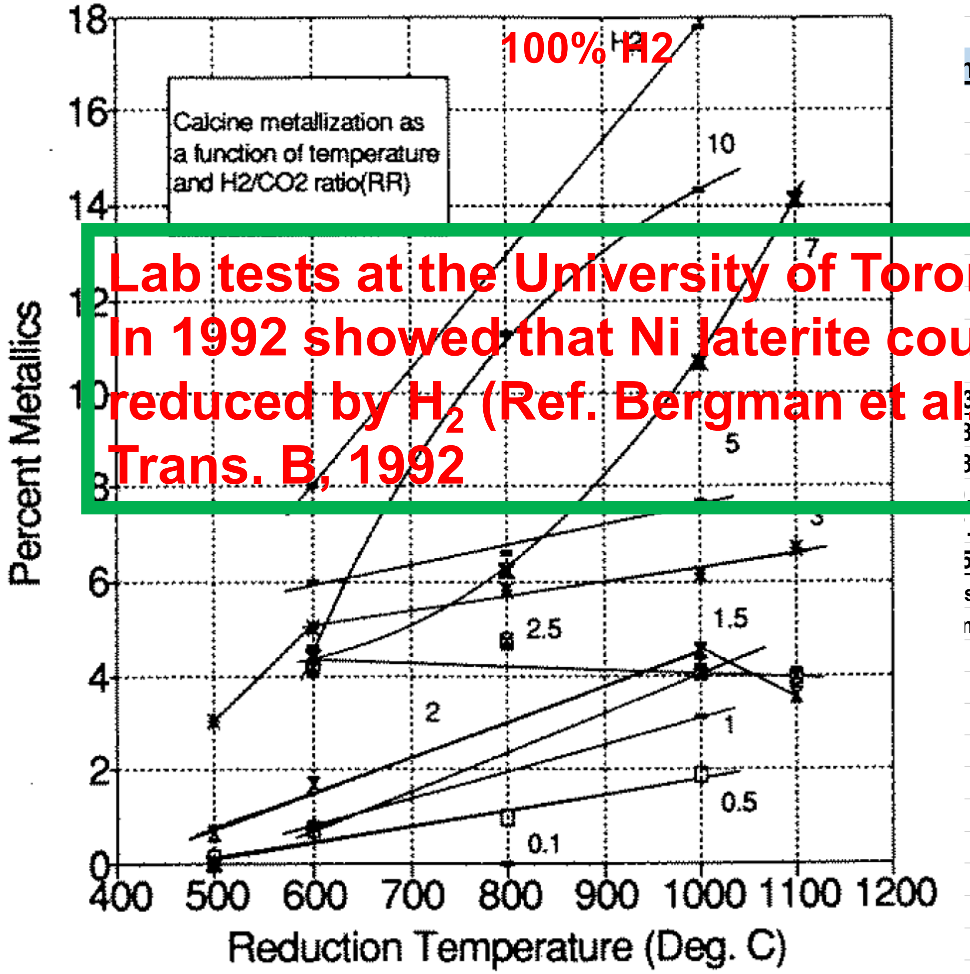


Source: P.J. Mackey, 2024

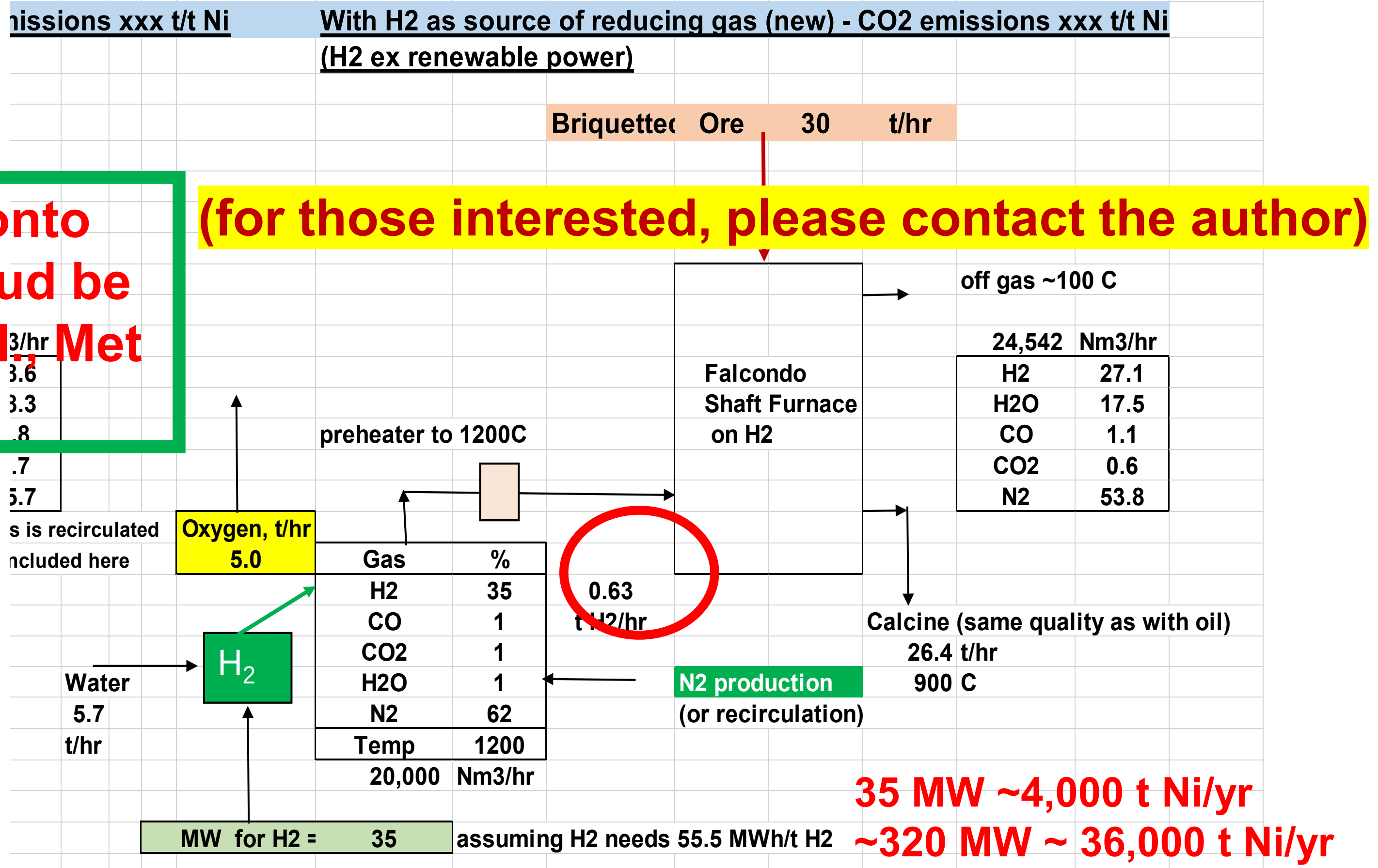
H_2 Shaft furnace for Ni - Potential new technology for nickel laterite
(Using a shaft furnace - much like Falcondo)

Falcondo nickel laterite shaft furnace process- using naththa as at present and also based on H2 (schematic flowsheet, draft only)

(Note, this is for 30 t/hr ore, equal to present capacity of one Falcondo shaft furnace, roughly 3800 t/yr Ni (ore 1.7% Ni, 95% rec, 330 d/yr)



Lab tests at the University of Toronto In 1992 showed that Ni laterite coud be reduced by H_2 (Ref. Bergman et al., Met Trans. B, 1992



(for those interested, please contact the author)

35 MW ~4,000 t Ni/yr
~320 MW ~ 36,000 t Ni/yr
Two EFs ~ 140 MW

inlet gas, kg/kg calcine	0.67	inlet gas, Nm3/kg calcine	0.76
		inlet gas, kg/kg calcine	0.65
(assuming 1.04 gm/Lit, refer Falcondo calc sheet)		(assuming 0.86 gm/Lit, refer Falcondo calc sheet)	

Note: The above projections for CO_2 reduction are based on modelling. Testwork and piloting will be required to develop actual process design criteria.

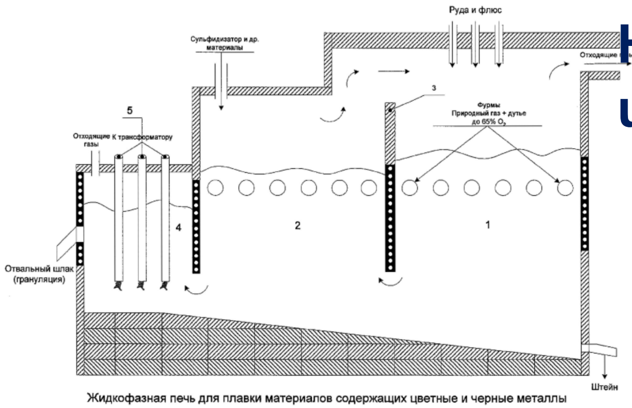
 Source: P.J. Mackey, 2024

Recent press release- Indonesia Coal/O_2 Ni bath smelting process

“Indonesia Hengsheng oxygen-enrich side-blown Ni project was successfully put into operation”,

20 September 2023

Reportedly 3-4 furnaces now in operation (10 kt Ni/ each furnace), 2 by CNGR in Morowali Park (started Oct. 2022), and 1 to 2 operated by Hengsheng, started 2023 as noted above. Furnace adapted from those used for copper, Ni process piloted in China



Representation of furnace (Russian Patent)

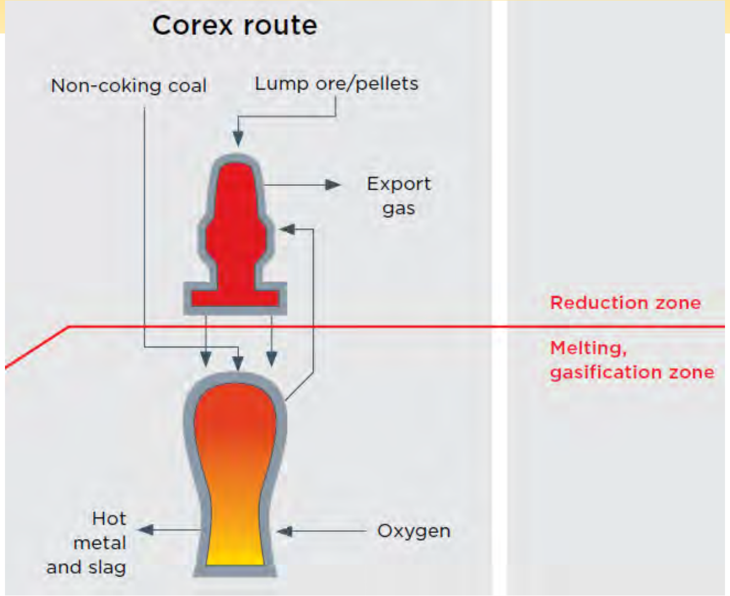
Photos: Thanks to J. Chuanyu

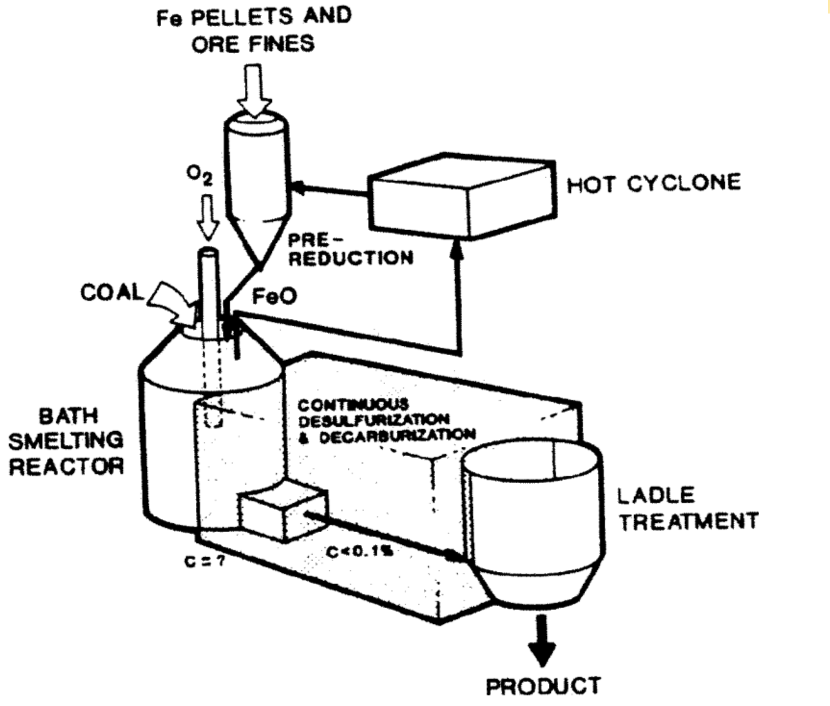
Matte tapping

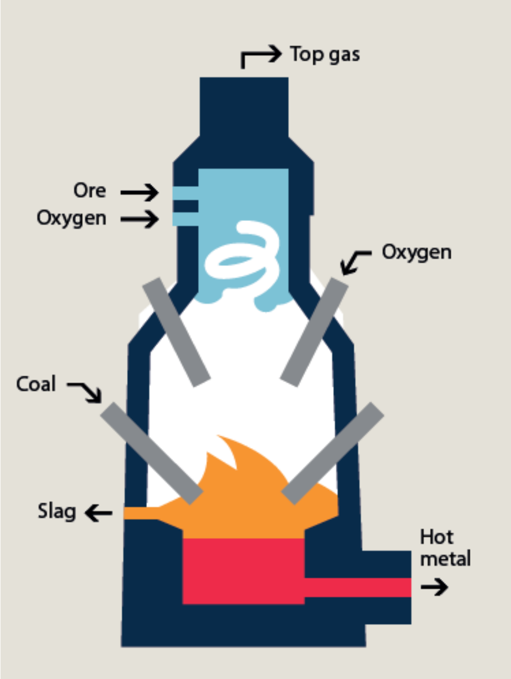
Cast matte ingots

Bath smelting (coal and O_2) has been studied for iron-making for decades
Schematic diagrams of three Fe bath smelting processes piloted

The approach is now been adapted in Indonesia for nickel laterites







Corex - Austria, 1970s

(Several commercial plants installed, most closed by now)

AIST- USA 1990s

(Tested on a 5 t/hr pilot plant, not commercialised)

Hisana-Europe 2000s

(Originally Hismelt in Australia, starting 1970s, commercial plant presently in China)

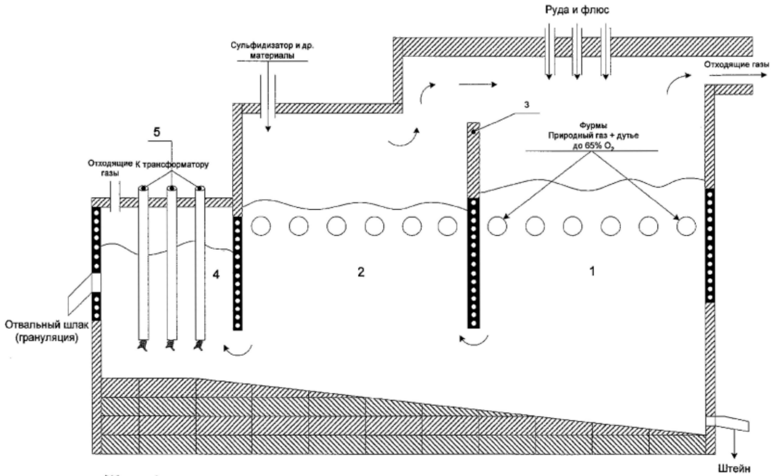
Source: Refer to P.J. Mackey, 2024

Bath smelting of nickel laterite with coal and oxygen

(With acknowledgement to Hengsheng New Energy Materials, Indonesia)

Vanyukov furnace arrangement used by Hengsheng

Potential Alternative arrangement (by Author)



Жидкофазная печь для плавки материалов содержащих цветные и черные металлы

Hengsheng plant, Indonesia

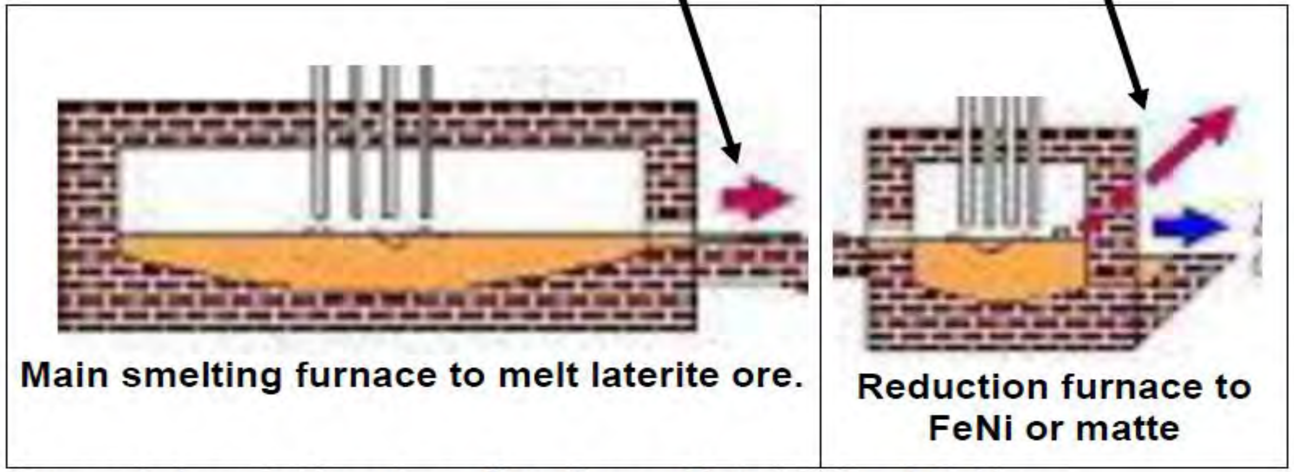
Schematic arrangement of bath smelting furnaces for nickel laterite (Rectangular or circular furnace, top lancing)

Inputs - Main furnace: partly dried ore, coal and O_2

Inputs - Reduction furnace: Coal, O_2-pyrite optional

Products: Matte or FeNi & slag

Molten ore flow



Source: Indonesia Hengsheng New Energy Materials Co., Ltd, News report, Sept 2023. Conceptual arrangement only

Source: P.J. Mackey, 2021

Bath smelting of nickel laterite with coal and oxygen
CO_2 emissions- RKEF and Bath Smelting compared- Very approx. only

	RKEF- Power from coal				Bath smelting (O_2-coal)	
	t coal/t Ni	t CO_2/t Ni			t coal/t N	t CO_2/t Ni
Mining (Diesel)	0.30	0.8			0.3	0.8
Coal for dryer	2.9	7.8			2.9	7.8
Coal for kiln (incl. reduction)	8.6	23.3			0.0	0.0
Power- Electric furnace (coal equiv.)	12.9	34.8		Bath smelting coal	10.6	28.5
Power- Other (coal equiv.)	2.6	7.0		Power (Other) (coal equiv.)	2.6	7.0
Power for O_2	0.0	0.0		Power for O_2 (coal equiv.)	2.1	5.6
<u>Total</u>	**<u>27.0</u>**	**<u>72.9</u>**			**<u>18.1</u>**	**<u>49.7</u>**
	(With hydro power ~36.1)				(Range considered 44 to 54)	
					Reduction relative to coal-fired	
					power- 20-30% (approx.)	

Ideas for lowering CO_2 emissions in ferronickel production

(CO_2 emissions as t CO_2/t Ni, power data assuming 30,000 t Ni/yr, ore 1.7% Ni)

Plant area	RKEF process Typical present	RKEF process Part use of H2 (50% of coal by H_2)	MFSF Process (new) H2 used as reductant in shaft furnace
Mining	0.8	13 MW	13 MW
Dryer	7.8	3.9	7.8
Kiln Burner	12.0	6.0	-
Kiln Reductant	11.3	11.3	-
Sub-total	31.9	21.2	7.8

Electric Furnace

Plant area	RKEF process				MFSF Process (new)	
	HYDRO	COAL	HYDRO	COAL	HYDRO	COAL
Electric furnace	0	32	0	16	0	16
Total, t CO_2/t Ni	31.9	63.9	21.2	37.2	7.8	23.8
% Reduction in CO_2	0	0	34	42	76	63
H_2 required, t H_2/t Ni				1.03		1.31
Renewable power, MW						
For H_2				217		298
For EF				70		70
Total, MW				287		368

Note: 1. RKEF: Rotary kiln-electric furnace, MFSF: Modified Falcondo shaft furnace;
2.Data approximate; 3. Power to pre-heat H_2 in MFSF included; 3. CO_2 does not include any additional fossil fuel related to use of H_2.

Stop press (Electrically heated kilns):

Pilot tests are now underway in Belgium and Norway of the use of an electrically-heated kiln in cement manufacture.

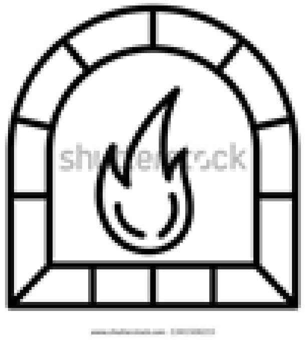
This may potentially be applied to a Ni laterite kiln

A large kiln – say for ~ 25,000 t Ni/yr - would require ~ 120 MW power- this will require a lot of development work

Note: The above projections for CO_2 reduction are based on modelling. Testwork and piloting will be required to develop actual process design criteria.

Source: P.J. Mackey, 2024

New technology- nickel sulphide concentrate - Reduction by H_2



Laboratory tests reported in the 1970s showed H_2 reduced the sulphides to metal at moderate temperatures with CaS formed from added lime.

The CaS is later converted to $CaCO_3$ and elemental S for use in the chemical industry

Reactions confirmed - thermochemical calculations (by author)

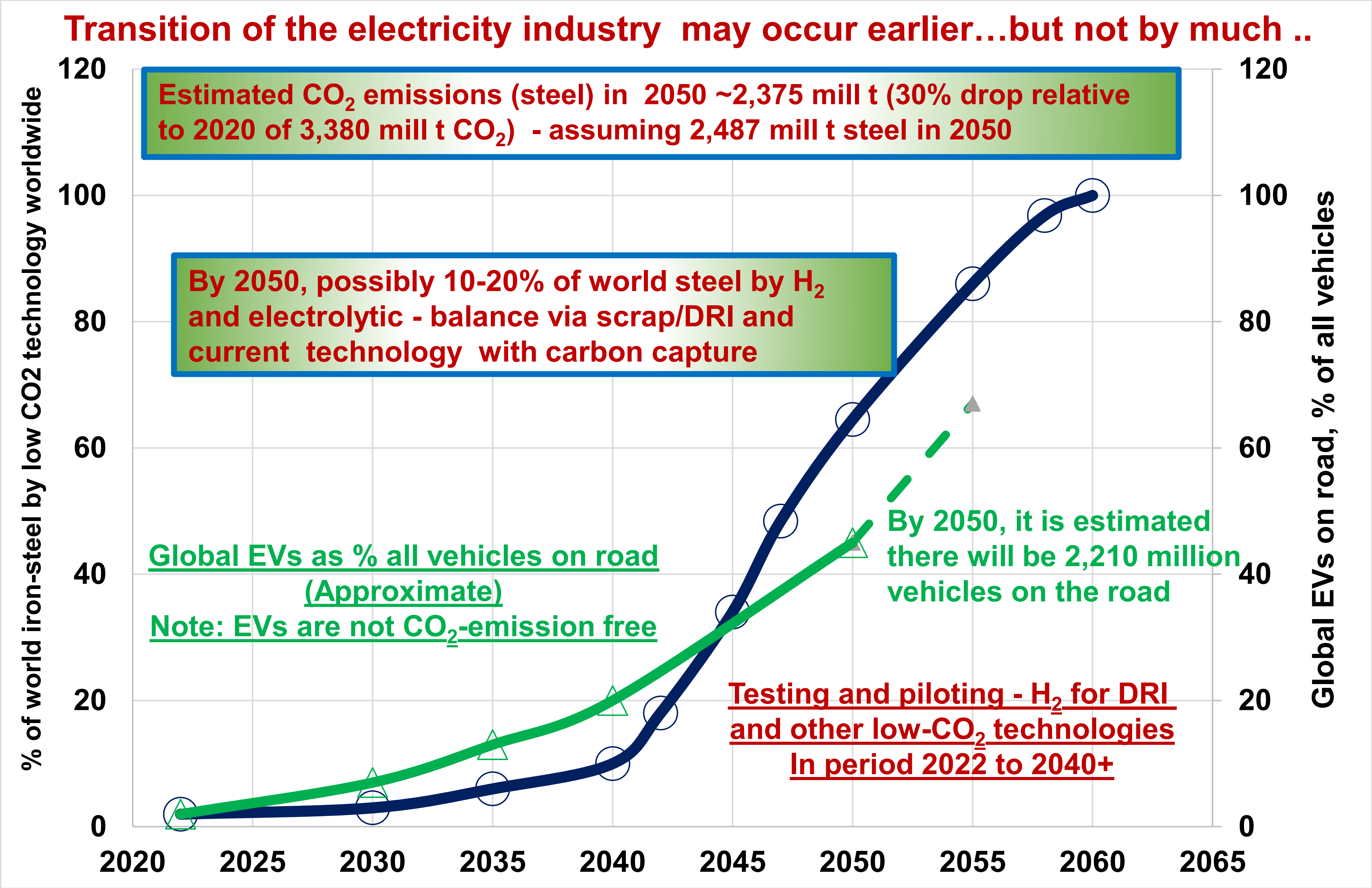
Avoids SO_2 /acid production, energy requirement to be reviewed

Candidate for new laboratory testing in 2024-2025 to verify technical feasibility (for those interested, please contact the author)

Source: P.J. Mackey, 2024

Projected rate of world-wide take-up of low carbon technology in iron and steelmaking

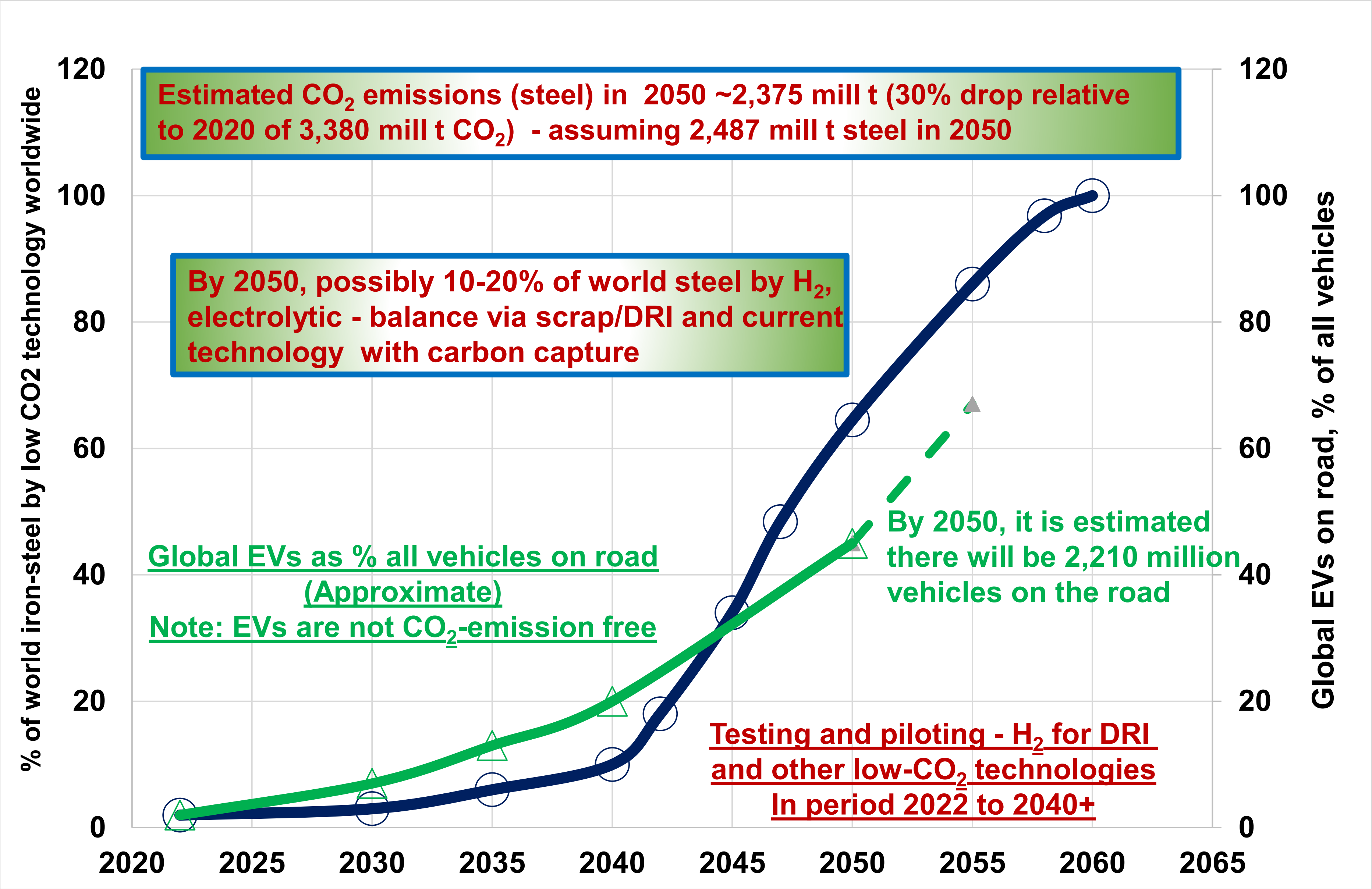
(and global EV as % of all vehicles on road)



Note: Low carbon steel is <200 kg CO_2/t steel

P.J. Mackey © 2024 Source: P.J. Mackey, 2022

Example of possible rate of world-wide take-up of zero/low carbon technology in iron and steel making (and global EV as % of all vehicles on road)



Note: Low carbon steel is <200 kg CO_2/t steel

P.J. Mackey © 2024

Source: P.J. Mackey, 2022

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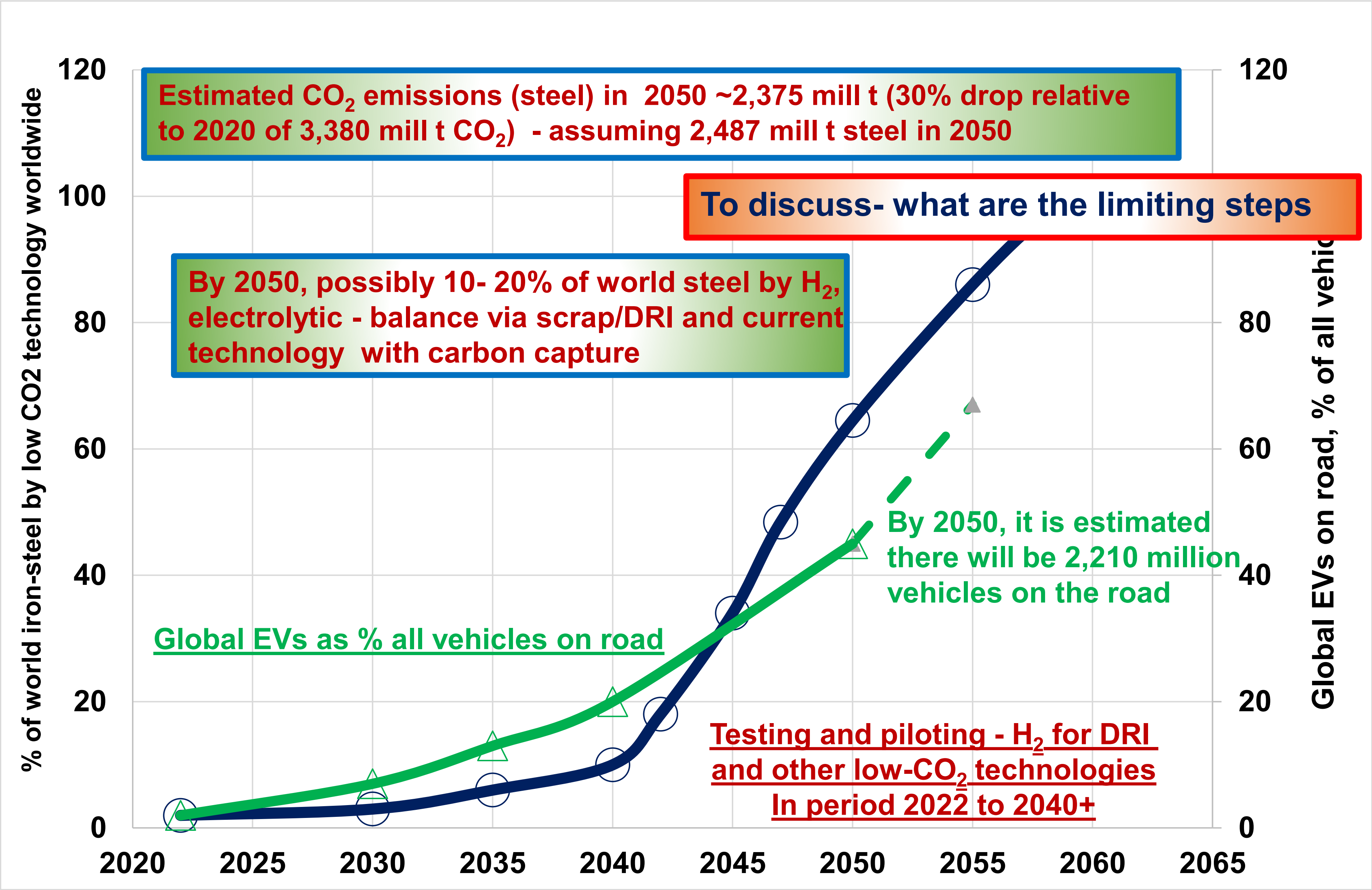
Example of possible rate of world-wide take-up of zero/low carbon technology in iron and steel making (and global EV as % of all vehicles on road)

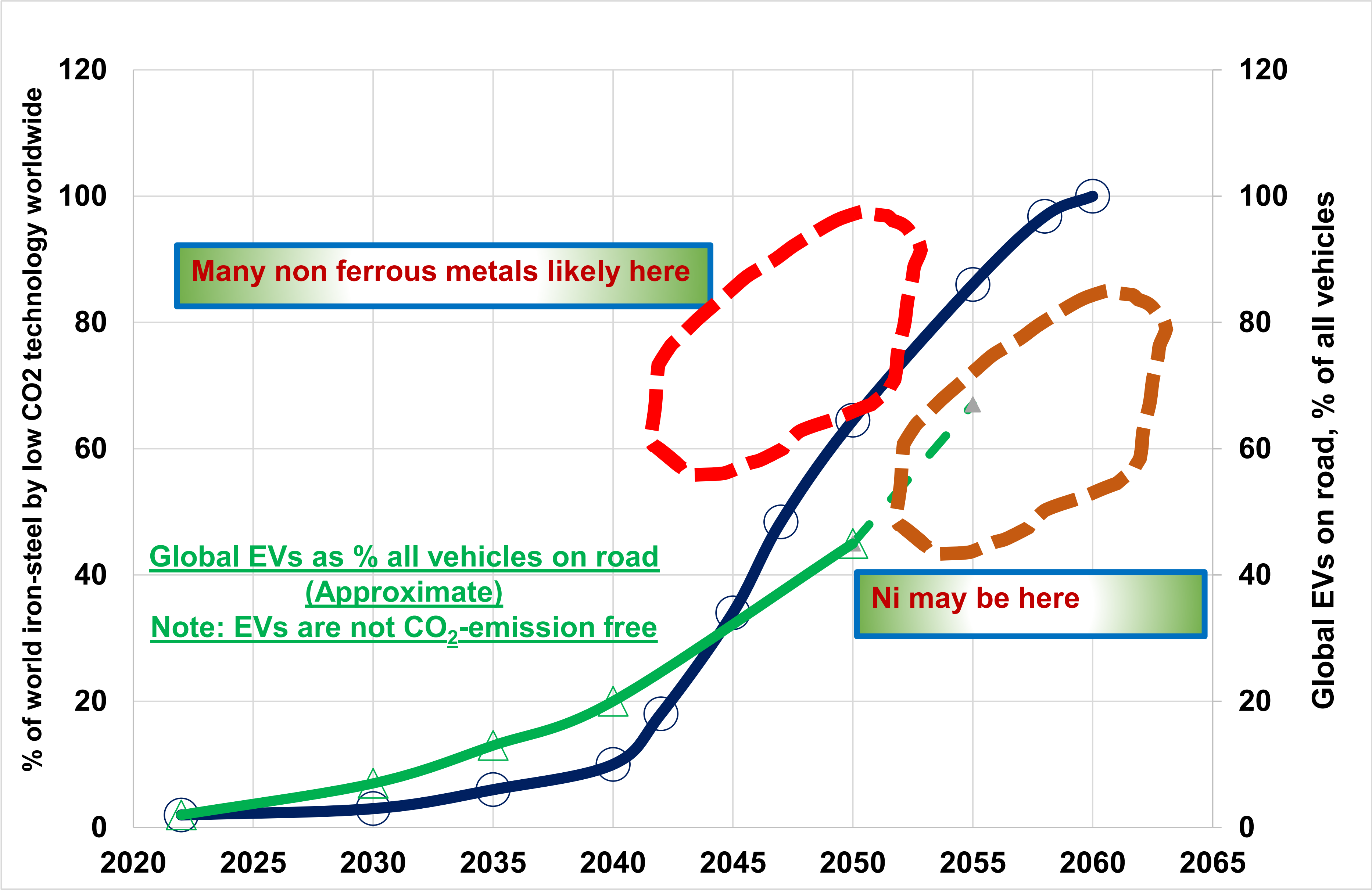


Note: Low carbon steel is <200 kg CO_2/t steel

P.J. Mackey © 2024

Source: P.J. Mackey, 2022

Example of possible rate of world-wide take-up of zero/low carbon technology in iron and steel making & Non ferrous metals (and global EV as % of all vehicles on road)



Note: Low carbon steel is <200 kg CO_2/t steel

Source: P.J. Mackey, 2022

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Is a significant technological transition in nickel technology around the corner?

- No – not immediately
- Present technology with enhancements will continue – at least for the next decade or more
- But work currently under way in iron and steel (H_2 reduction- in a shaft furnace or H_2 bath smelting), if successful, will start to spread to nickel within about a decade or two.

Concluding Comments - 1

Present technologies in use for Ni will continue for the next decade - but a wide range of incremental improvements will continue: automation, use of bio-mass, heat recovery from slag, greater use of "green" electricity etc. Whether we will large numbers of new HPALs is debateable. More O2/coal plants are expected

A large number of new developments are in progress for the low CO_2 production of iron and steel, especially the use of H_2; these concepts will slowly spread to Ni

Concluding Comments - 2

As in the past, technology developments in the iron and steel industry will likely be adapted for Ni- probably starting over the next decade

The energy transition (& EVs) and decarbonization of the metal industry, including Ni, will take many decades

Obrigado
Thank You
Merci
Gracias
Questions and Discussion

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Appendix
Additional slides

Appendix slides to be added later