The Decarbonisation Journey of the Aluminium Industry
Opportunities and Challenges to Achieve Net-Zero

Dr. Martin Iffert

MARTIN IFFERT CONSULTING GmbH

EP ENERGY POOL GmbH

Presented by: Dr. Martin Iffert

Martin's Bio

Dr. Martin Iffert

Master Electrical Eng.
(1993 RWTH Aachen)
PhD Chemical Eng.
(2007 UNSW Sydney)
Executive MBA
(2009 IMD Lausanne)

The Networker for the Industry


French President
Emmanuel Macron


German Chancellor
Olaf Scholz

Dr. Martin Iffert's Biography

- *30 years experience in Aluminium Smelting*
- *Former CEO of TRIMET and PdG TRIMET France*
- *Former President of German Association WVM*
- *Advisor for Policy Makers*
- *Advocate for Flexibility and Sustainability*
- *Founder of the Virtual Battery Concept*

MARTIN IFFERT CONSULTING GmbH

- Boutique Consulting Firm for Aluminium and Energy-Intensive Industries
- Operation, Leadership, Energy Politics, M&A

EP ENERGY POOL GmbH

- Flexibilization of Energy-Intensive Industries
- Centre of Excellence for Aluminium Smelting

Decarbonization…

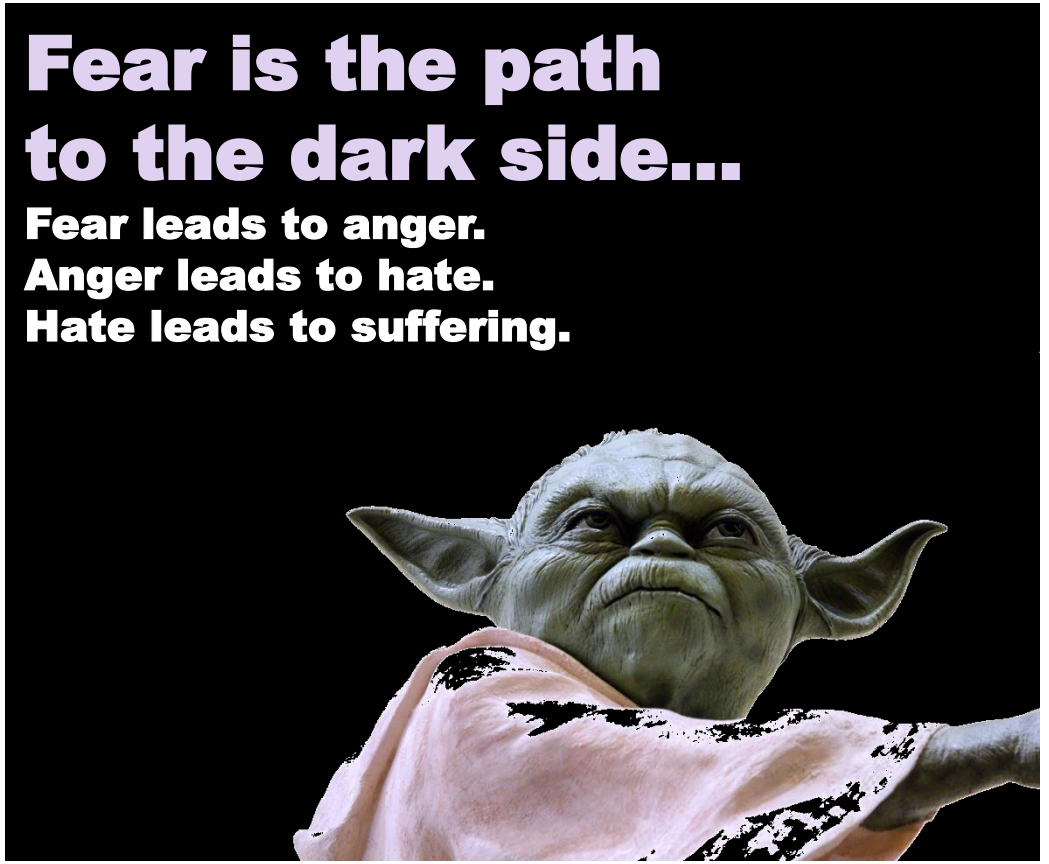
Playing not to Lose

…is a RISK

Playing to Win

…is an OPPORTUNITY

Contents

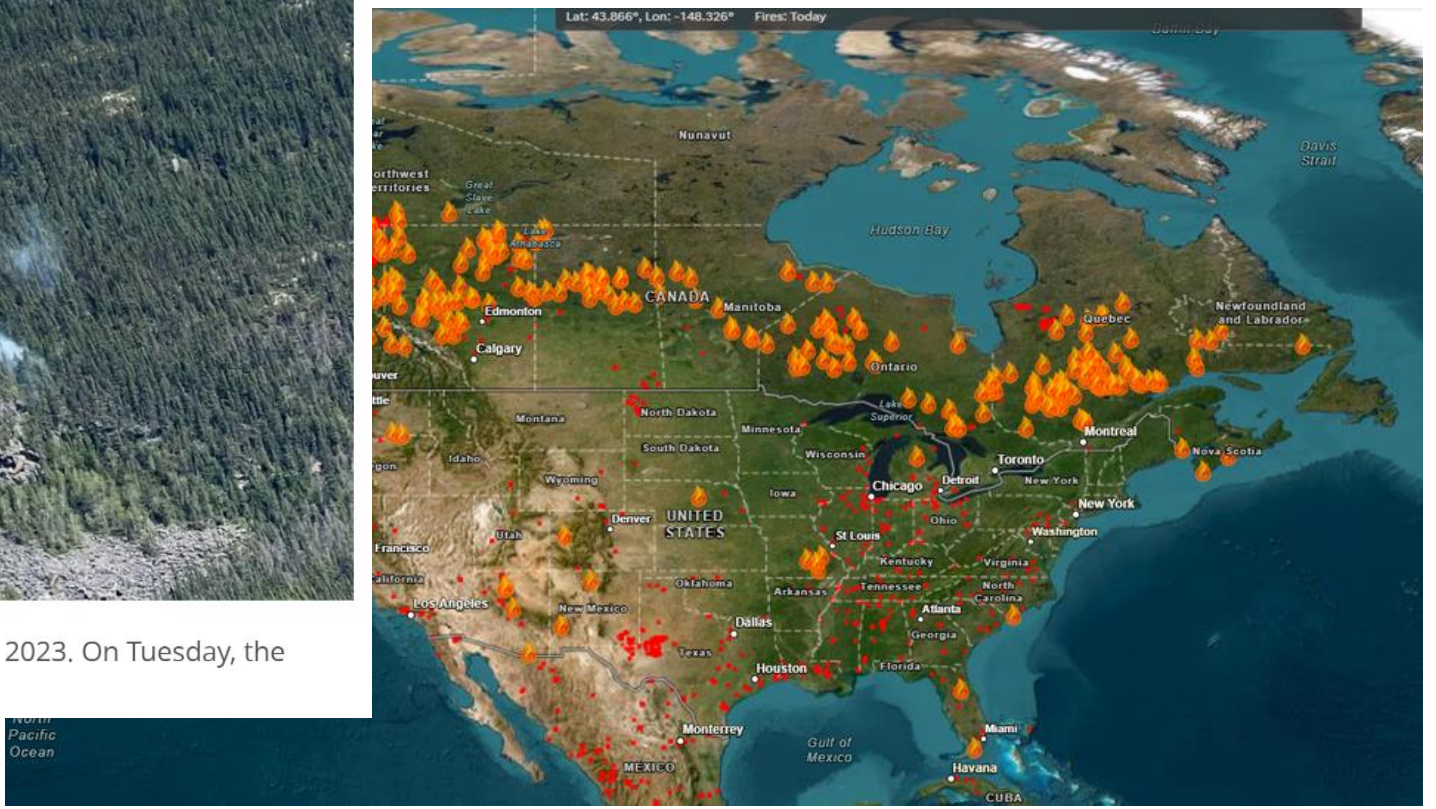


The World on Fire

Public View of Industry has Changed

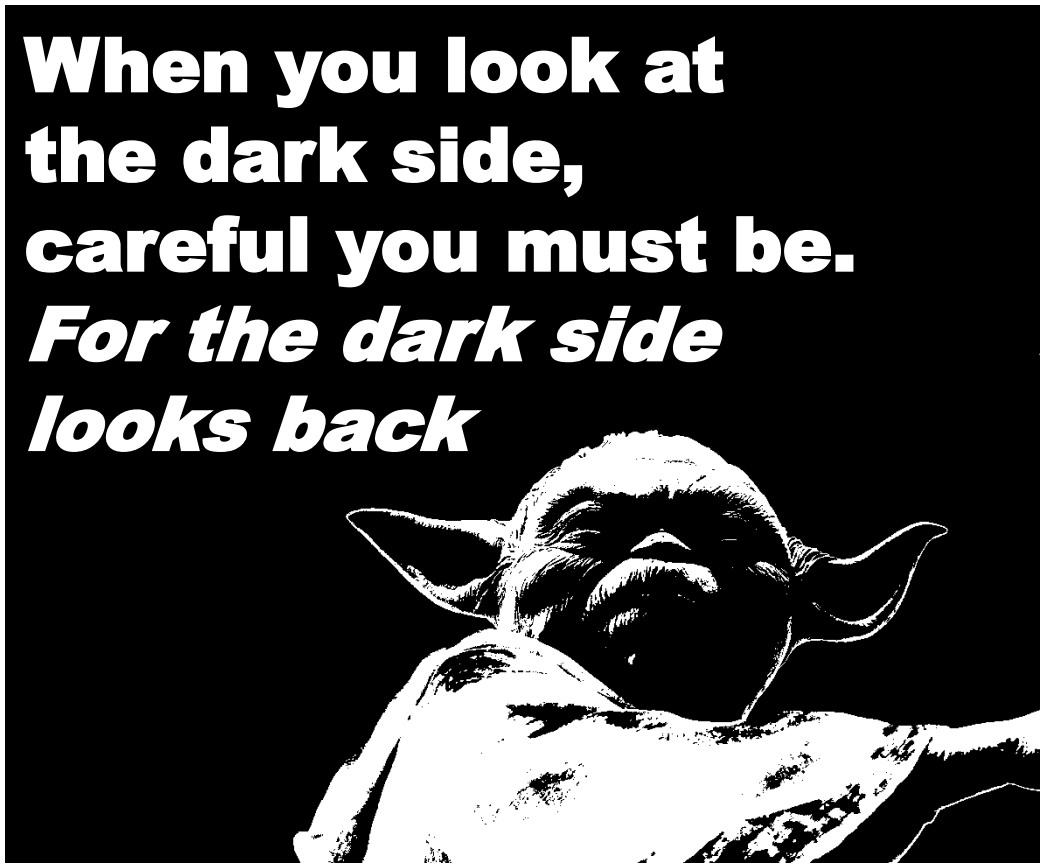
Wild Fire Canada - Quebec

This photo shows an overhead view of forest fires in the Sept-Îles area from June 2, 2023. On Tuesday, the evacuation order for the city was lifted. (Submitted by André Michel)



Public View of Industry has Changed

What is your License to Operate?



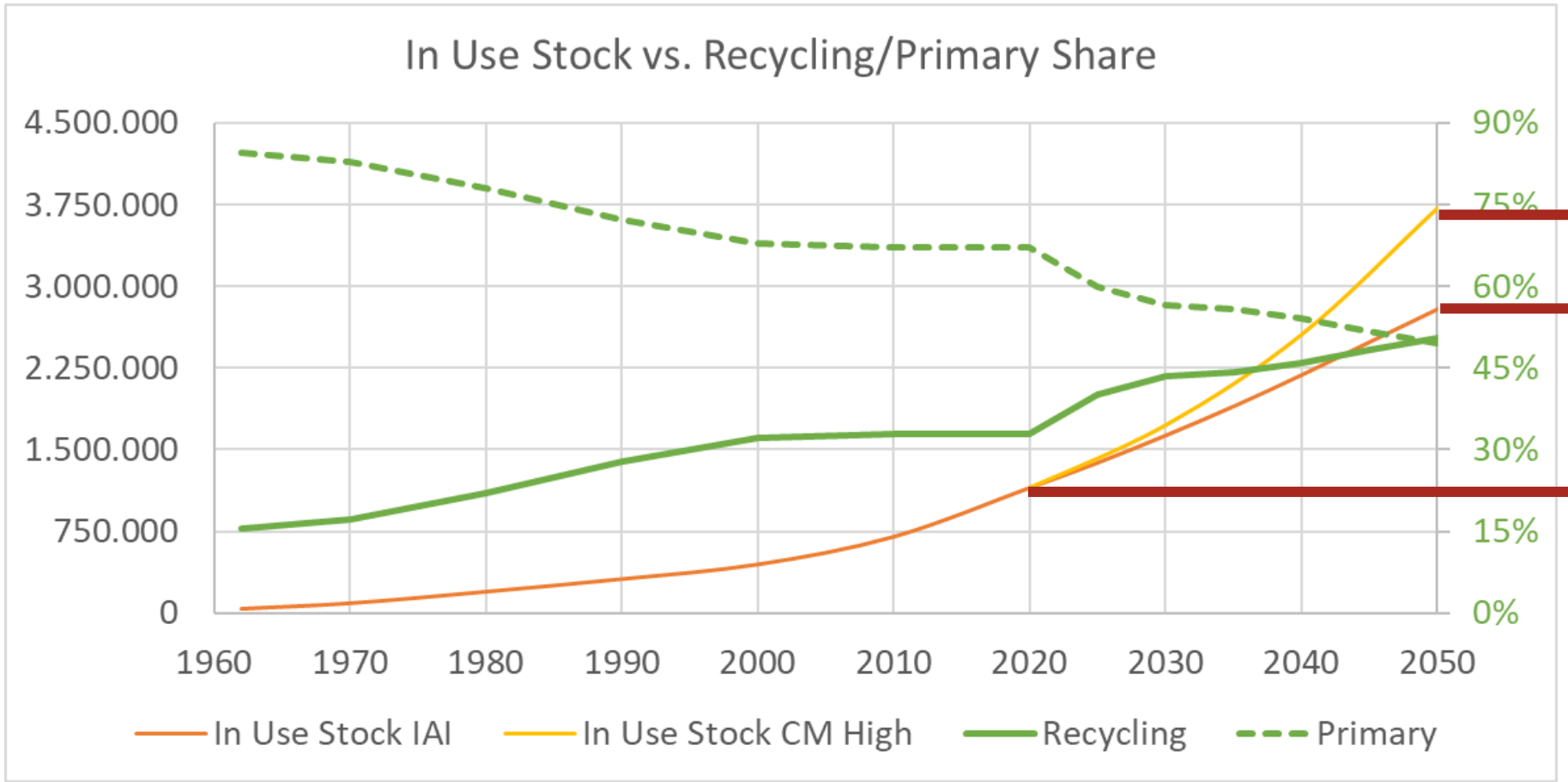
Aluminium Demand with Strong Potential

Aluminium Semis Demand in Sectors

- Strong growth in Transport, Electrical Equipment and Infrastructure is triggered by the energy transition with electrification of the society
- Aluminium can gain market share from competing materials due to its superior material performance and recyclability
- Long product life in many application require strong production from primary metal sources

	Product Lifetime	Steel	Copper	Plastic	Glas	Wood	2020 CRU	2030 CRU	2050 extra-polation
Construction	15 - 50 Years						21,3	25,9	38,7
Electrical & Mechanic	25 - 50 Years						20,2	28,3	42,3
Tranportation	10 - 30 Years						19,9	31,7	47,4
Packaging	6 - 12 Months						15,0	20,5	30,6
Others	10 - 15 Years						10,1	13,4	20,0
		Opportunity	RISK				86,5	119,8	179,0

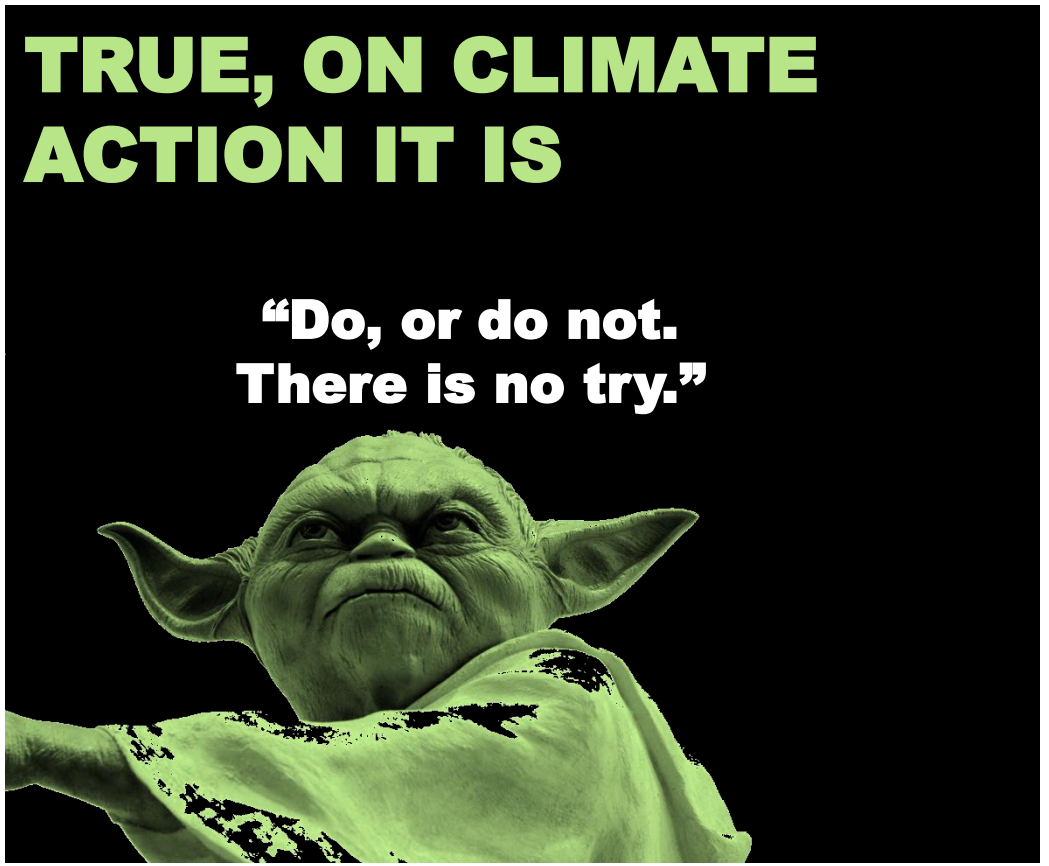
Aluminium In-Use-Stock – Actual & Projections



2050: 3,700 Mt

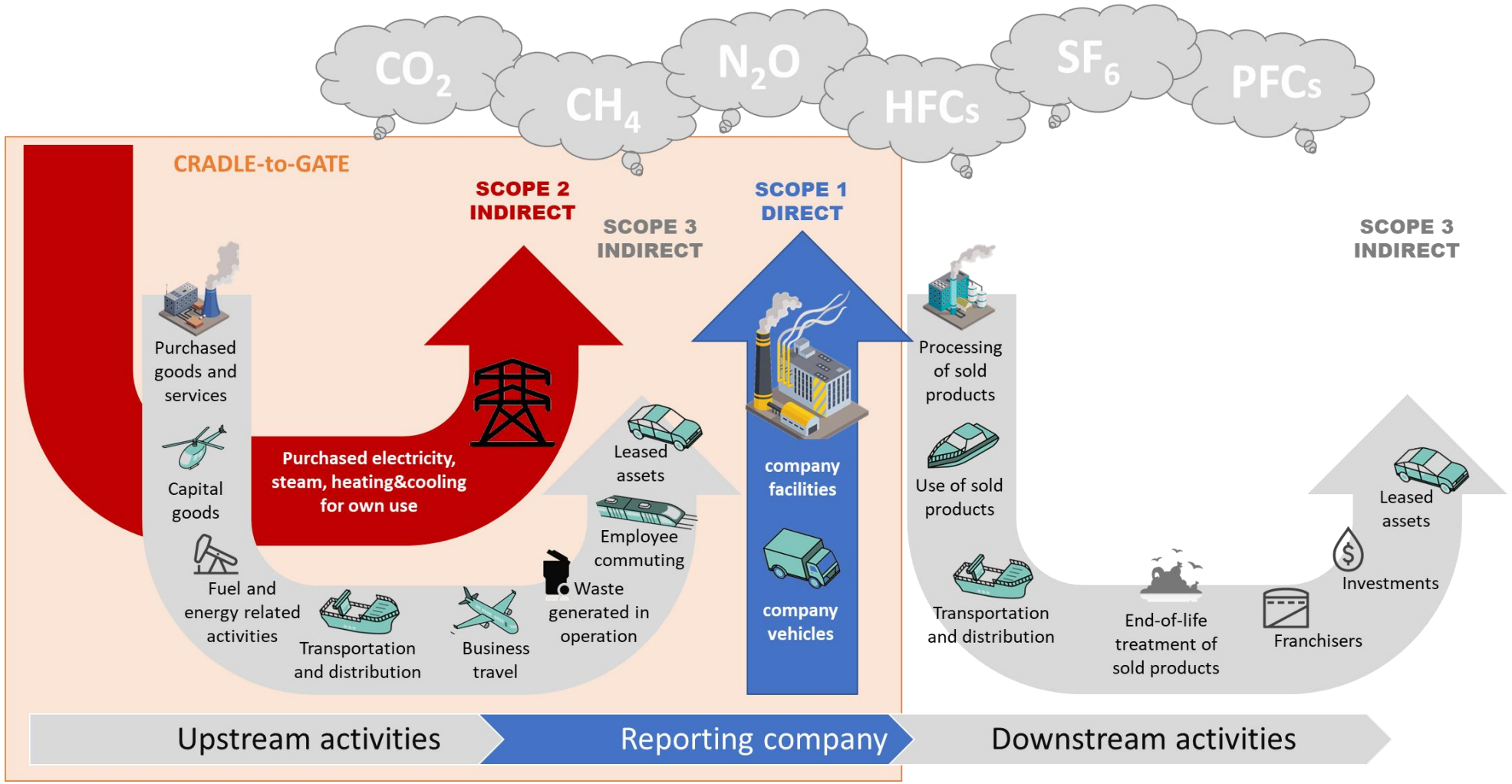
2050: 2,800 Mt

2020: 1,150 Mt

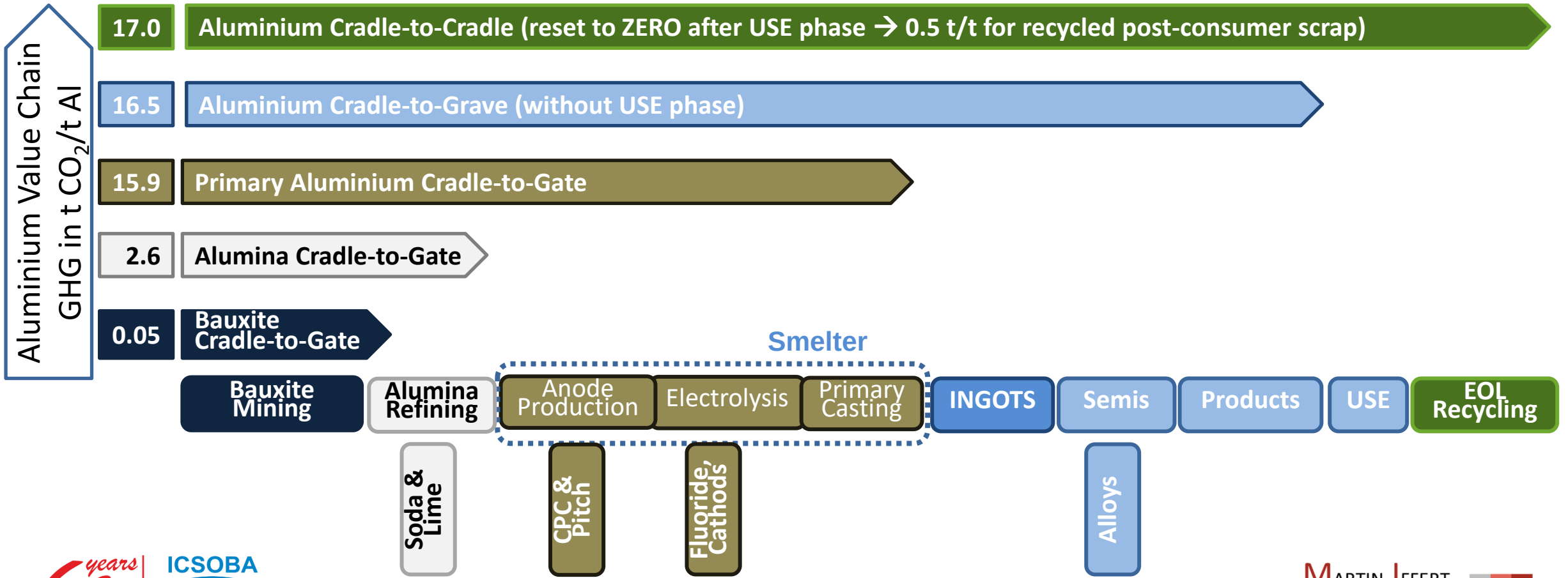


Greenhouse Gas Emissions and Decarbonisation Scenarios

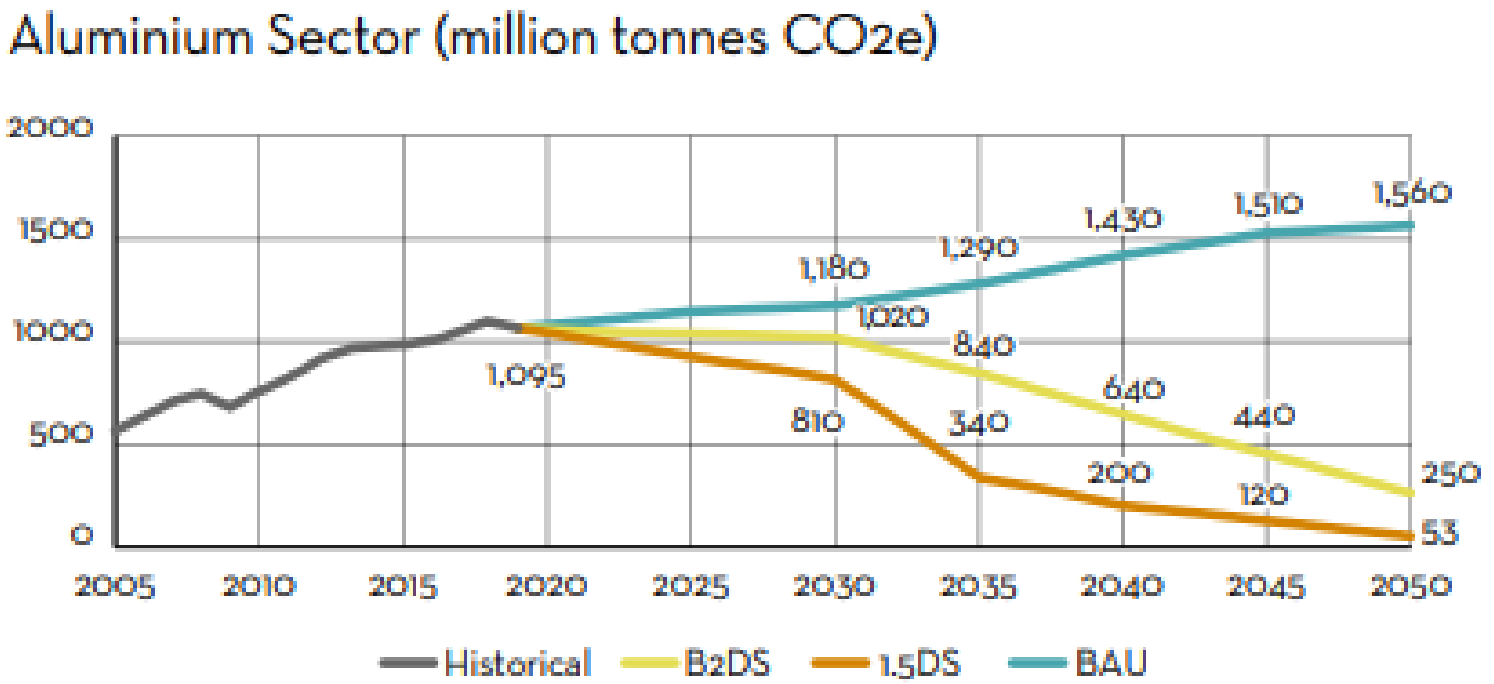
Cradle-to-Gate Emissions - Scopes

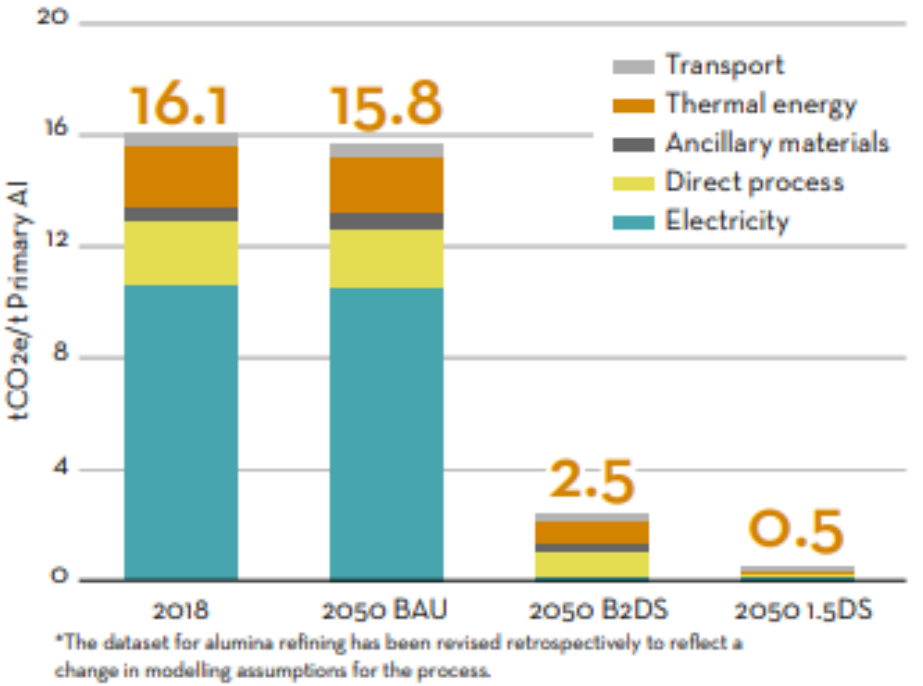


AL Value Chain



2.0 & 1.5 DEGREES SCENARIO from IAI





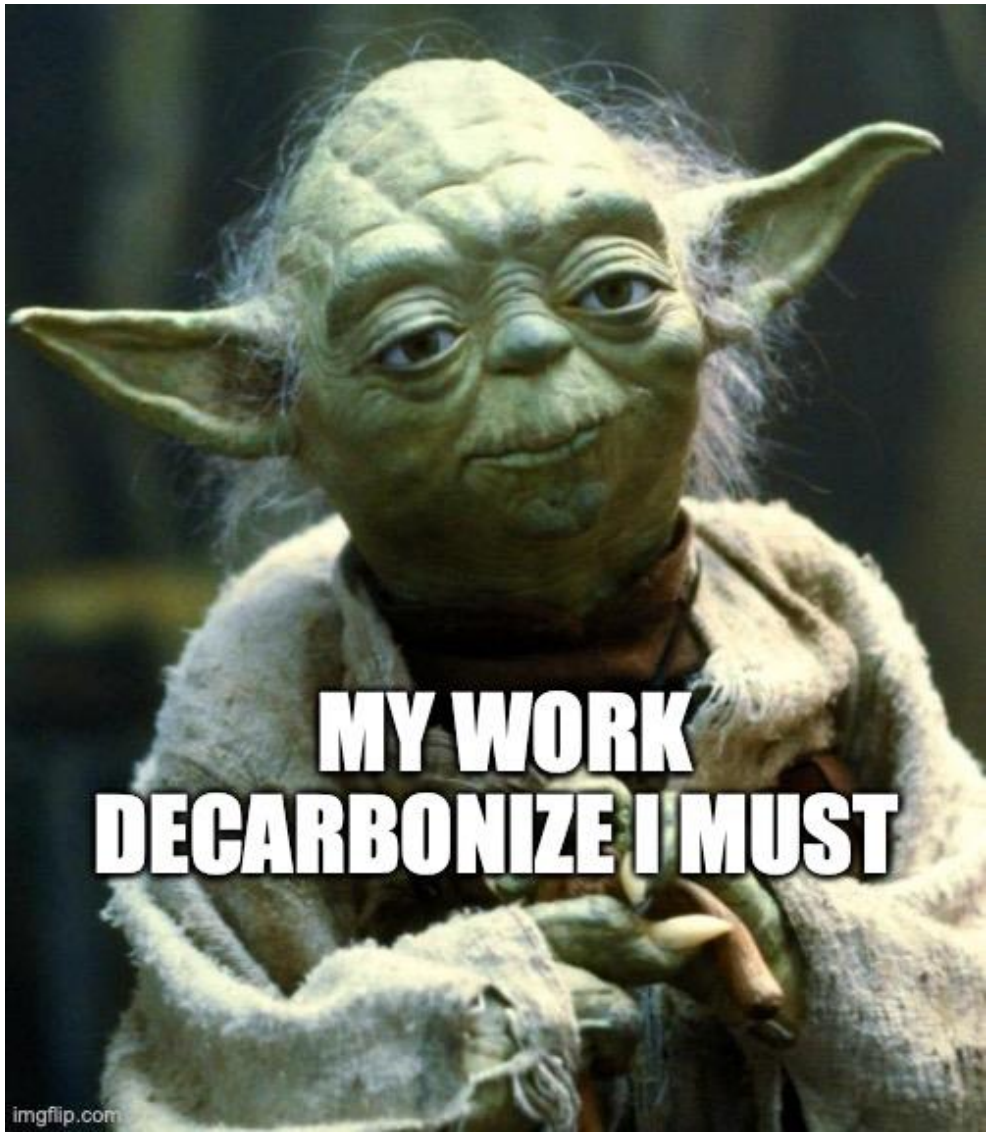
Categorization of Primary Aluminium Emission

Global (tonnes CO_{2e} per tonne Primary Al)	Total	Bauxite	Alumina	Anode	Electrolysis	Casting	Total
Electricity-Indirect	10.6				65%		67%
Perfluorocarbon (PFC) - Direct	0.6				3%		3%
Process (CO2)-Direct	1.5			1%	9%		10%
Ancillary Materials-Indirect	0.6		1%	2%	1%		4%
Thermal Energy-Direct/Indirect	2.1	0%	11%	1%		1%	13%
Transport-Direct	0.5		2%		2%		3%
Total-Cradle to Gate	15.9	0%	16%	3%	80%	1%	100%

Renewable Energies

AI Process Control

Carbon Capture



Decarbonisation Strategies for the Aluminium Industry

Smelter Decarbonization Race

CCS with x% Bio-Pitch-Coke is equal to Inert Anodes in terms of CO_2

INERT

ANODES

New Process with new supply Chain

CPC ANODES

with

CCS & CCU

De-Carbonization added after process

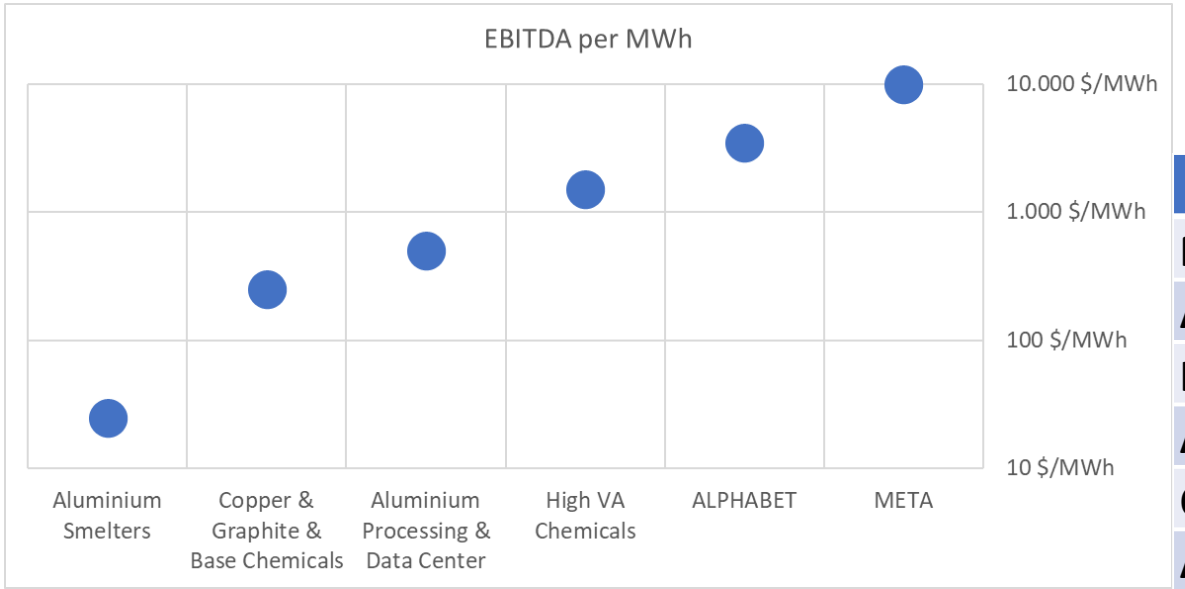
BIO-BASED

ANODES

Exchange CPC with Bio-Mass

- All processes can decarbonise the production of aluminium
- A combination of BIO-BASED Anodes with CCS could even create a CO_2 sink → depending on sustainably produced bio-mass

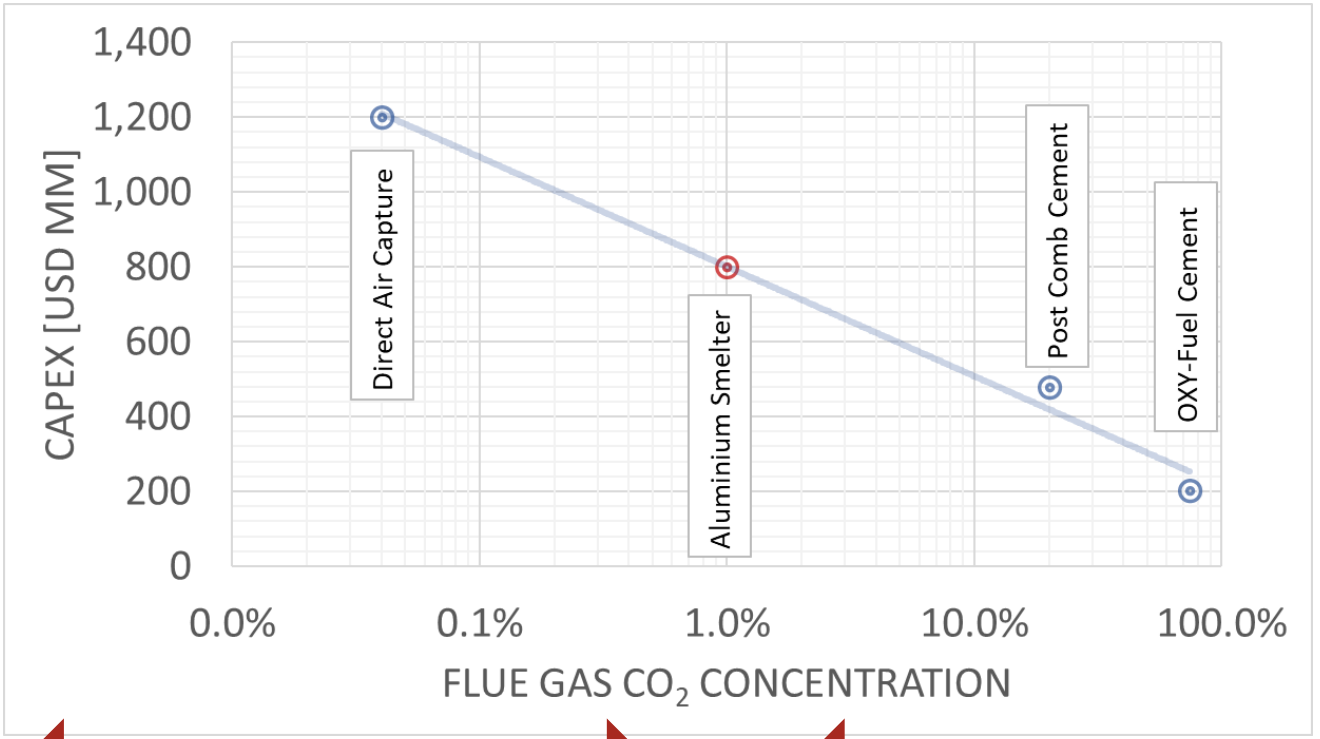
Power Intensity of Industries



	EBITDA per MWh
META	10.000 $/MWh
ALPHABET	3.500 $/MWh
High VA Chemicals	1.500 $/MWh
Aluminium Processing & Data Center	500 $/MWh
Copper & Graphite & Base Chemicals	250 $/MWh
Aluminium Smelters	25 $/MWh

- Aluminium Smelters are at the low end of the "**Electrical Food Chain**" → Smelters could be successful in stranded situation without electrical competition
- Grid connected smelters could be successful, if grid was populated with abundant cheap and dispatchable power (e.g. Canada, Norway)
- Hydrogen will compete with smelters for power, but likely even lower on the "Food Chain" → Hydrogen and Aluminium Smelters could be complimentary successful

CCS in different Industries & Smelter



50 $/t CO_2 | **50 $/t CO_2**

CCS Plant CAPEX → CCS Plant OPEX → CO_2 Transport → CO_2 Storage

Long-Term 2050 Potentials

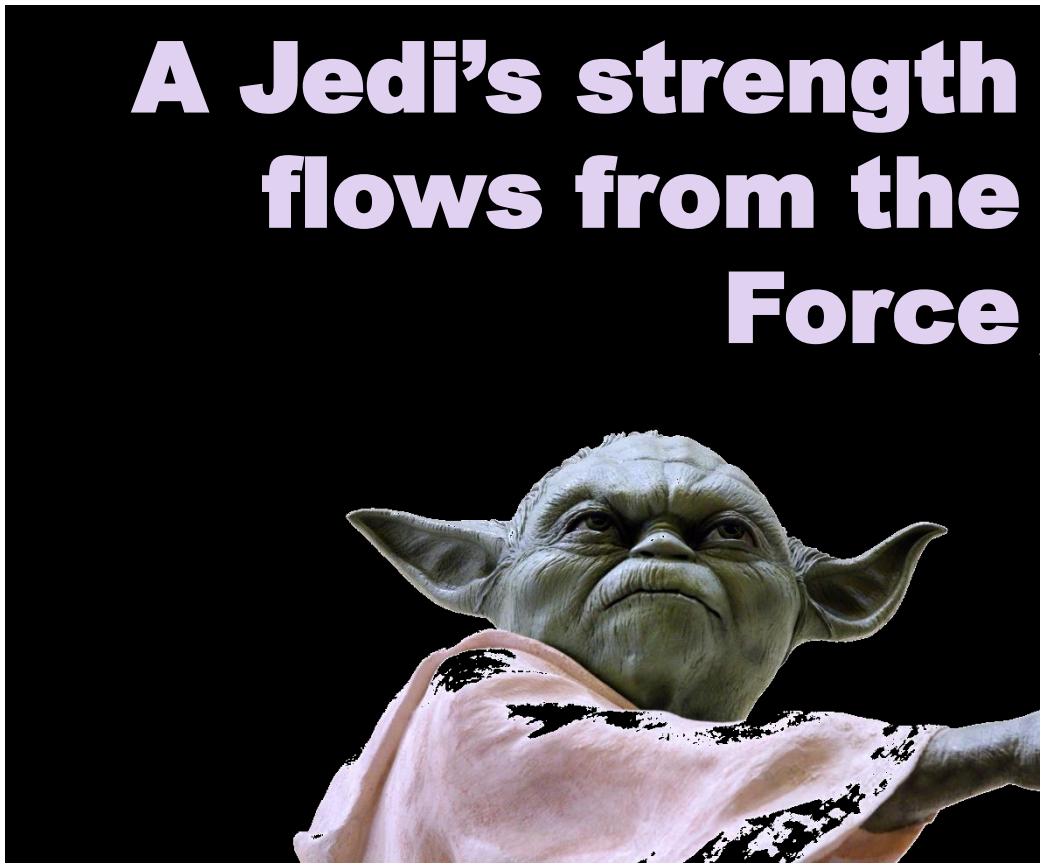
- ➢ Hooding Efficiency 99%
- ➢ Carbon Capture Target – 80%
- ➢ Anode Effect PFC + 5%
- → Overall GHG Capturing 75%
- → @25% Biomass = Net Zero Scope 1, 2
- → @75% Biomass = Net Zero Scope 1, 2, 3

MIC Estimates for 2040:

- ➢ CCS @ 100 $/t → +150 $/t Al
- ➢ 75% Biomass @ +200 $/t → +75 $/t Al
- → +225 $/t Al for Net Zero 1, 2, 3

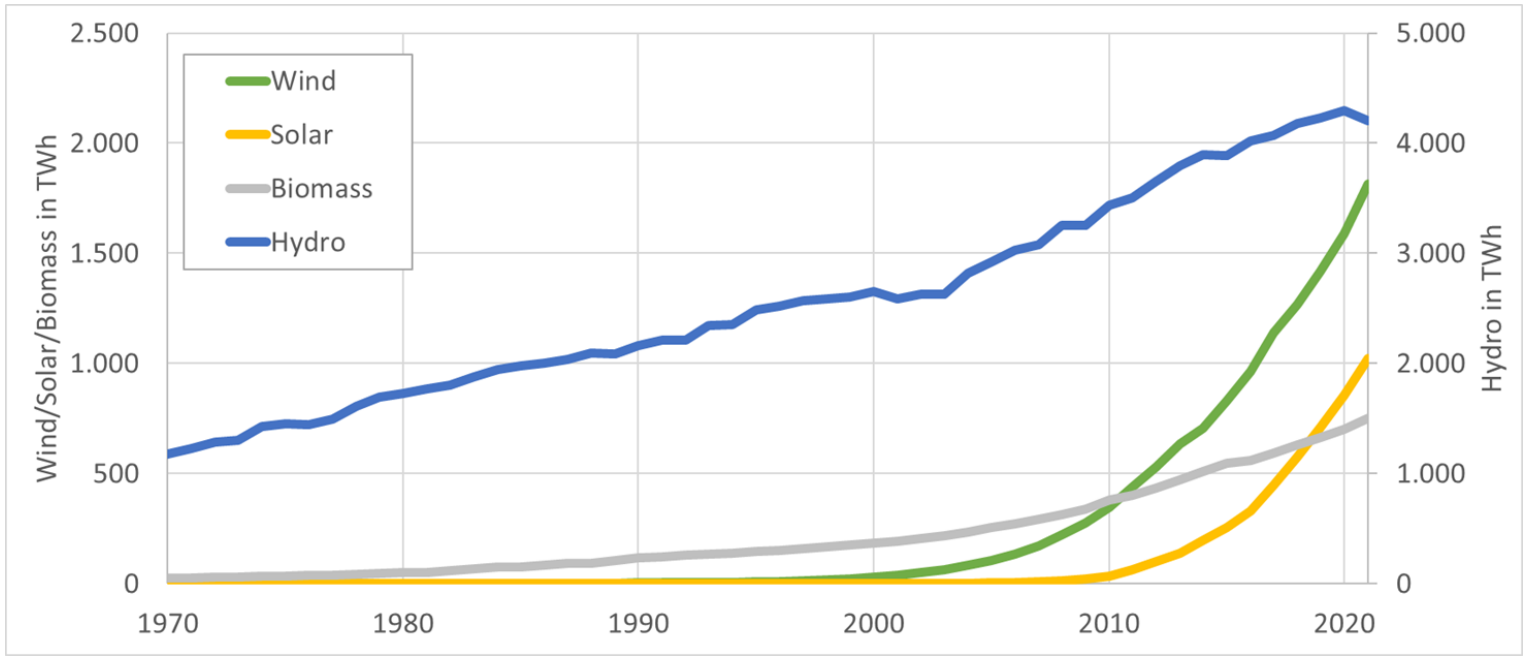
Assuming remaining Scope 3 emissions in 2050, only 0.75 t/t

Assumption for 2040 with USD_{2022}



Aluminium is an Energy Carrier

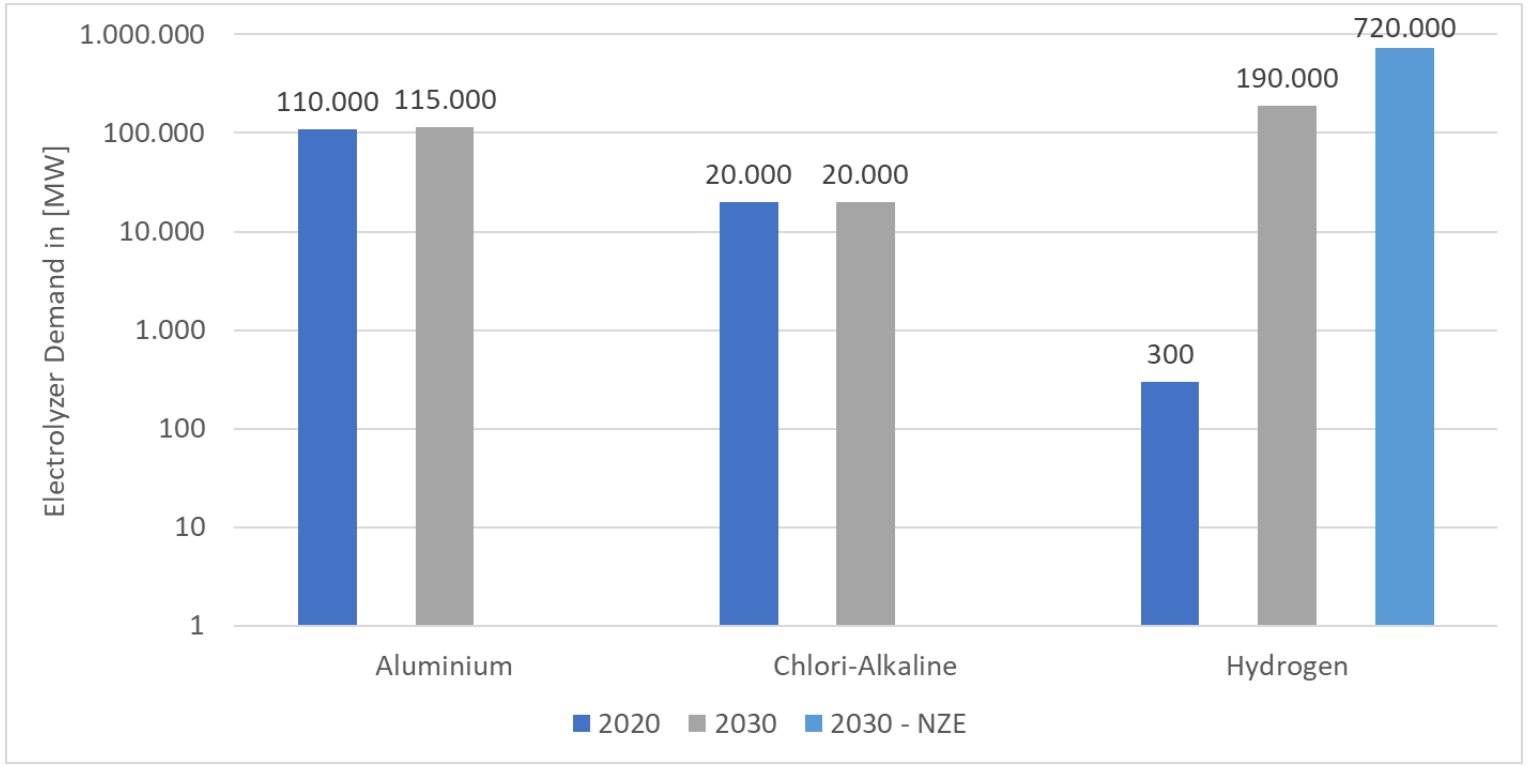
World Renewable Energies



Electricity Ratios in 2021 out of a World Total Electricity Generation of 27,500 TWh: Hydro = 15.3% / Wind = 6.6% / Solar = 3.7% / Biomass = 2.7% → ∑28.3% = 7,800 TWh

BNEF expects Electricity Generation to exceed 100,000 TWh by 2050 in a Renewable Intensive Scenario

GREEN Aluminium vs. GREEN Hydrogen

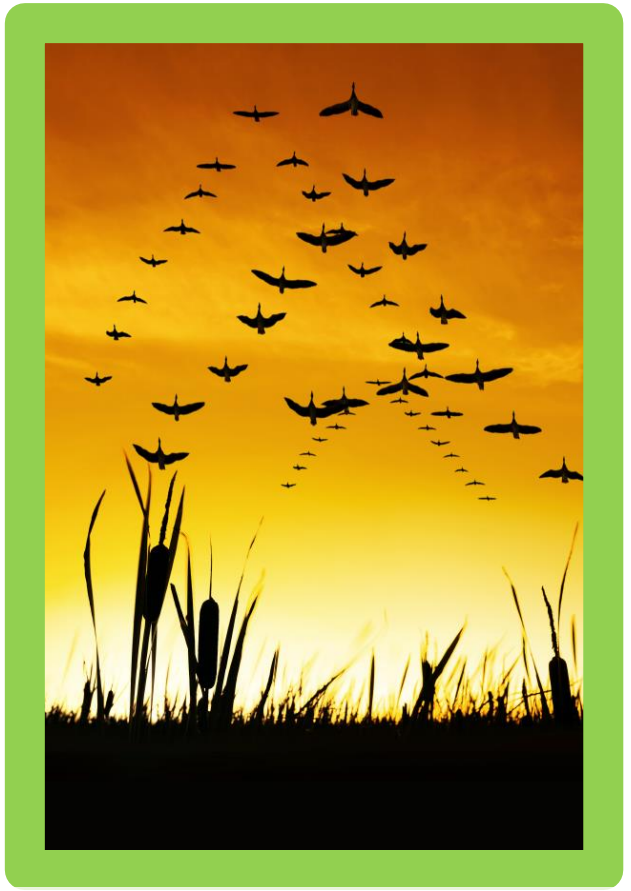


- Aluminium by far the biggest energy carrier today
- IEA forecast that hydrogen will be btw. 1.5x to 6x the size of aluminium by 2030
- Hydrogen and aluminium production are “twins”
- Aluminium smelter CAPEX @ 4 $/W
- H_2 Electrolyser CAPEX @ 1 $/W

Potential long-distance Green Energy Carrier are Hydrogen, Ammonia, Green Steel, Green Aluminium
50 MWh → 1 t H_2 → 12.5 MWh Power → 1 t Aluminium (without H_2 transport losses)

What Direction to Take?

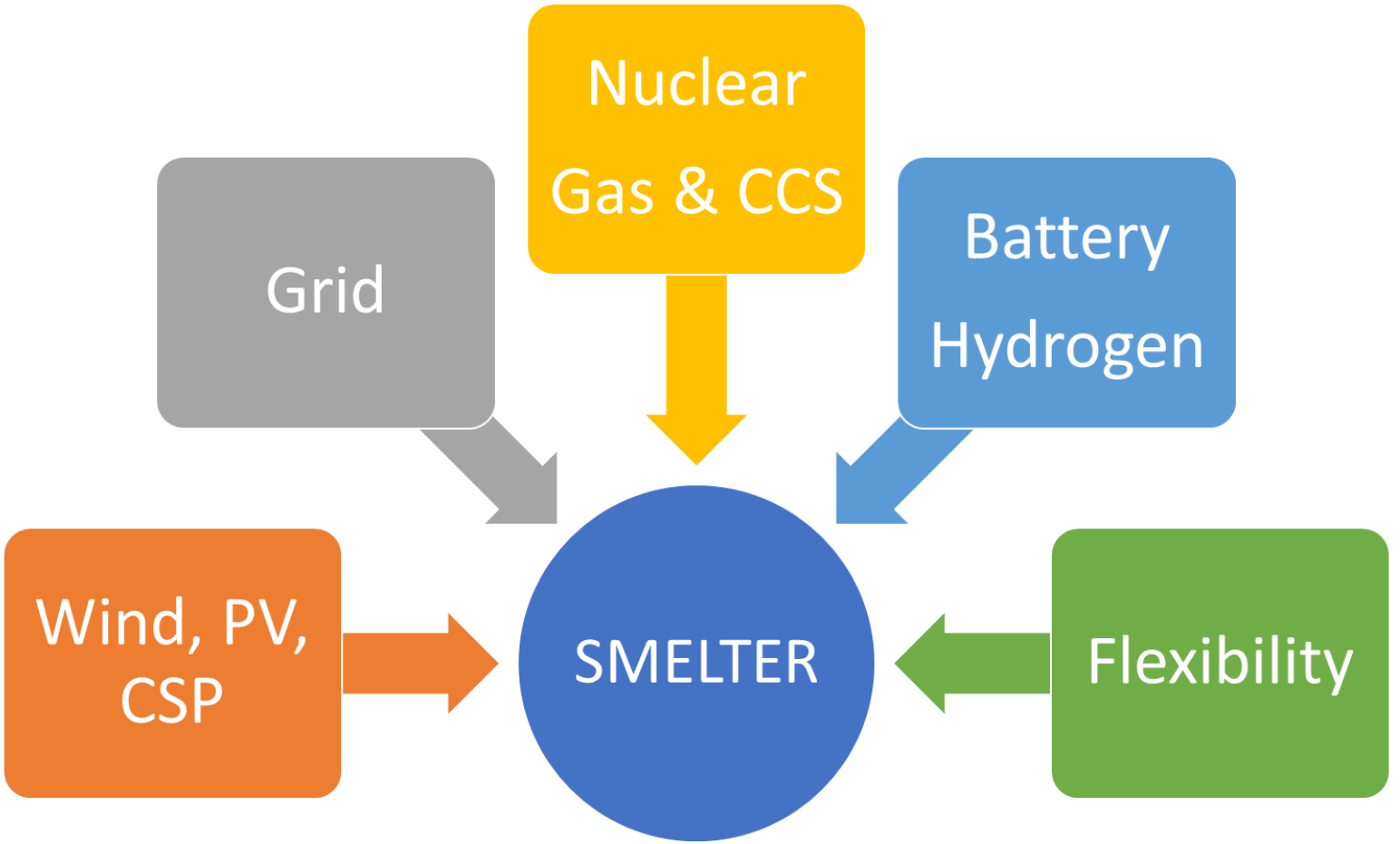
Seeking for Solutions that are **Affordable** and **Achievable**



- **Achieve climate goals through renunciation**

- **Knowledge**
- **NetZero Technologies**

Carbon Free Smelter Supply Options

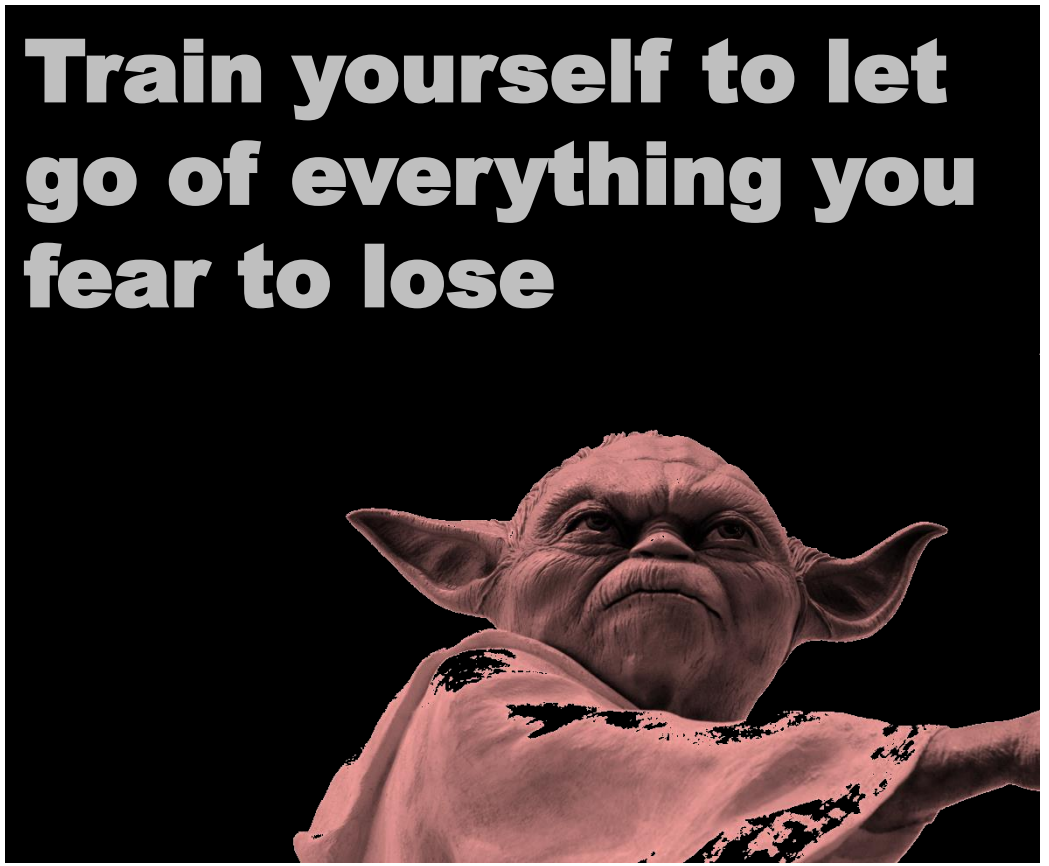


Hydro and Geothermal Power are already essential base load supply options for smelters, but most resources have been exploited and won't fill the 70% supply gap

Carbon Free Smelter Supply Options 1,750 MW

- Stranded Hydro was the most economical choice for smelters in the past
- Wind+PV+Hydrogen as baseload option
- Government subsidised nuclear and lignite gained market shares in the ’70s, followed by stranded gas in the Middle East in the ’80s
- Internalization of CO_2 costs is a very European Scheme (and smelters are compensated for the costs)

Power Plant Type	CAPEX Life	CAPEX	OPEX 25 years	Interest	CAPEX	O&M	Fuel @market	CO2 @100 $/t	LCOE w/ CO_2	LME Ratio @2,500 $/t	LCOE w/o CO_2	LME Ratio @2,500 $/t
					$/MWh	$/MWh	$/MWh	$/MWh	$/MWh	%	$/MWh	%
Hydro	75 Years	USD 8 bn	USD 4 bn	5,0%	26	10			36 $/MWh	22%	36 $/MWh	22%
Gas CCGT	50 Years	USD 2 bn	USD 21 bn	7,5%	10	5	50	40	105 $/MWh	63%	65 $/MWh	39%
Coal	50 Years	USD 4 bn	USD 20 bn	7,5%	21	10	43	85	159 $/MWh	95%	74 $/MWh	44%
Nuclear	50 Years	USD 9 bn	USD 8 bn	10,0%	61	15	7		83 $/MWh	50%	83 $/MWh	50%
Wind/PV with Battery/Hydrogen	25 Years	USD 9 bn	USD 4 bn	5,0%	40	10			50 $/MWh	30%	50 $/MWh	30%



Flexibility is the new Scarcity

New Locations for Energy Intensive Processes

BUSINESS | NAMIBIA

Germany eyes Namibia's green hydrogen

Jasko Rust | Lisa Ossenbrink

12/02/2022

Namibia wants to become one of the world's leading producers of green hydrogen. Germany is interested in the project, but not everyone is cheering in Namibia.

6 GW Renewables

15 TWh Electricity

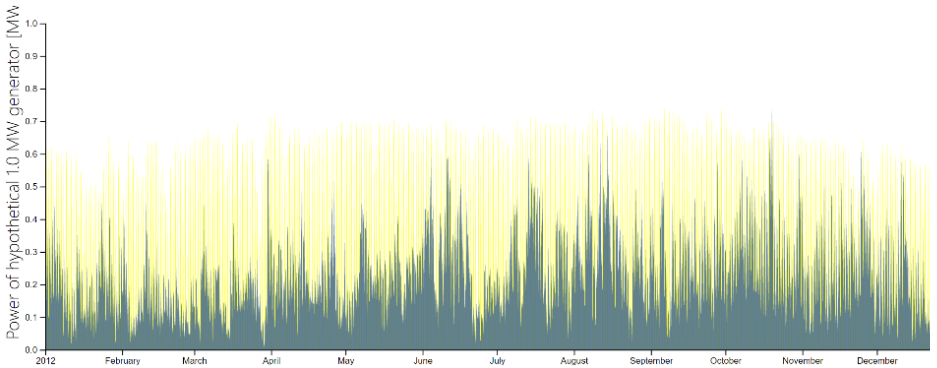
3 GW Electrolyser

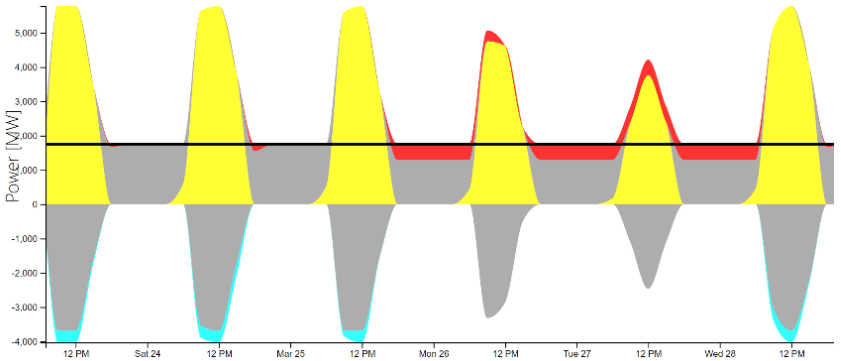
USD 10 bn CAPEX

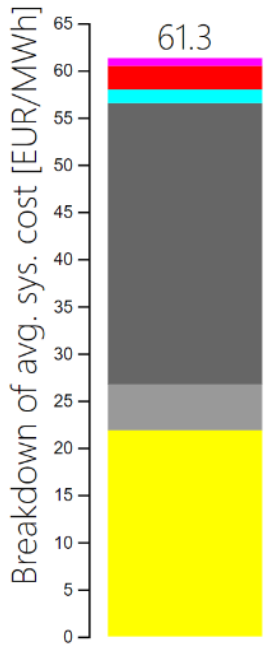
300 kt/a H2

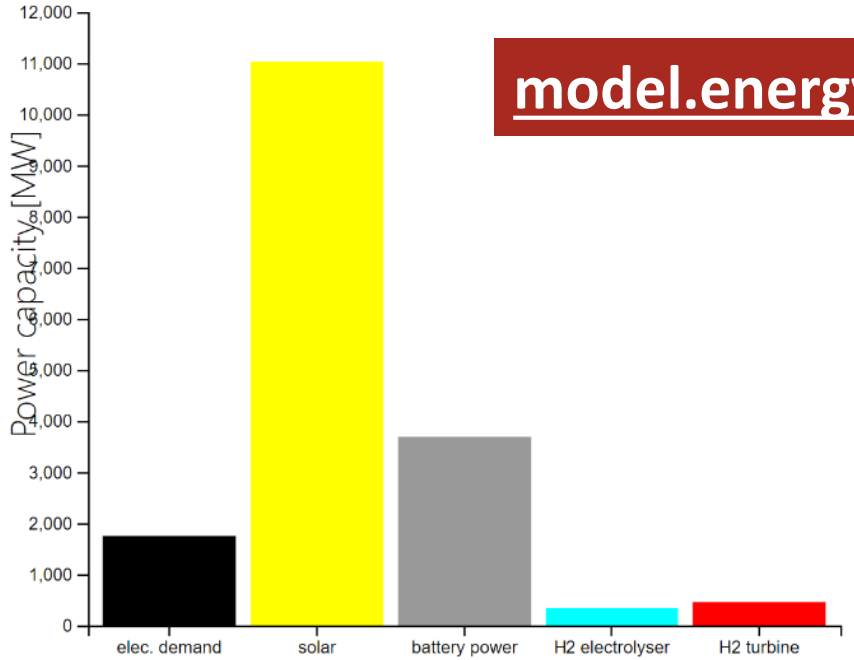
(could also power 1 Mt smelter)

Example: Namibia
1,750 MW Zero Carbon Base Load

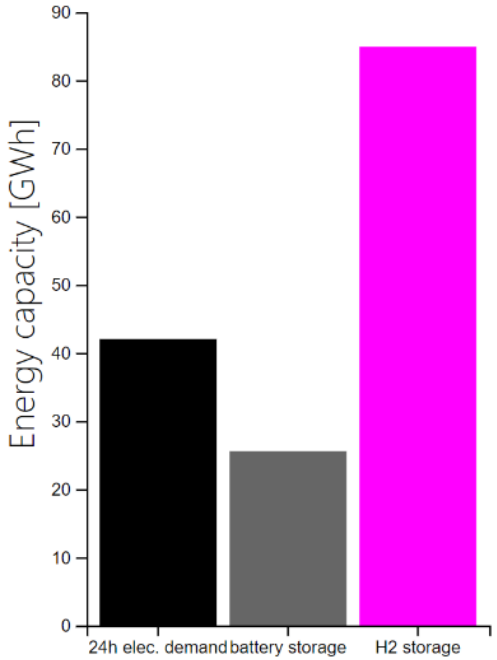






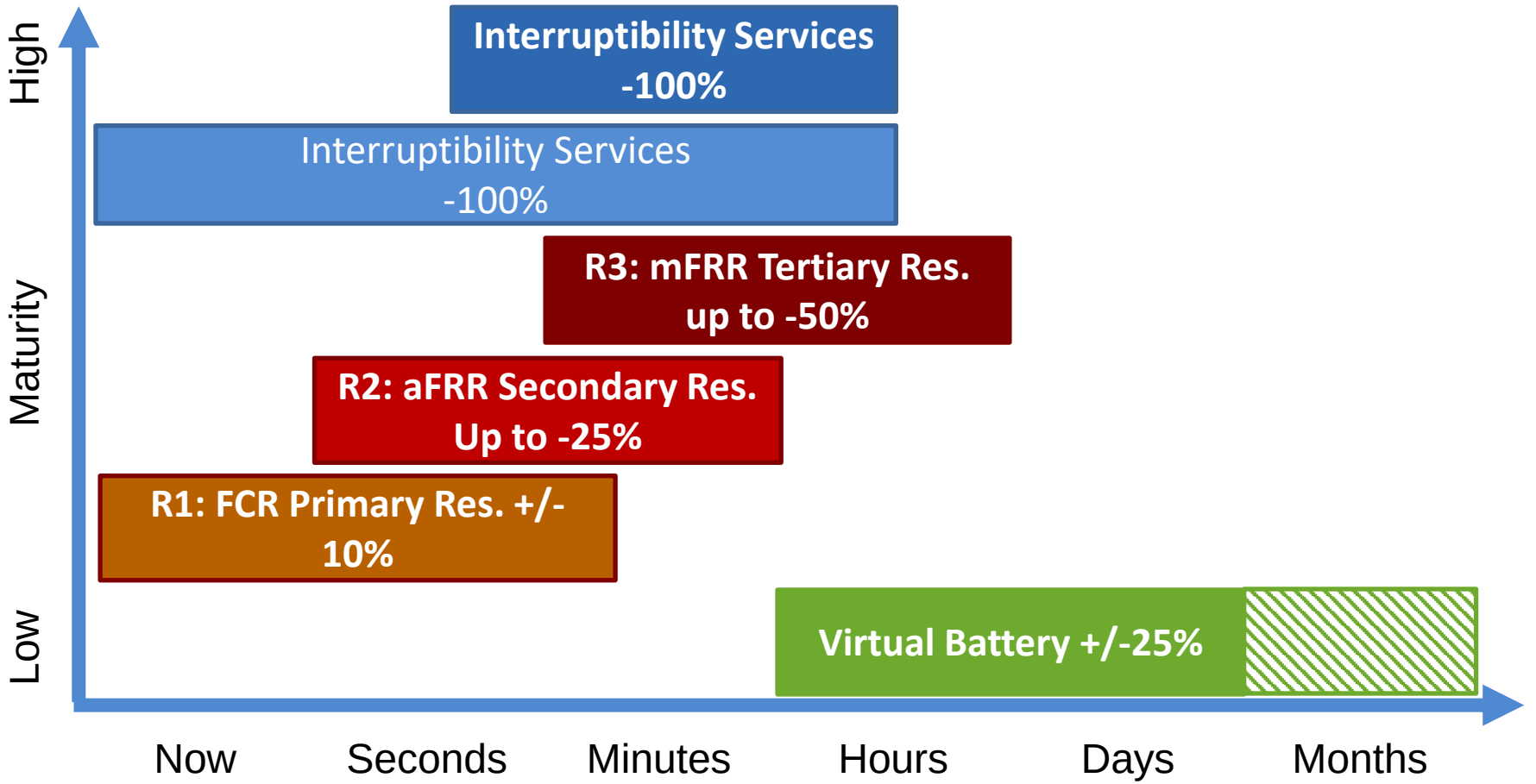


model.energy



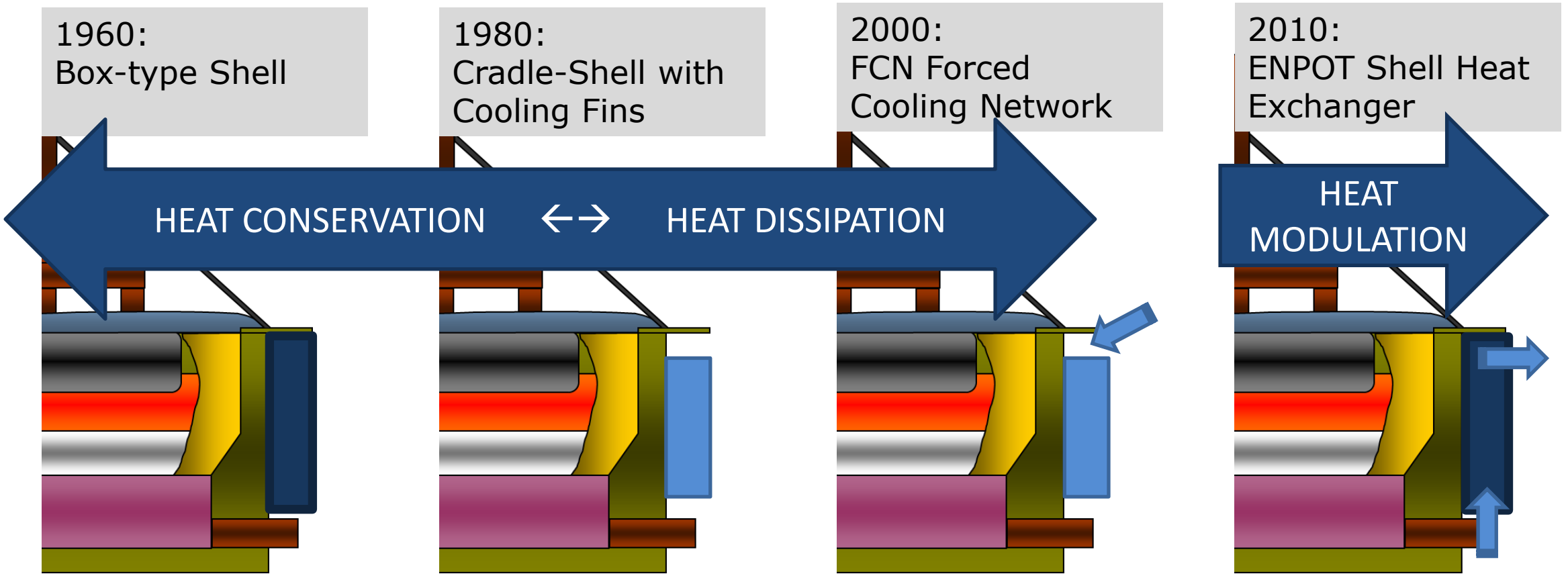
@2,500 USD/t LME
20 → 12% Ratio
40 → 24% Ratio
60 → 36% Ratio

Balancing Services of Aluminium Smelters



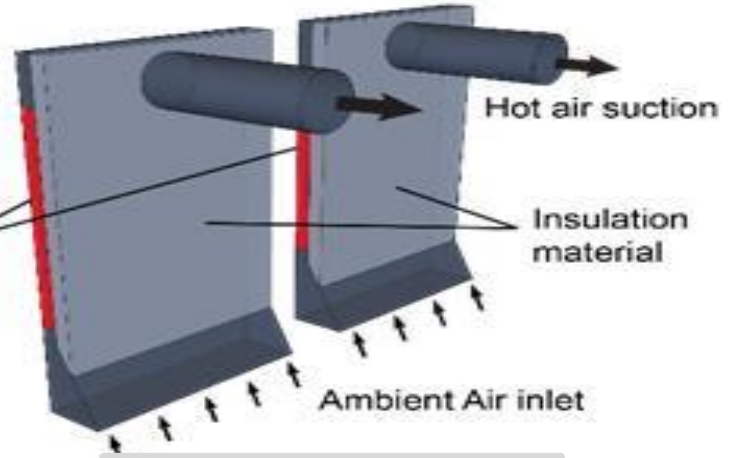
Aluminium smelter: Development

Side Wall Heat Loss Development



VIRTUAL BATTERY Example

+/- 25%
48 hours



Flexibility & Heat Recovery

Heat for CCS

Virtual Battery Components

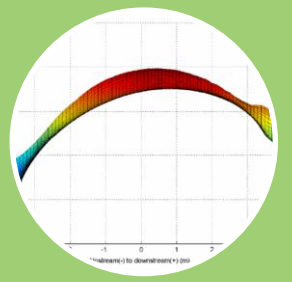
SHE

Modulating the Side-Wall Heat Loss from the Cell

GTC Flex

Modulating the Top-Heat Losses from the Cell

Thermal Regulation



Magnetic Compensation

Reducing Magnetic Effects & Metal Pad Heave

Flex Control

Adaptation of Process/Pot Control System

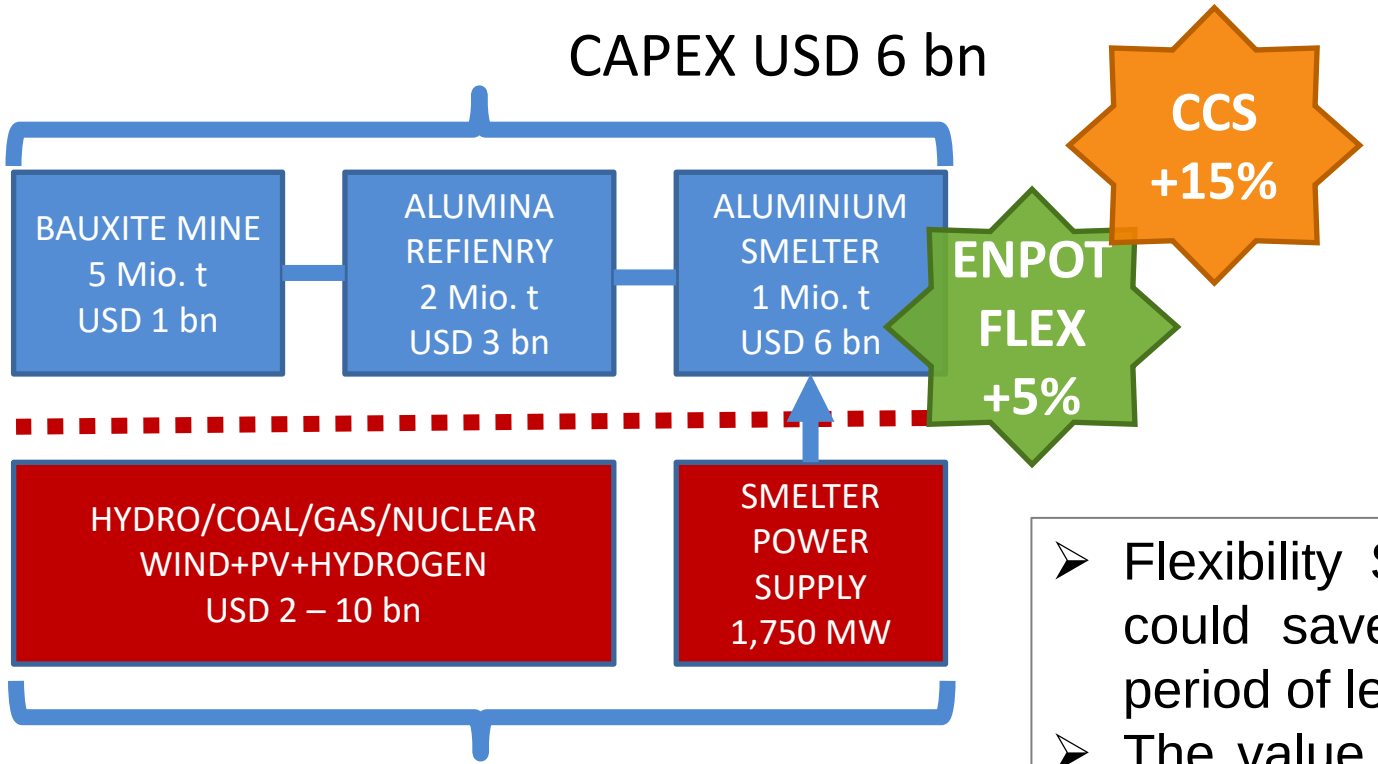
Energy Supply

Increase Responsiveness with Transducers

Aluminium Production Value Chain CAPEX

1 Million ton Smelter → 15 TWh Electricity

SMELTER
CAPEX USD 6 bn



Baseload Renewable Energy Supply
PV/Wind/Battery/Hydrogen USD 9 bn

1 Million Ton Smelter:

a. USD 6 bn Smelter CAPEX
   Conventional incl. Anode plant and Casthouse
b. plus additional 5% = USD 0.3 bn for Flexibility
   Magnetic Compensation, Auxiliary upgrade
c. plus an additional 15% = USD 0.9 bn for Carbon
   Capture → Full CO_2 capture plant (amine-based)
   80-90% capture rate

- Flexibility Services plus Heat for CCS from ENPOT could save 100 – 250 MUSD (creating a payback period of less than three years)
- The value of the captured heat alone would save 25 MUSD per year → already, the heat for 12 years would pay the whole investment.

Investment Incentives

		EBITDA per t Al	CAPEX per anual ton	Pay Back Period
Aluminium Smelter	LME+MB/MW = 2,500 USD/t	500 $/t Al	6,000 $/t Al	12 years
Carbon Capture	Green Premium = 250 USD/t	100 $/t Al	900 $/t Al	9 years
Flex + Heat	Power Discount 5 USD/MWh_{El} Heat 16 USD/MWh_{th}	100 $/t Al	300 $/t Al	3 years

Conclusion

Conclusion

NEAR ZERO ALUMINIUM is achievable

It requires:

- No Accounting Loopholes and Greenwashing
- Combine Flexibility and Heat Recovery
- Green Premium of 10-20% of LME

My boss told me to have a good day...

So I went home.

THANKS for your ATTENTION