SUSTAINABILITY IN THE CARBON SUPPLY CHAIN

Les Edwards

Rain Carbon Inc.

RAIN

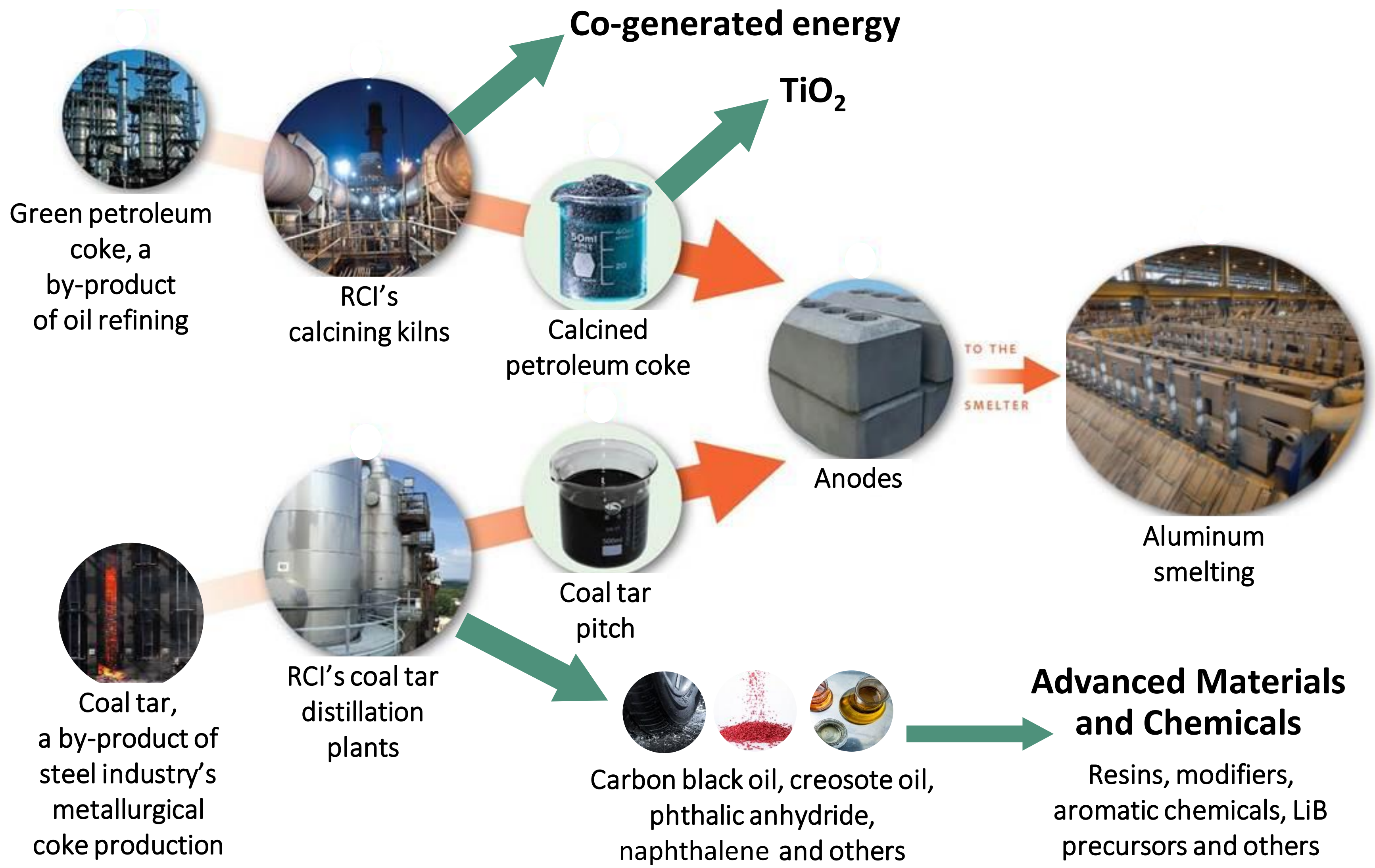
RAIN CARBON INC.

About the Presenter

- Les Edwards, Rain Carbon Inc. (les.edwards@raincarbon.com)
- Current role: VP Production Control and Technical Services
- Location: Houston, Texas
- Degrees: BSc. (University of Western Australia), MBA (Tulane University, New Orleans).
- Background: Rain Carbon/CII Carbon: 1998 - Present

  Comalco (now RioTinto): 1987-1998
- Regular presenter/contributor at TMS
  - Leader of TMS Anode Technology Course
  - 2 x Program Organizer of Electrode Technology Sessions
  - 4 x Light Metals Best Paper Awards
  - >30 Technical papers & 6 patents

Rain Carbon Inc.



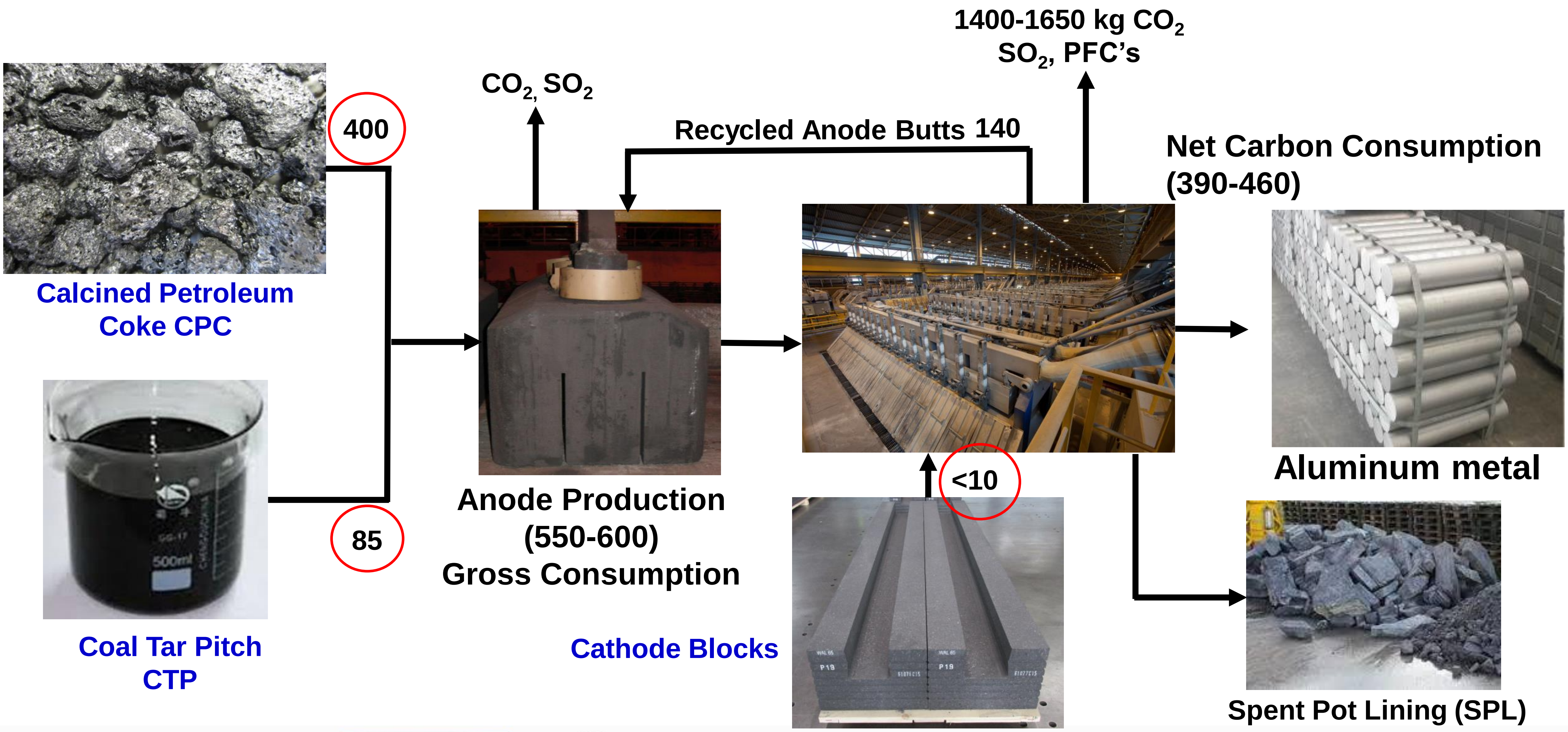
Rain Carbon upcycles byproducts into a wide range of value-added products

www.raincarbon.com

Presentation Outline

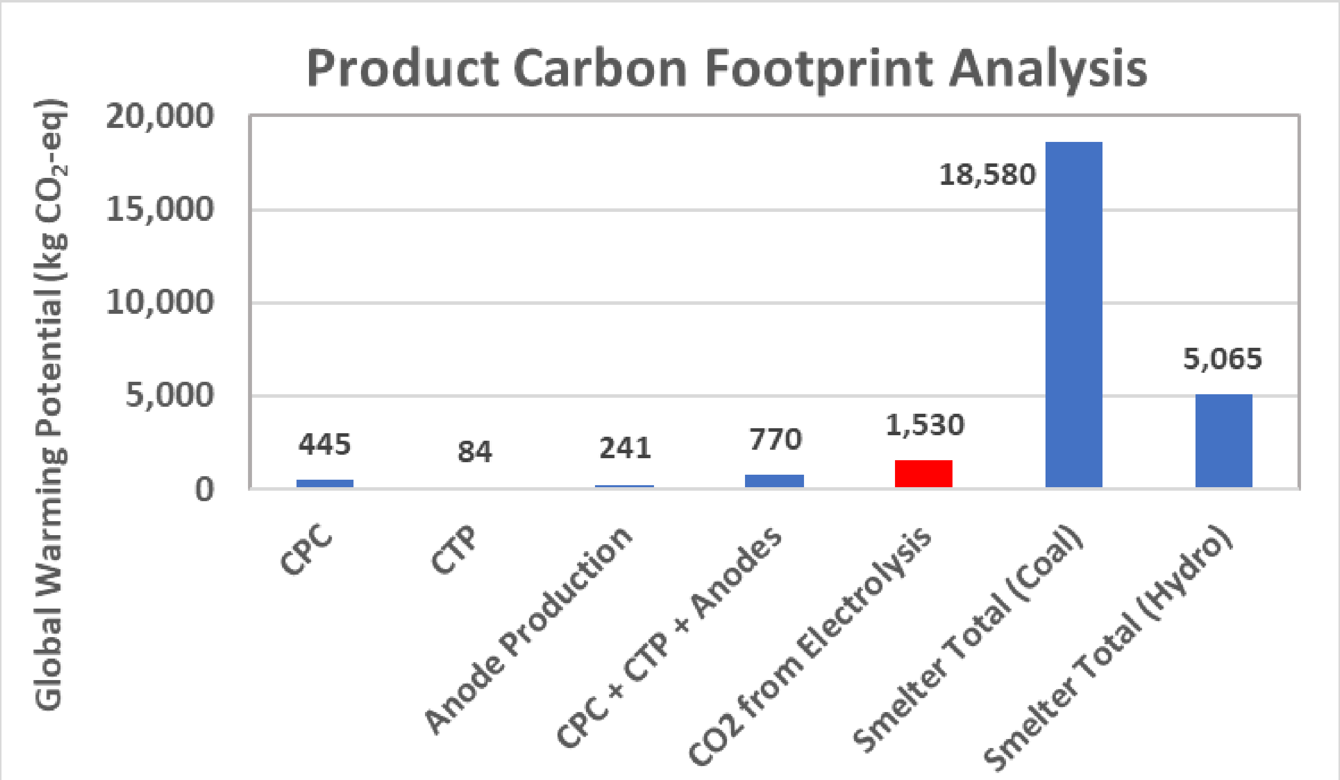
- Carbon raw materials and contribution to smelter CO_2 footprint.
- CPC production and opportunities to improve sustainability.
- Pitch binders and cathode lining materials.
- Bio-based carbon alternatives.
- Inert anodes.
- Summary and conclusions.

Carbon Use in Al Production (kg C/ton Al)



Carbon Supply Chain CO_2 Footprint Contribution

- **What is the materiality of CPC, CTP and anode CO_2 emissions to total smelter footprint (cradle-to-gate)?**

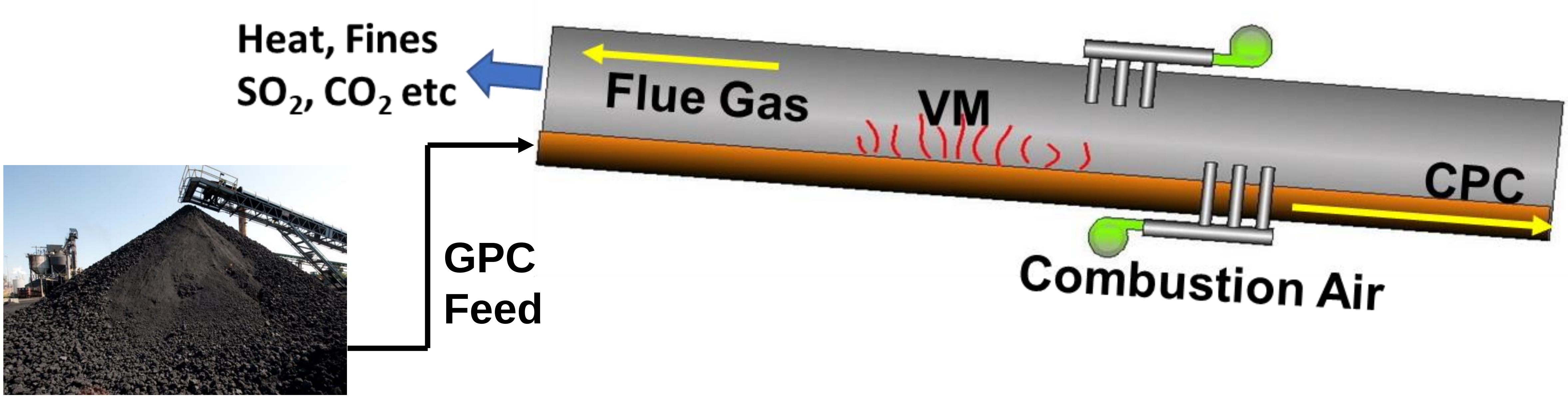


* Modeling based on GaBi Professional database

Will do a deep dive into CPC production which is largest contributor to anode footprint prior to use.

CPC Production Overview

Rotary Kiln Calciner



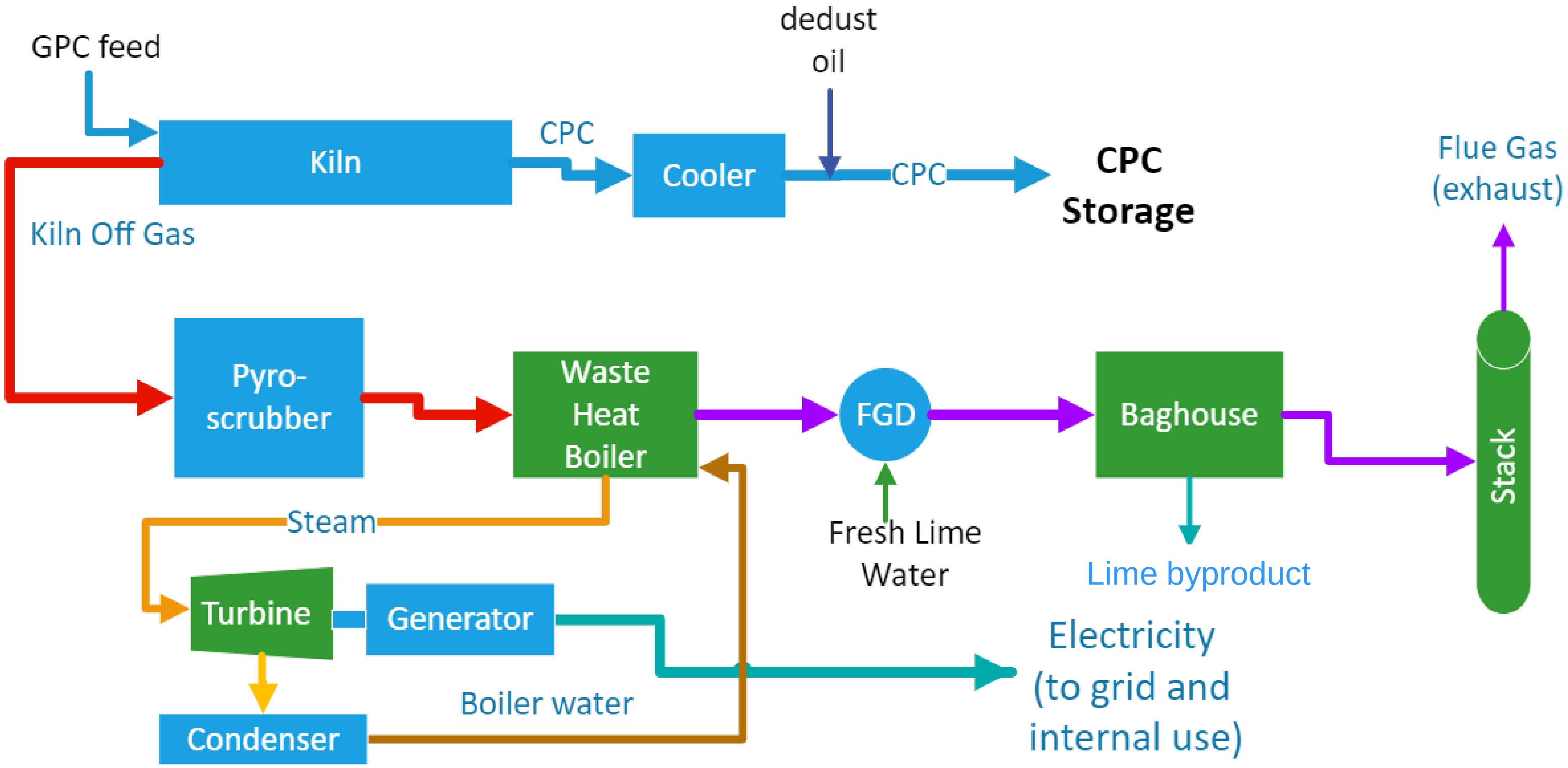
- Combustion of volatile matter (VM) in GPC and loss/combustion of coke fines (~10%) generates a large amount of heat.
- Emissions include CO_2, H_2O, SO_2, NOx and solid particulate matter (SPM).

Example: Vizag Calciner

- Located in Visakhapatnam on East coast of India (Andhra Pradesh State).
- Rain Carbon and India's largest calciner with annual CPC production of 500 kt/yr.
- 2 x 68 m long rotary kiln calciners.
- Requires ~700 kt/yr of GPC.

ICSOBA 2020: Sustainable CPC Production at the Vizag Calciner

Process Overview



FGD = Flue Gas Desulfurization

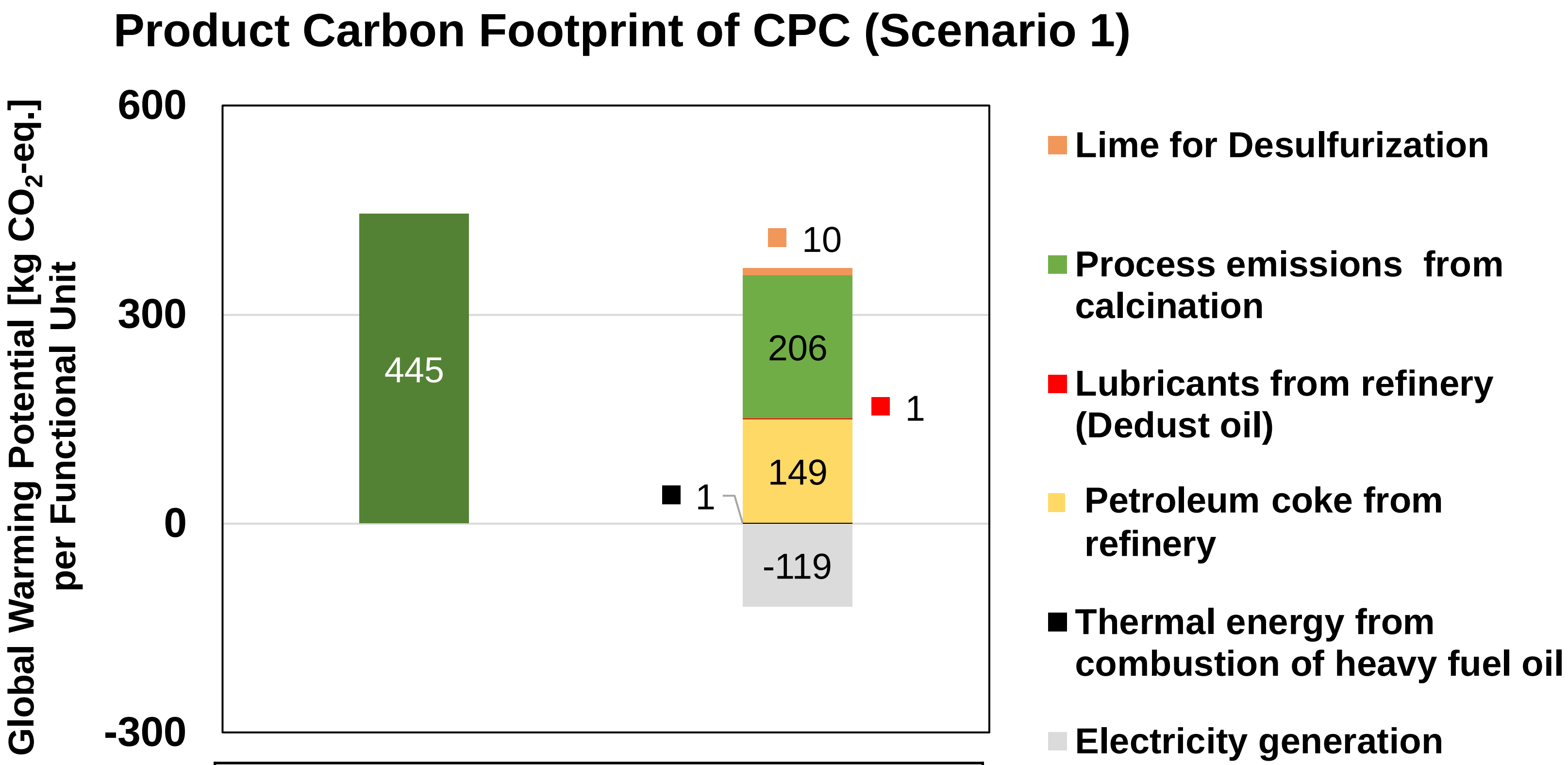
Addition of Waste Heat Recovery and FGD Significantly Improves Sustainability

Key Input/Output Data

Inputs	Units	Value
GPC Feed Tons (Wet Tons)	MT	679,282
Hydrated Lime Use	MT	20,010
Power Use by Plant	MWh	50,897
Thermal energy from fuel combustion	MWh	5,995
Outputs	**Units**	**Value**
CPC Production	MT	504,660
Power generation	MWh	309,422
CO_2 Emissions	MT	365,061
SO_2 Emissions from Kiln to Pyroscrubber	MT	9,766
SO_2 Emissions from Cold Stack	MT	146
Sulfated Lime Byproduct	MT	31,895
Average Stack SO_2 Concentration	mg/Nm^3	55
Average Stack SPM Concentration	mg/Nm^3	60
Average Stack Flow Rate	Nm^3/h	180,000

- **CO_2 emissions significant.**
- **Plant uses ~15% of energy generated and exports 85%.**
- **Amount power equivalent to power plant burning 115,000 tons coal/yr.**
- **SO_2 removal efficiency very high at ~98%.**

Product Carbon Footprint: CPC

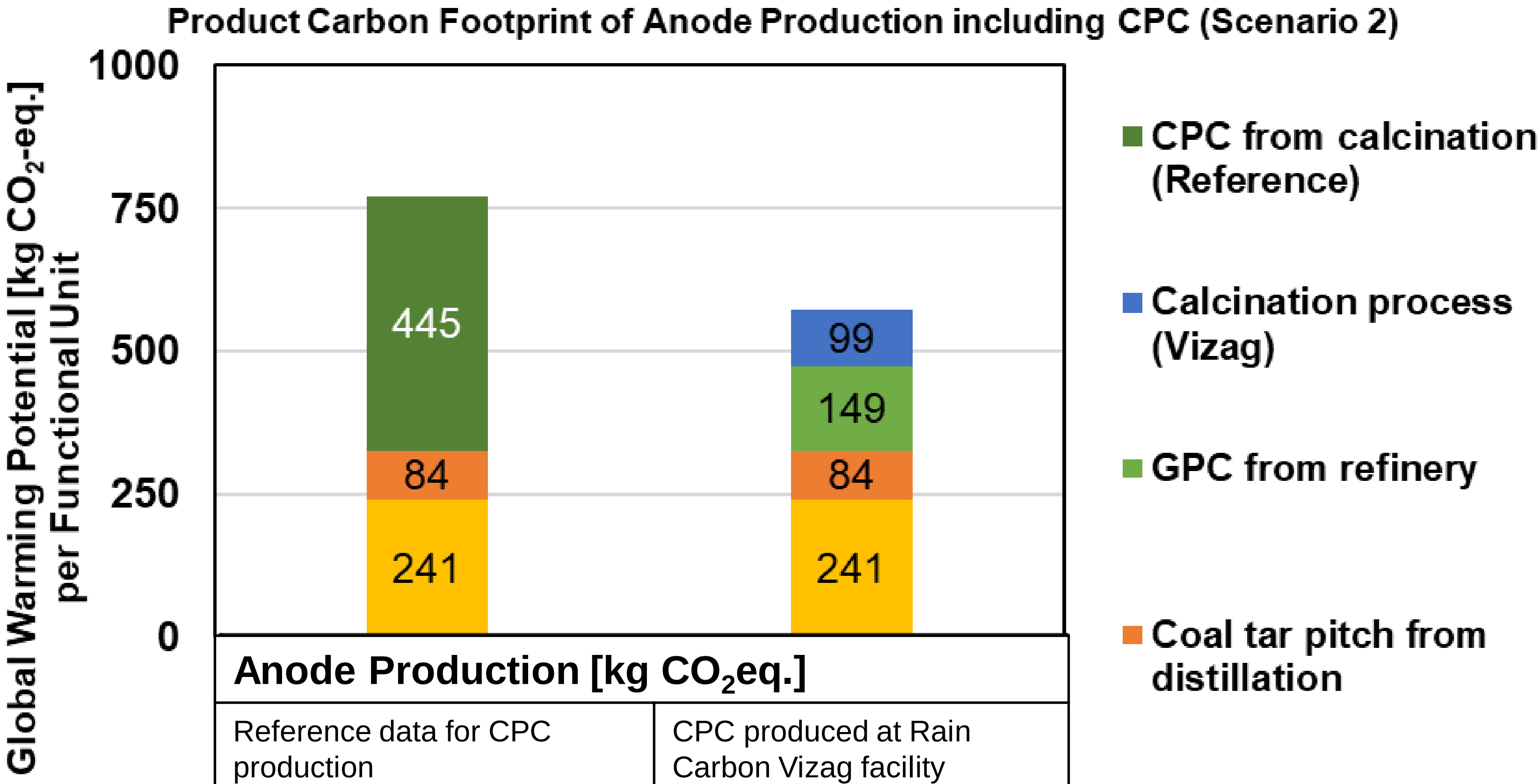


CPC Production [kg CO_2eq.]	
Reference data for CPC production	CPC produced at Rain Carbon Vizag facility
445 kg CO_2e	248 kg CO_2e (- 44%)

Functional Unit (FU) = 1 ton Aluminum

- **Modeling with GaBi database.**
- **Power exported to grid receives CO_2 credit/offset.**
- **India national grid emissions factor: 0.82 tons CO_2/MWhr power.**

Carbon Footprint - Anodes



Anode Production [kg CO_2eq.]	
Reference data for CPC production	CPC produced at Rain Carbon Vizag facility
770 kg CO_2e	573 kg CO_2e (- 26%)

2021 collaborative study with smelter & GPC supplier underway to better quantify emissions.

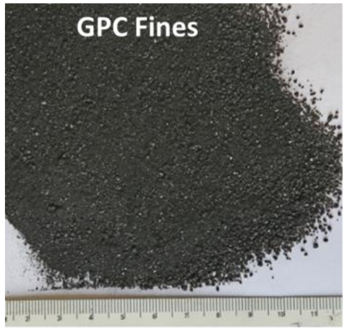
Goal is to compare to model output.

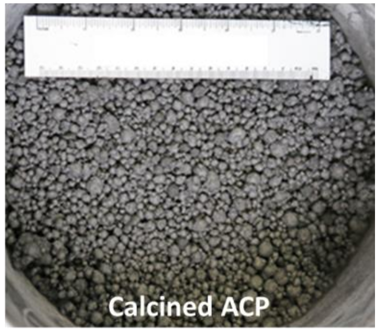
Other Improvements in Calcining

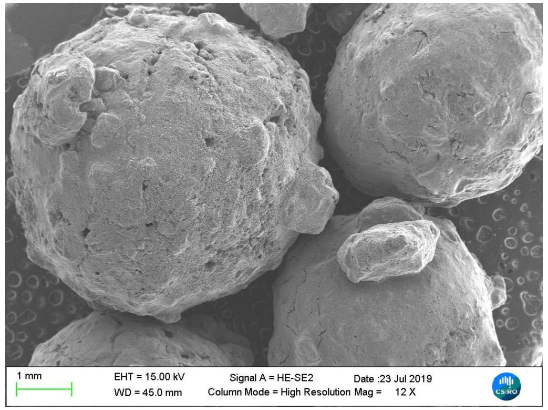
- A shaft calciner offers more sustainable CPC production vs rotary kiln.
  - GPC fines loss is lower (3-5%) so more tons CPC/ton GPC.
  - Lower fines loss = less CO_2 and SO_2.
  - Closed loop water cooling system for CPC.
- New RCI calciner will have NH_3scrubber = NH_4SO_4 byproduct.

Anhydrous Carbon Pellets

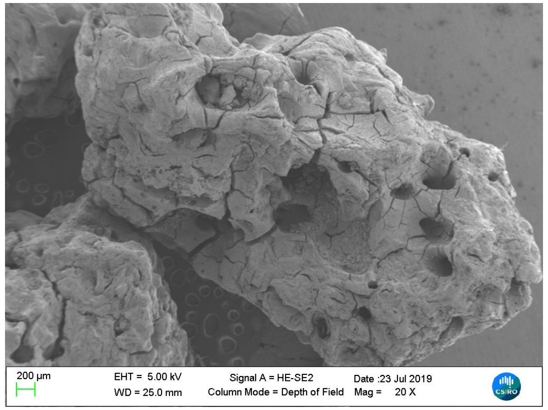
- An innovation aimed at further reducing fines loss and emissions.
- Enhances product quality with production of higher bulk density pellets.
- Construction of commercial plant underway.







Calcined ACP

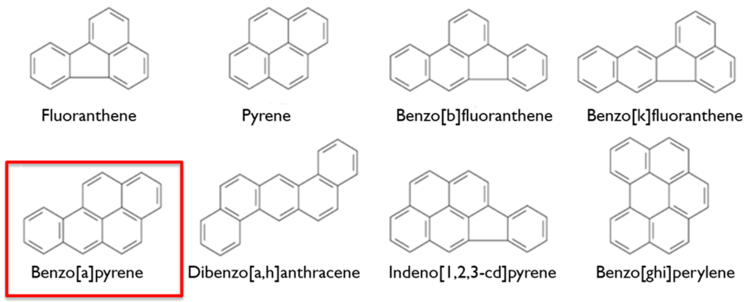


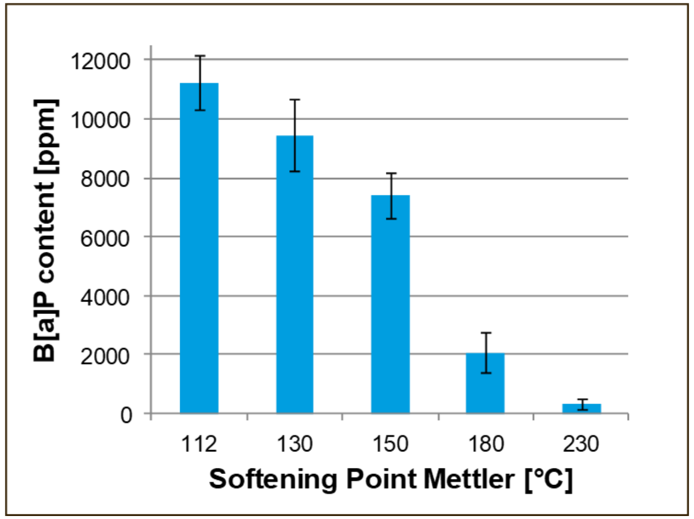
Regular CPC

Sustainability Issues With Coal Tar Pitch Binder Use

- **Use of CTP has come under increased regulatory pressure due to PAH content (carcinogenic).**
- **Most smelters use CTP in liquid form to reduce OH&S risk but more controls being added.**
- **Significant work done to explore lower PAH pitches**
  - **Petroleum pitches have 10x lower PAH (EPA) levels. Hybrid pitches are CTP/PP blends. LM 1971 – 2019, ICSOBA 2019.**
  - **Hybrid pitches used successfully in past in prebake smelters and extensively in Soderberg smelters.**
  - **Rusal: EcoSoderberg Technology – LM 2021 Thurs am.**
  - **High and very high SP pitches (130-180°C) promising but economics have moved in wrong direction LM 2015, 2017.**

PAH's – PolyAromatic Hydrocarbons





Developments with Cathode Lining Materials

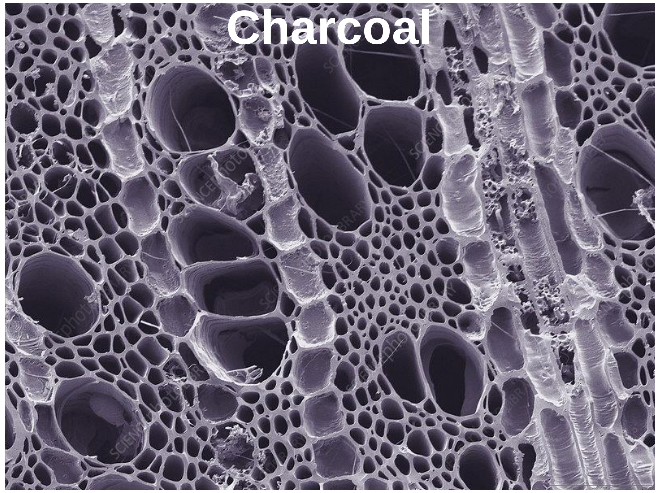
- Ramming pastes traditionally produced with CTP.
- A significant number of suppliers offer “green” ramming pastes using binders like molasses or very low PAH CTP materials (like CARBORES®).
  - LM 2011, 2012, ICSOBA 2015, ICSOBA 2019.
  - Is now a regularly used material in the industry.

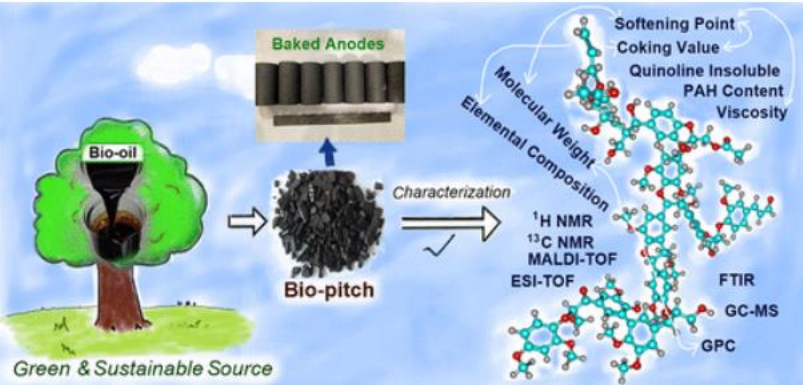
neo² RAMMING PASTE
cleo² RAMMING PASTE
ideo² RAMMING PASTE

Bio-Carbon Alternatives

- **Substantial work done in multiple studies to evaluate bio-derived carbons.**
  - Hydro Aluminium: LM 2010 (charcoal).
  - UQAC: MS&T 2013, Energy Fuels 2018 (biomass coke).
  - CSIRO: US Patent 2010 (biomass coke).
  - US Department of Agriculture: LM 2017 (bio-coke).
  - Laval University: ICSOBA 2016 (charcoal) LM 2019 (bio-pitch), ACS 2020 (bio-pitch).
  - SINTEF: extensive work since 2016, LM 2020. Review paper being presented Wed in Electrode session.

➡ **Challenging due to low density, high reactivity, low coking value etc.**





Inert Anodes

- **Now 20 years since 2001 TMS keynote session on inert anodes.**
- **Triggered by Wall St. report issued in 2000 titled "An Aluminum Revolution".**
- **Full commercial implementation projected within 2-3 yrs.**
- **Inert anodes remain very desirable goal for industry but technology development is complex and challenging.**

Inert Anodes and Other Technology Changes in the Aluminum Industry—The Benefits, Challenges, and Impact on Present Technology

Les Edwards and Halvor Kvande JOM • May 2001


Les Edwards

Although the year 2000 will be remembered by many people as the start of the new millennium, for those in the aluminum industry, it will also be remembered as the year in which inert anodes became the most talked-about technology in the industry. On 22 June 2000, a now well-known Wall Street analyst, Tom Van Leeuwen, issued a report titled *An Aluminum Revolution*,[1]

what are the benefits, what new breakthroughs have been made, what challenges remain, and so on. Against this background, the session "Responding to Inert Anodes and Other Technology Changes in the Aluminum Industry—The Benefits, Challenges, and Impact on Present Technology" was organized.

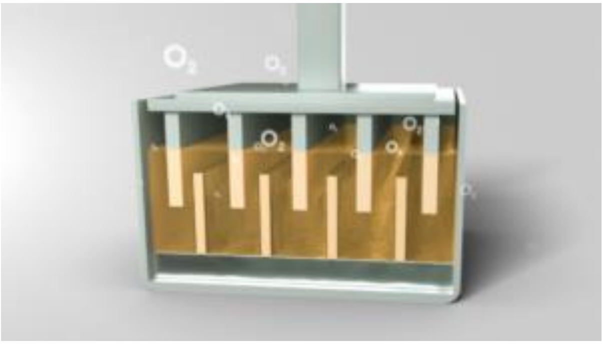
Experts from around the world were invited to prepare presentations and papers on various aspects of inert anode technology. Their work resulted in the following program, which was organized in a logical sequence to address some of the critical issues raised:

Cells," by Craig Brown, discussed potential advantages to taking a new approach to designing and operating an inert anode/wettable cathode cell. Most work to date has concentrated on retrofitting inert anodes to conventional cells, imposing many operating and design constraints.


Halvor Kvande

Inert Anodes

- Will eliminate smelter CO_2, SO_2 and PFC process emissions + carbon supply chain emissions.
- ELYSIS approach combines inert anodes with wettable cathodes.
- Rusal has large IA program.
- Energy penalty vs carbon anode cells significant (Solheim LM 2018).
- Supply chain emissions from IA & wettable cathodes not known.



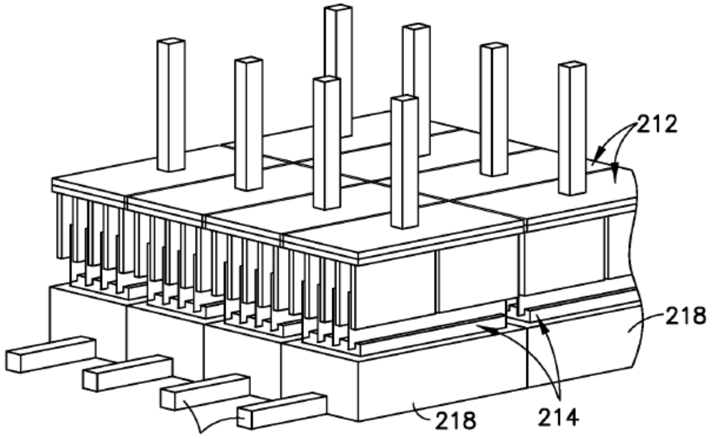


FIG.5

Elysis: US Patent 2020/0010967 A1

Summary and Conclusions

- Carbon supply chain emissions (CPC + CTP + anode production) contribute ~15% to hydro based smelter CO_2 emissions and ~4% for smelters using coal powered smelter emissions.
- Addition of waste heat recovery and FGD systems improves sustainability of CPC production.
- Efforts to find more sustainable carbons will continue but limited success to date. Eco-friendly ramming pastes now routinely used.
- Carbon anodes likely to remain in use for foreseeable future but work on inert anode development will continue.
- There are many opportunities to reduce carbon related emissions and the industry should continue to pursue these.