



9 June 2016
Nancy, France

PRODUCING STRATEGIC METALS TO SUSTAIN AN URBANIZING PLANET

ROBERT FRIEDLAND, Executive Chairman

IVANHOE MINES
NEW HORIZONS



Beijing's smog-shrouded year

2015 month-by-month rows of daily images of a slice of Beijing's skyline



COURTESY ZOU YI

Source: CNN, March 16, 2016

Disruption happens quickly: Can you spot the *car* in 1900?



5th Avenue, NYC, April 15, 1900

Disruption happens quickly: Can you spot the *horse* in 1913?



Source: Tony Seba, from US National Archives

5th Avenue, NYC, March 23, 1913

25 29 - 9

Airpocalypse:

Scenes of an urban scourge

**“UK air pollution
is a public health emergency”**

theguardian 27 April 2016



Photo: John Esslinger

**“New Delhi begins second
round of car restrictions
to limit air pollution”**

AP Associated Press 15 April 2016



Photo: Hindustan Times/Getty

Airpocalypse...

**“Mexico City’s smog is so bad,
it wants 40 percent of cars
to stay off the road”**

Ap Associated Press **2 May 2016**



Photo: Ronaldo Schemidt/AFP/Getty Images

**“Paris introduces
once-a-month ban on cars
in bid to tackle air pollution”**

THE INDEPENDENT **26 April 2016**



Photo: Reuters

“China air pollution kills 4,000 people a day”

Bloomberg 13 August 2015



Picture alliance/AP Images

A high price: Sickened cities

Toxic smog clouds future of urbanizing Earth

“Air pollution kills 3.3 million a year globally”

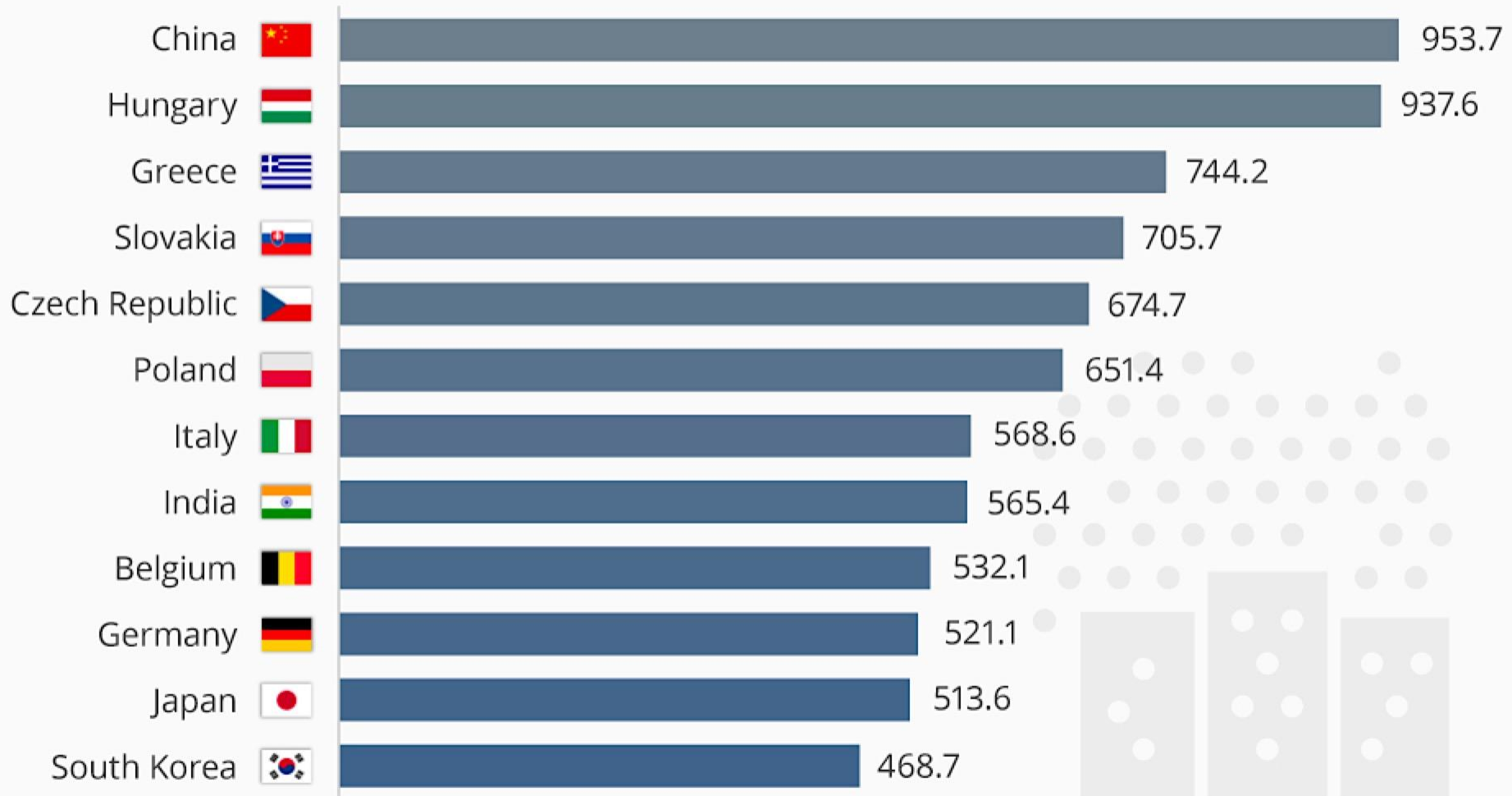
AP Associated Press 16 September 2015

- Countries with most annual fatalities:
China 1.4 million; India 645,000; Pakistan 110,000.
- Air pollution kills more people than HIV and malaria combined.
- A study projects yearly death toll from polluted air will double by 2050 if trends don't change.



Europe Matches Asian Giants In Air Pollution Deaths

Deaths from ambient particulate matter & ozone pollution per million inhabitants*



* selected countries, 2010

Source: OECD

Studies reveal dangers of prolonged exposure to air pollution

April 2015 Long-term exposure even to low levels of increased particulates in the air can cause **brain damage** and **higher risk of strokes**.

South China Morning Post

May 2016 Landmark study of elderly Hongkongers ties air pollution to **multiple types of cancer**.

South China Morning Post

January 2016 19% higher risk of women **giving birth prematurely** if they are exposed to fine-particle air pollution during pregnancy.

UNIVERSITY OF
Cincinnati



Air pollution a global “public health emergency” – WHO declaration January 2016



March 2014. The UN's World Health Organization released estimates of air pollution's toll on humanity, declaring risks to be far greater than previously thought.

- Air pollution accounts for one of every eight deaths around the world. It claimed 7 million lives in 2012 – almost half caused by outdoor sources of pollution.
- *“This finding more than doubles previous estimates and confirms that air pollution is now the world's largest single environmental health risk.”*
- *“Few risks have a greater impact on global health today than air pollution; the evidence signals the need for concerted action to clean up the air we all breathe.”*

— Dr. Maria Neira, WHO Director

Platinum-group metals critical to healthier air

- Urbanizing and industrializing nations are progressively upgrading rules requiring catalytic converters that use platinum-palladium-rhodium to control harmful emissions in exhausts from vehicles and factories.
- China has pledged to remove **6 million** high-polluting cars and trucks from its roads. Beijing has imposed stricter, Euro 5-type emission standards on new gasoline-powered vehicles sold in the city.
- China's fleet of 90 million passenger cars will balloon to 400 million by 2030.



Japanese government backs commercialization of fuel-cell vehicles



- ▶ **2016 is Honda's Year of the Fuel Cell.** Sales of the Clarity sedan began in Japan in March. California launch planned in late 2016, with pricing similar to hybrids: \$60,000. Targeted range more than 480 km.



- ▶ **Toyota's Mirai** travels 500 km on a tank of hydrogen and refills in under 5 minutes. 3,000 vehicles to be produced in 2017 to meet stronger-than-expected demand.

Sources: insideevs.com; Nikkei, May 29, 2014; Reuters, Jan 21, 2016; Toyota, November 17, 2014.

“South Korea wants one in 10 of new cars sold in the country to be a fuel-cell model by 2030”

THE WALL STREET JOURNAL December 2015

- In December 2015, South Korea announced a 27.5 million won (\$23,250) subsidy to each buyer of a fuel-cell car, which sells for around 85 million won (\$74,300).
- South Korea plans to increase number of hydrogen refuelling stations from 10 at present to 520 by 2030.



Fuel-cell-powered Hyundais delivered to customers in the UK.

Germany's Audi and Volkswagen purchased fuel-cell patents from Canada's Ballard in 2015

BMW Gran Turismo. Range 500 km (310 miles).
“By around 2025 to 2030, we expect fuel-cell cars to have an established presence...”

– Matthias Klier, head of BMW powertrain research.

Source: BMW AG, Bloomberg, July 2, 2015



Volkswagen has been testing its hydrogen fuel-cell technology with a fleet of VW Passat HyMotion cars in California.



The **Audi A7 H-Tron Quattro Concept** combined hydrogen fuel-cell technology with a plug-in hybrid.

Built with help from Ballard Power Systems.



Source: Transportevolved.com, February 11, 2015; Audi

“China’s hydrogen-powered future starts in trams, not cars”

Bloomberg March 2015

- A world first: China’s tram (streetcar) runs on hydrogen power via onboard fuel cells.
- Refuels in 30 minutes; emits only water.
- China to spend \$32 billion extending tracks over more than 1,200 miles.



Photo: Qingdao Sifang Co.

Signposts to the hydrogen century...?

- South Korea's POSCO Energy ► operates the world's largest fuel-cell park near Seoul (its 59 megawatts could power 59,000 homes).



- ◀ Germany's largest fuel-cell power plant commissioned in Berlin in Dec 2014.

- In London, England, a new 37-storey office tower ► with a rooftop public park, will be powered and heated by a 300-kilowatt fuel-cell stack.



London's 'Walkie-Talkie' building

In theory, fuel-cell vehicles vs electric vehicles when using gas-fired power generation

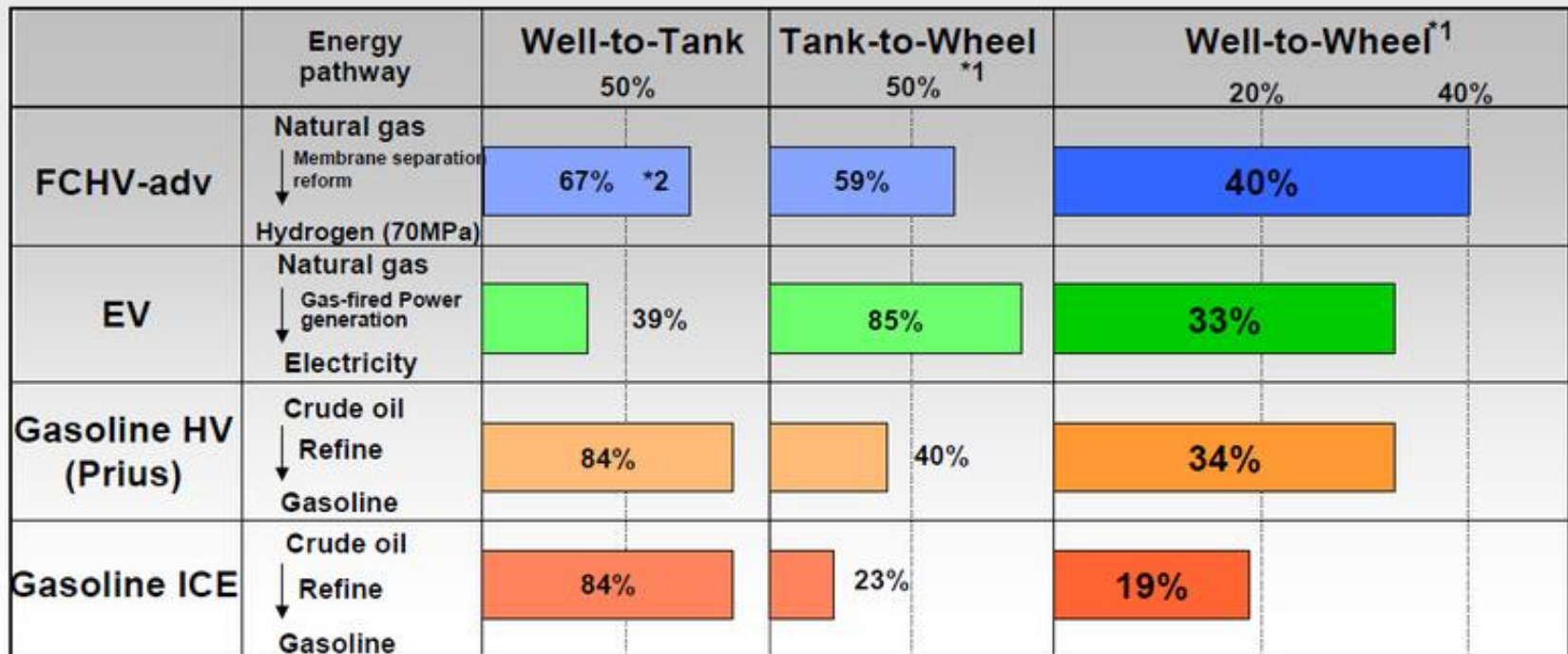
| FUEL CELL VEHICLES | ELECTRIC VEHICLES |
|--|--|
| <u>CONVERSION EFFICIENCIES:</u> Natural gas to Electricity ~39% Electricity to Hydrogen (Electrolysis) ~70% Hydrogen to Electricity (Fuel Cell) ~60% TOTAL PATHWAY EFFICIENCY is $39\% \times 70\% \times 60\% = \sim\mathbf{16.38\%}$ | <u>CONVERSION EFFICIENCIES:</u> Natural gas to Electricity ~39% Electricity to Battery ~85% TOTAL PATHWAY EFFICIENCY is $39\% \times 85\% = \mathbf{33.15\%}$ |

In theory, electric vehicles are ~2x as efficient as fuel-cell vehicles using gas-fired power generation.

However, this is not what happens in practice, nor what is intended.

In practice, bulk hydrogen is usually produced by steam reforming

In today's energy system, the more accurate comparison of energy efficiency between fuel-cell vehicles vs electric vehicles is to use the steam reforming method of producing hydrogen for fuel-cell vehicles and gas-fired power generation to generate electricity for electric vehicles, as shown in Toyota's recent research below.



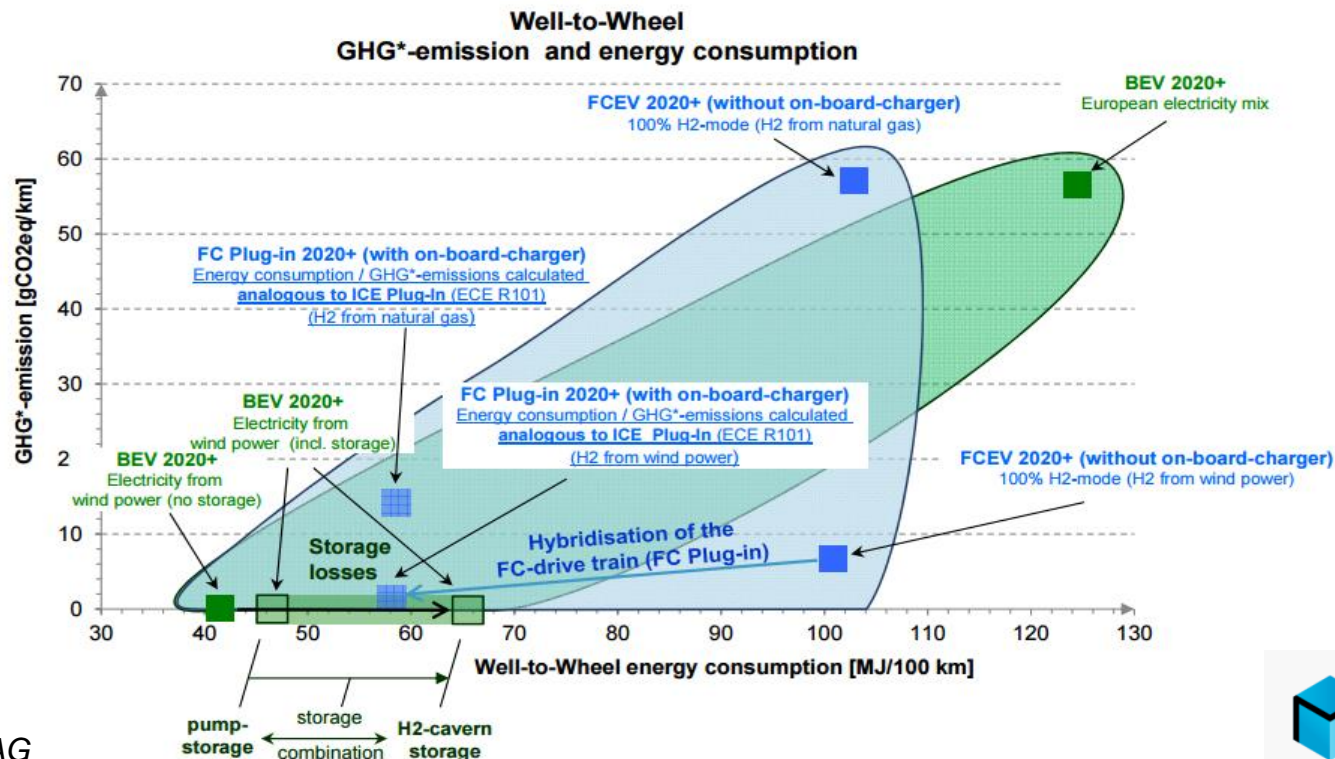
*1 Tank-to-Wheel efficiency: measured in the Japanese 10-15 test cycle

*2 Efficiency difference between 35MPa and 70MPa: approx. 2%

Well-to-wheels energy consumption: Largely equal between fuel cell vehicles and electric vehicles

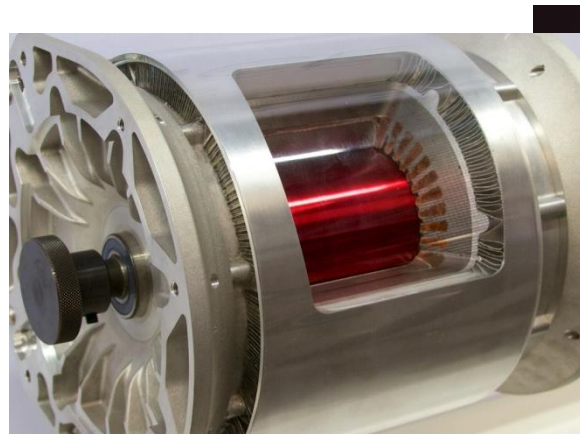
A study by Daimler which compares fuel-cell vehicles and electric vehicles emissions in the EU has found fuel cell vehicles and electric vehicles are largely equal on a well-to-wheels energy consumption basis.

Comparison of the WTW GHG*-emission and energy consumption EUCAR BEV / FCEV / FC Plug-in 2020+



Buyers paid US\$1,000 deposits on **115,000** Tesla 3 all-electric cars even before its unveiling March 31

- Unprecedented worldwide market enthusiasm for an all-electric car pushed paid reservations to 276,000 in just three days. Would-be buyers lined up for days outside Tesla stores.
- **Tesla 3 could become the most successful electric-car launch in automotive history.**
- In 2015, U.S. electric & hybrid registrations totalled 116,000; in Japan, 25,000; Britain, 28,000.
- Tesla uses highly advanced, efficient, copper induction motors, with copper rotors (*inset*).
- Price US\$35,000; range 346 km (215 miles); 5-seater; 0-97 km (0-60 mph) in 6 seconds.



Copper at heart of lithium battery technology

Hybrid & all-electric vehicles use 200% to 300% more copper than conventional gasoline-powered autos

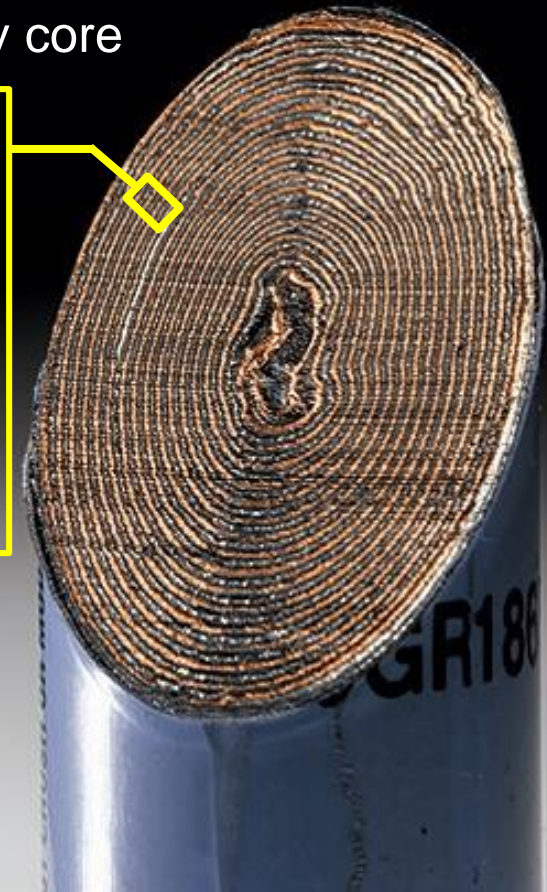
Copper foil used in lithium batteries



Lithium battery core

Layers of:

- Copper
- Lithium cobalt oxide
- Plastic
- Graphite
- Copper

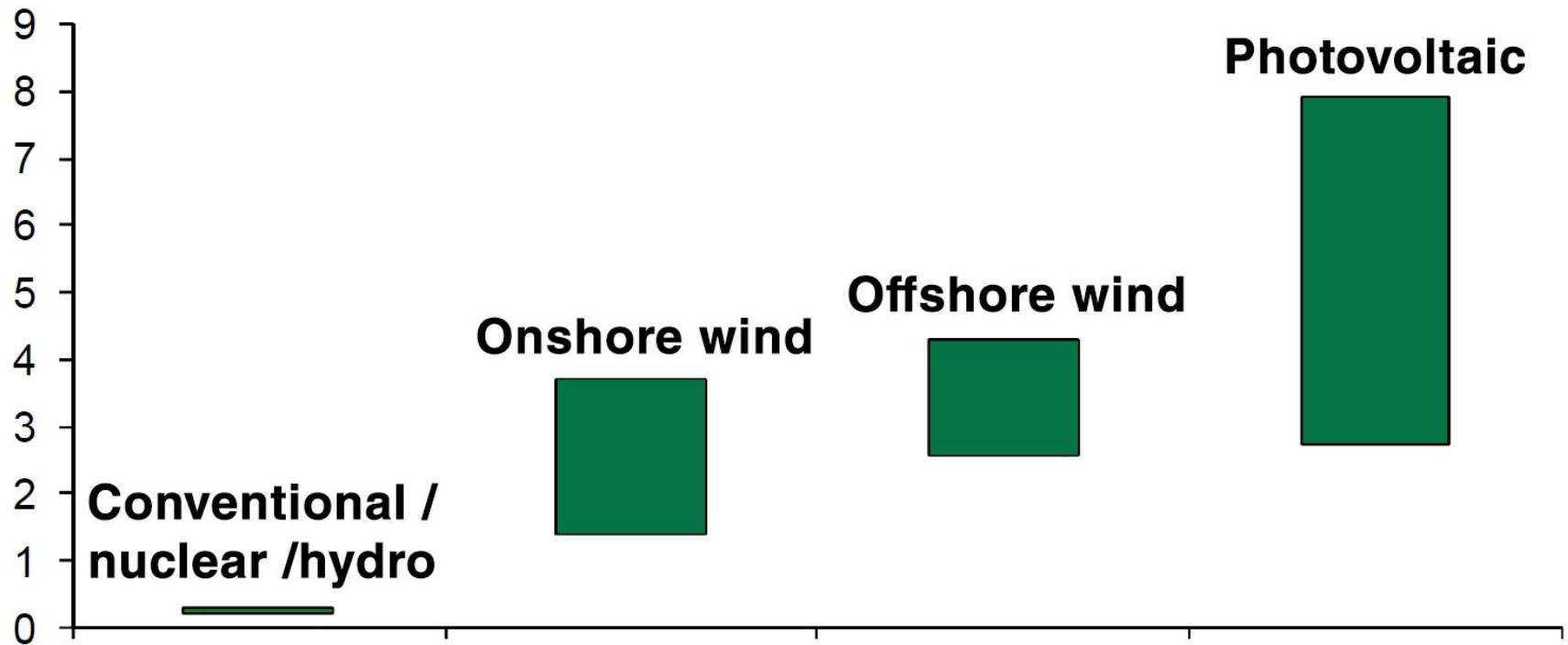


Green energy demands copper use

Renewable sources can be up to 37 times as copper intensive as the same energy generated from conventional capacity!

Copper required for increased power output

kg copper per incremental megawatt hour of output



Copper: the friendly, **green**, bug fighter

ANTI-MICROBIAL COPPER: THE BIGGEST LIFE-SAVING ADVANCE AGAINST HEALTHCARE-ACQUIRED INFECTIONS SINCE HAND WASHING

- Surfaces in hospital rooms covered with **anti-microbial copper** can reduce by 58% patient infections acquired through health-care.
- Anti-microbial copper (including alloys such as brass and bronze) can kill up to 99.9% of bacteria, including 'superbugs' resistant to antibiotics, within 2 hours – and keep on killing, studies show.
- WHO: 7 million infections a year in healthcare facilities cost \$80 billion globally. In U.S., 1 of every 20 patients develops a healthcare-related infection, resulting in 100,000 deaths a year.
- Products include bed rails, tray tables, door knobs, IV poles, basins & stretchers.

**Copper everything
in intensive-care room**



Oyu Tolgoi, Mongolia

COPPER

- December 2015 – Signing of \$4.4 billion project finance facility
- May 2016 – Approval for \$5.3 billion underground mine to proceed
- 2015 production – **202,000 tonnes copper & 653,000 oz gold**
- 2015 mine-site cash costs - \$0.57 per pound of copper
- 2015 operating cash flow - \$650 million



Platreef Platinum Mine Development

South Africa



Mining by hand common in South African narrow-reef mining

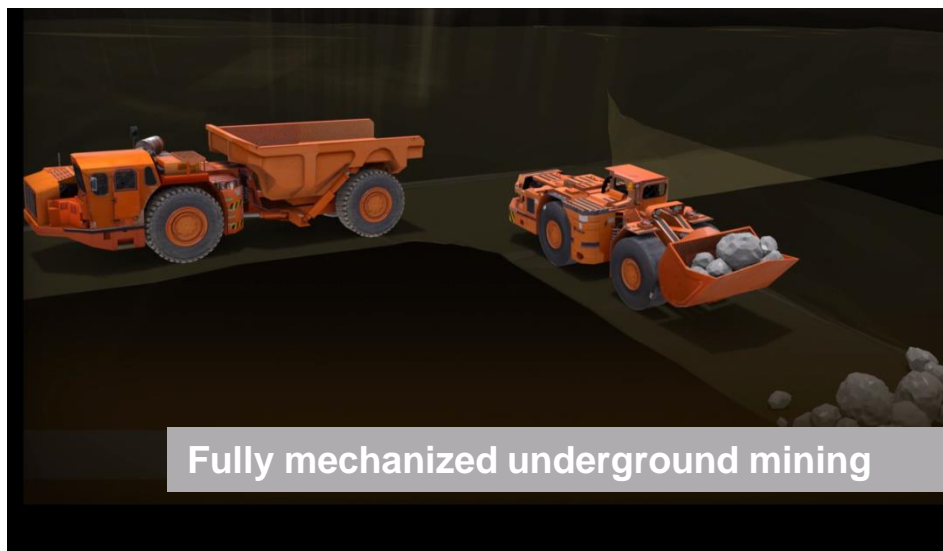
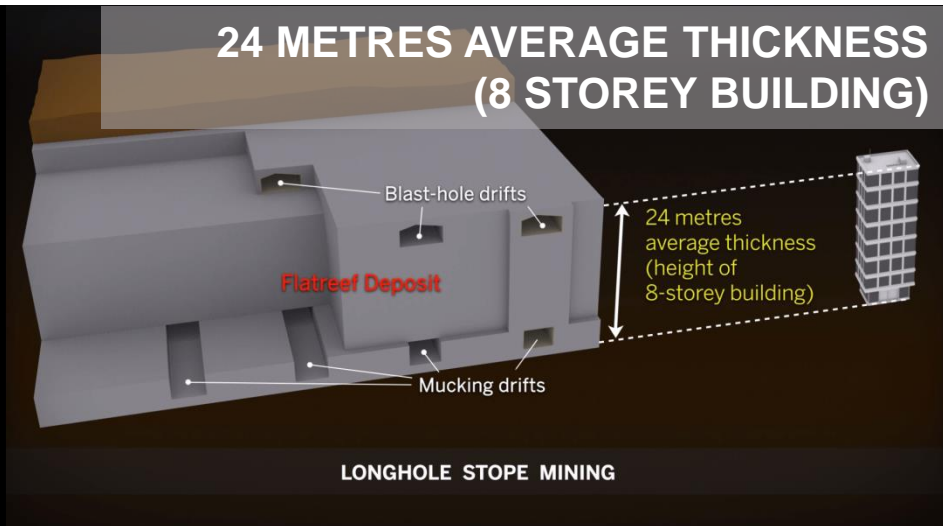
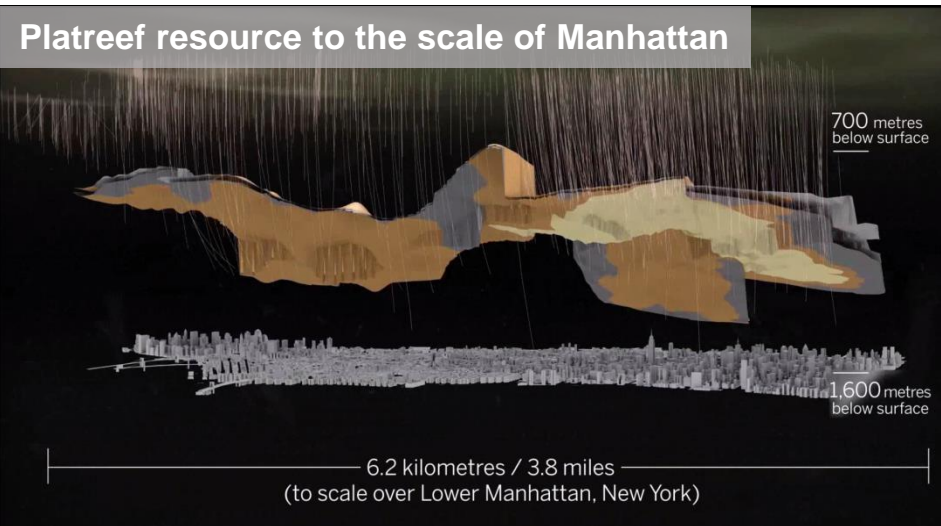
PLATINUM



(For illustration purposes only; photo not taken at Platreef Project.)

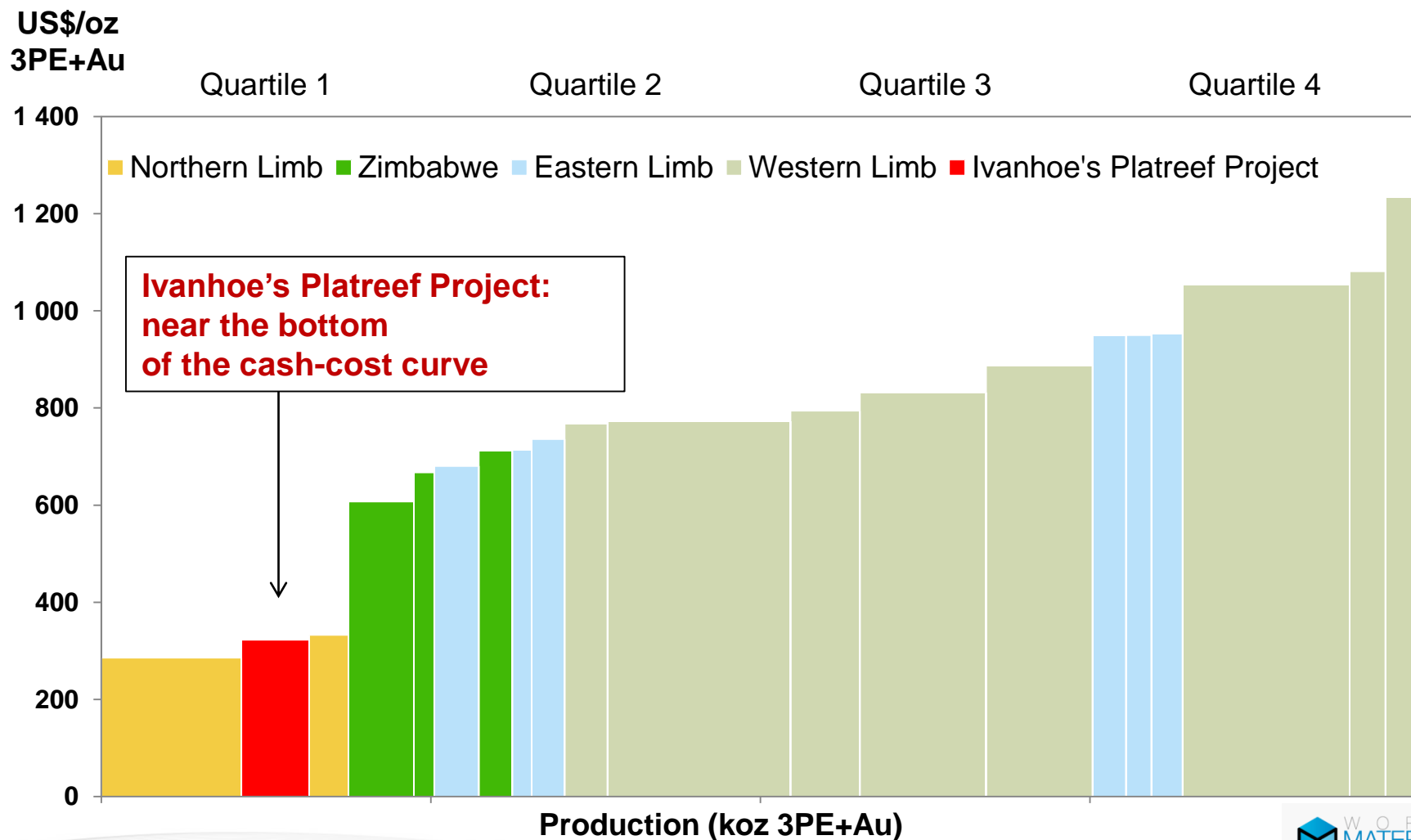
Fully automated underground mining in current Platreef development

PLATINUM



Platreef's potential US\$322 per 3PE+Au ounce (net of base-metal by-products) ranks near the bottom of the world's cash-cost curve

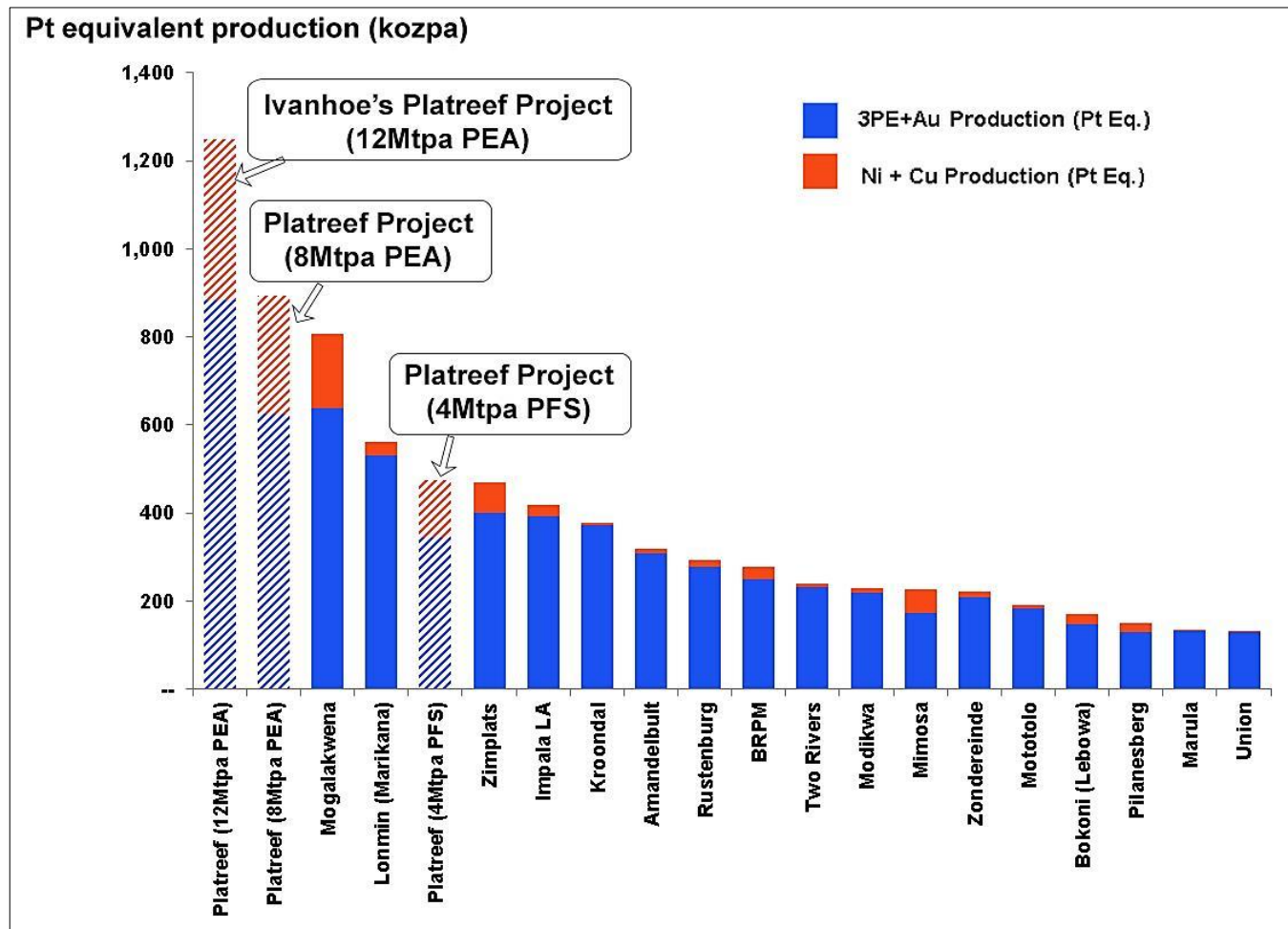
PLATINUM



Source: SFA (Oxford) 2015. Data for Platreef Project and Waterberg are based on each project's reported PFS and PEA parameters respectively, and are not representative of SFA's view.

At 12 million tonnes/year, Platreef will be the world's largest platinum-group metals mine

PLATINUM



Source: Production estimates for projects other than Ivanhoe's Platreef Project have been prepared by SFA (Oxford). Production data for the Platreef Project (platinum, palladium, rhodium, gold, nickel and copper) are based on reported PFS and PEA data and are not representative of SFA's view. All metals have been converted by SFA (Oxford) to platinum equivalent ounces at price assumptions of US\$1,384/oz platinum, US\$803/oz palladium, US\$1,265/oz gold, US\$1,173/oz rhodium, US\$7.66/lb nickel, and US\$3.11/lb copper. Note: As the figures are platinum equivalent ounces of production they will not be equal to 3PE+Au production.

Strong and supportive strategic partners

- Itochu, JOGMEC (Japanese government) and JGC acquired 10% for ~US\$300M.
- Potential Japanese government-supported project financing and off-take agreements.



**Itochu team
site visit,
December 2015**

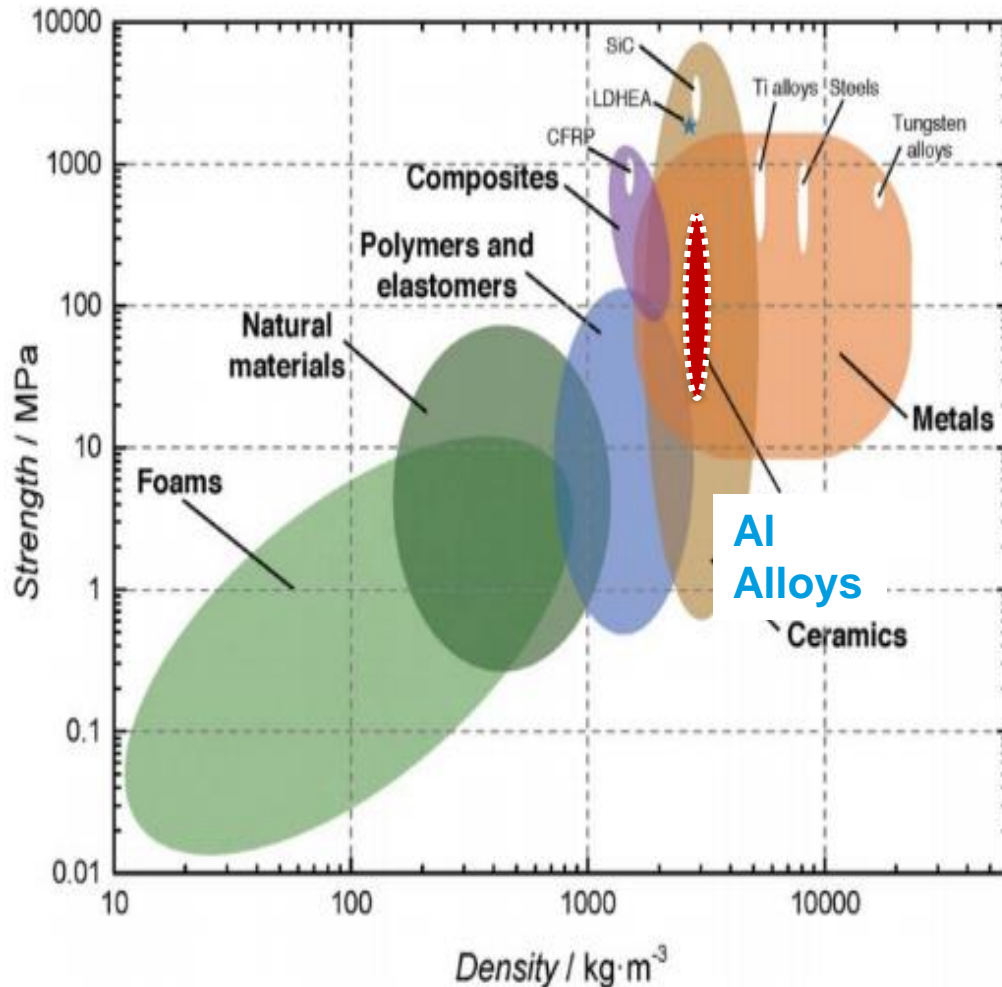


SYERSTON PROJECT
AUSTRALIA

Clean TeQ Holdings Limited
(ASX:CLQ)



Scandium I Revolutionising aluminium



Scandium has the highest strength to weight ratio of any aluminium alloying element¹

Modest additions of scandium (0.2 – 0.7%) to existing alloys can provide low-cost, high strength, light-weighting solutions for:

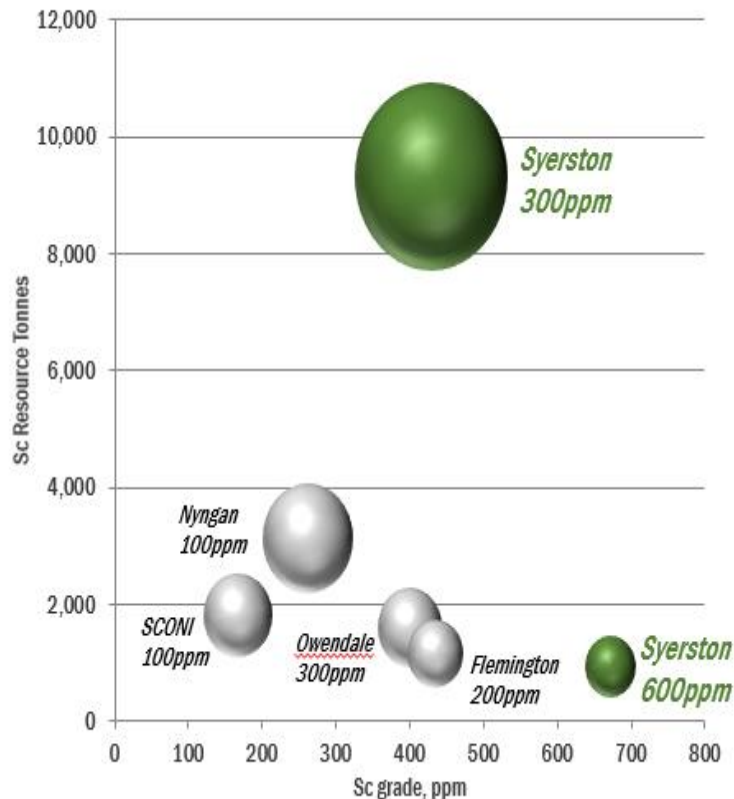
- Aerospace
- Automotive
- Rail
- Marine

Scandium also enhances the alloy's corrosion resistance, weldability and plasticity

¹: K. Venkateswarlu, et al, High Strength Aluminum Alloys with Emphasis on Scandium Addition, 2008

Scandium I Supply issues resolved

Australian Scandium Mine Comparison¹:



(ASX:CLQ)

Clean TeQ's Syerston Project in Australia contains the world's largest known mineable resource of scandium

The 18,000 tonnes of contained scandium oxide is enough to meet large scale industrial demand of alloy for hundreds of years

The exceptionally high grades allow low-cost production with easy scalability

¹ Measured and indicated JORC resources shown at stated Sc cut-off.

Scandium I New materials, new industries



Airbus APWorks' Light Rider – the world's first 3D printed motorcycle, launched May 2016

The frame weighs 6kg and is manufactured from Scalmalloy – an aircraft-grade aluminum-scandium alloy that rivals the specific strength of titanium

The entire bike weighs 35kg and runs on a 6kWh Li-ion battery, for a total range of 60km

An excellent example of high-performance aerospace technology being leveraged across industries and platforms



Introduction to I-Pulse





Thank you

Ivanhoe Group of Companies

IVANHOE MINES
NEW HORIZONS

