

Vital metals to sustain an urbanizing planet



29-30 June 2017

Coming soon:
8 billion of us.

ROBERT FRIEDLAND
Executive Chairman

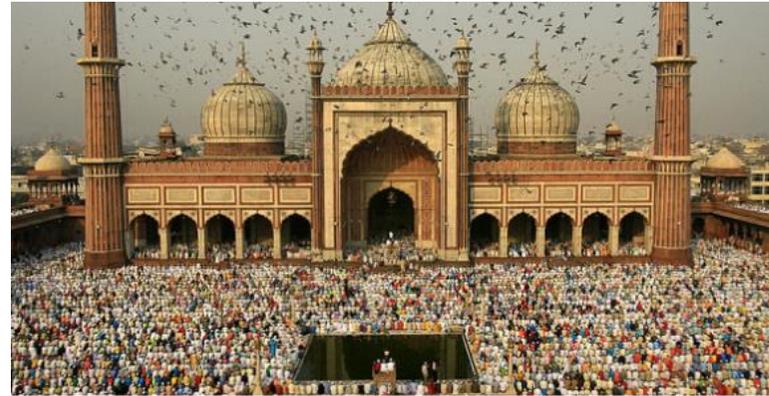
IVANHOE MINES
NEW HORIZONS

By **2050**, 6.3 billion people could live in urban areas.
That would be around 2.5 billion more than today.

Today's top 4 megacities
(each with more than 10 million people)



1. Tokyo: 1990, 32.5 million; 2014, 37.8 million;
2030 (est.), 37.1 million.



2. Delhi: 1990, 9.7 million; 2014, 24.9 million;
2030 (est.), 36.0 million.



3. Shanghai: 1990, 7.8 million;
2014, 22.9 million; 2030 (est.), 30.7 million.



4. Mexico City: 1990, 15.8 million;
2014, 20.8 million;
2030 (est.), 23.8 million.

Sources: United Nations; Wikipedia.

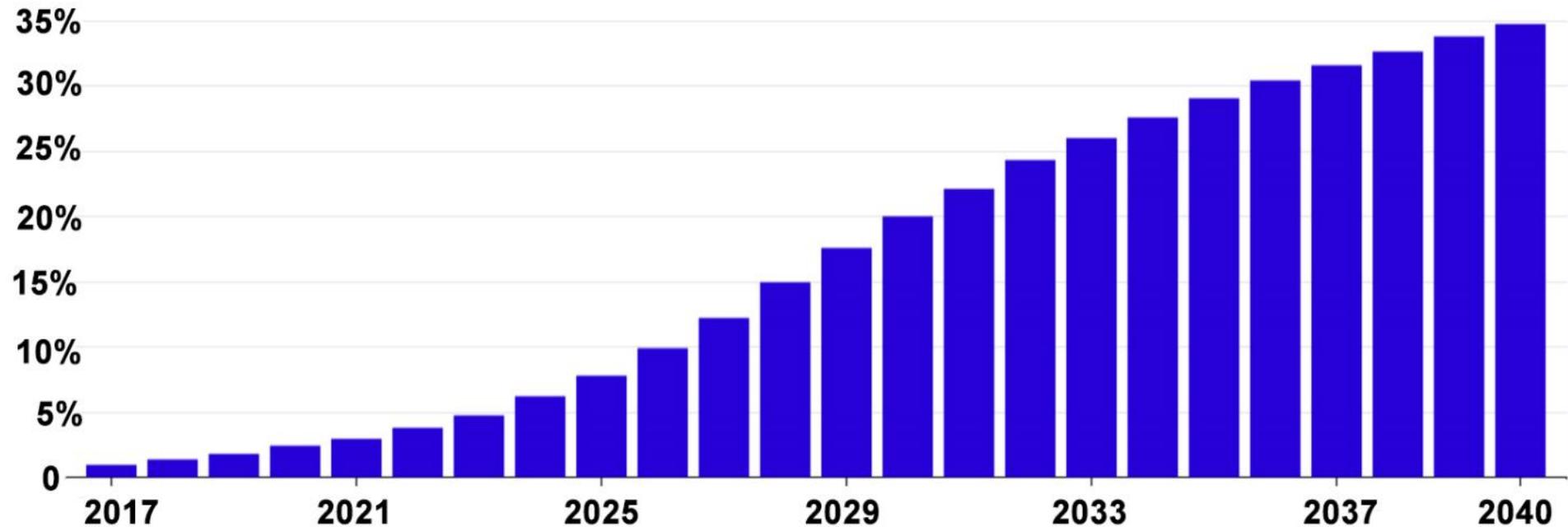
“The era of the electric vehicle is dawning ”

– Mark Fields, Ford CEO, February 2017

“Almost every automaker has some electric vehicle program”

– Elon Musk, Tesla CEO, April 2017

EVs projected to make up a fifth of new car sales by 2030, and 35% by 2040.



The EV Initiative, a multi-government program – including China, France, Germany, the U.K. and U.S. – aims for 30% market share by 2030.

Source: Bloomberg New Energy Finance

Toxic smog clouds future of urbanizing Earth

Outdoor air pollution linked to 3 million deaths each year.

– UN World Health Organization, May 2017

Ambient air pollution is the greatest environmental risk to health.

– UN World Health Organization, May 2016

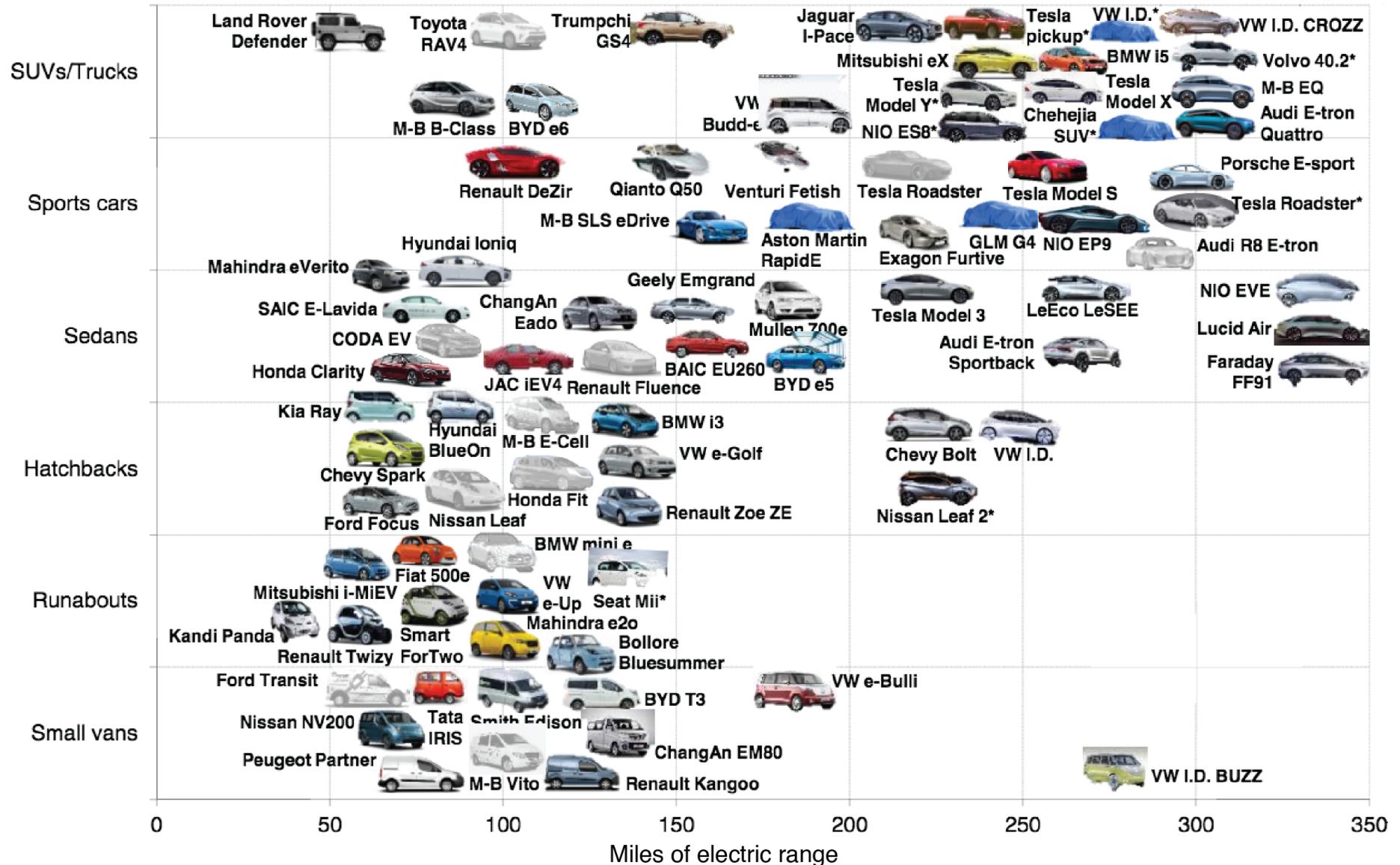
Key is to satisfy the needs of new urbans and offer them access to clean air & water as well as to proper housing and mobility solutions.

– World Materials Forum, June 2017



Electric-car boom

More than 120 models by style and range available through 2020



Source: Bloomberg New Energy Finance

Four of the world's top carmakers to build super-fast electric-car charging network across Europe in 2017

- **Daimler, BMW, Ford** and **Volkswagen** plan to electrify Europe by installing hundreds of fast-charging stations.
- EV owners will be able to take road trips across Europe without range anxiety.
- Network's 350 kW capacity will be 140% more powerful than Tesla's 145 kW supercharger network.



Next: Recharging – without plugging in!

In January 2017, Ford unveiled a pilot program in Europe and the U.S. that will provide **wireless induction charging** of electric cars parked over a surface pad that generates an electromagnetic field.

Copper demand for electric cars to rise nine-fold by 2027

– International Copper Association

Copper, a major commodity winner in growing market for EVs, is at the heart of lithium batteries and induction motors

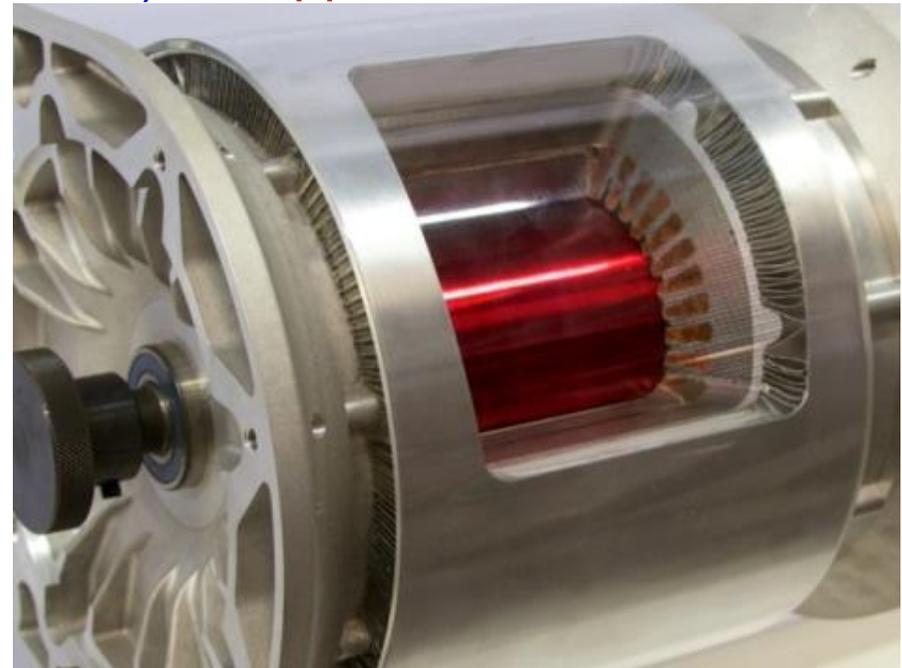
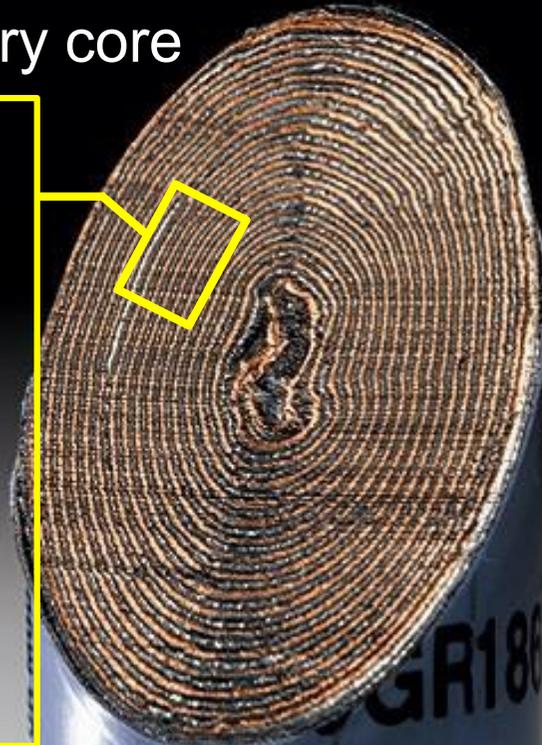
Windings contain approx. 40 kg (88 lbs.) of copper.

Battery pack contains approx. 37.5 kg (83 lbs.) of copper.

Lithium battery core

Layers of:

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



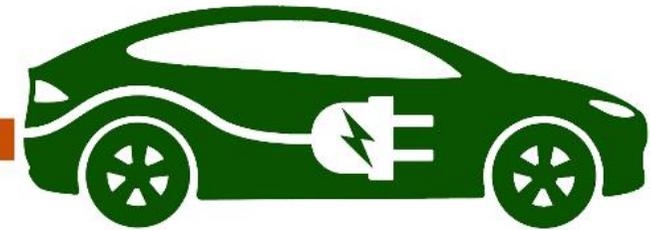
Tesla 3 induction motor.
Kilos of copper – no rare earths!

All-electric cars now use four times more copper than conventional gasoline-powered autos. Future, larger electrics could use much more.

FUTURE PLUG-IN ELECTRICS

(Bernstein projection for a generation of bigger, longer-range electrics)

360 lbs. / 163 kg



PLUG-IN ELECTRIC

176 lbs. / 80 kg



Tesla Model 3

HYBRID

88 lbs. / 40 kg



Hyundai Hybrid

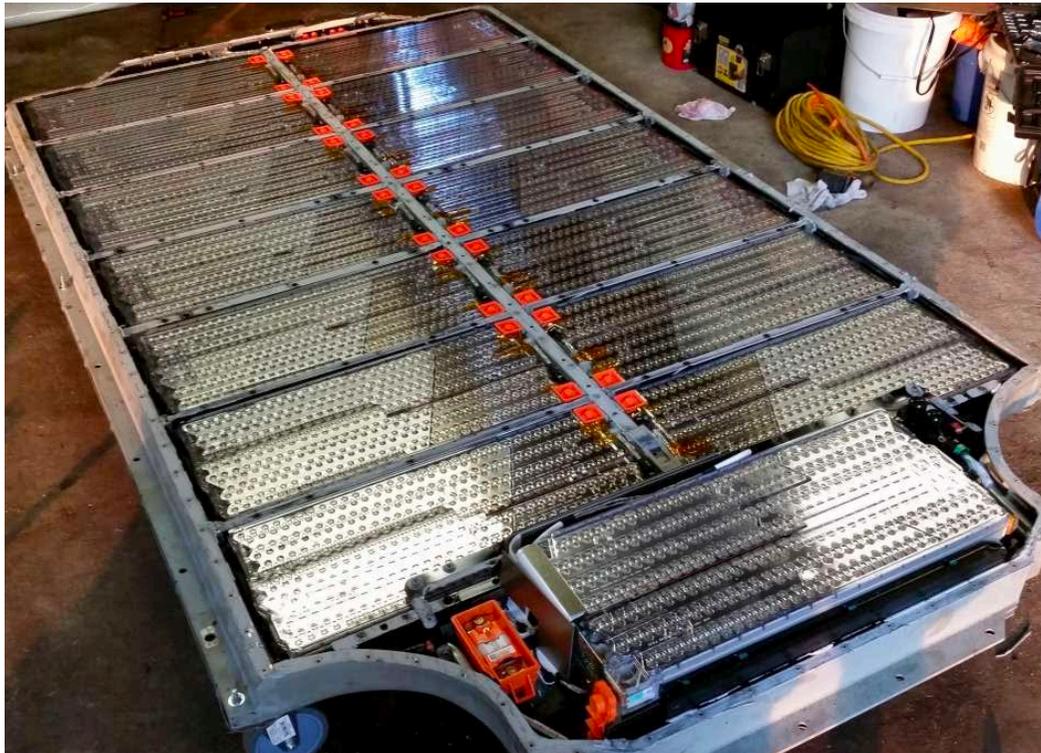
GASOLINE

66 lbs. / 20 kg



Ford Mustang

Batteries in new Tesla Model 3 are 30% more energy-dense than in the earlier Model S – requiring more copper, nickel and cobalt



+ CATHODE

An NCA formulation is used with the approximate ratio:



80%
Nickel



15%
Cobalt



5%
Aluminium



Lithium

- ANODE



Silicon



Graphite

ELECTROLYTE



Lithium
salt

OTHER



Copper /
aluminium
foil

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.
- Johnson Matthey expects the market will remain in a “significant” deficit in 2017 as new Euro 6 legislation boosts demand from autocatalyst manufacturers.



Platinum also a key to hydrogen's potential

A stack of fuel cells powering a small car contains approximately 30 grams (approximately one ounce) of platinum.

Fuel-cell electric vehicles (FC-EVs) use compressed hydrogen gas, that when combined with oxygen and drawn through an electrolyte, creates electricity.

The electricity is used to send power to a lithium-ion battery, which then powers an electric motor.

The only exhaust is water vapor.

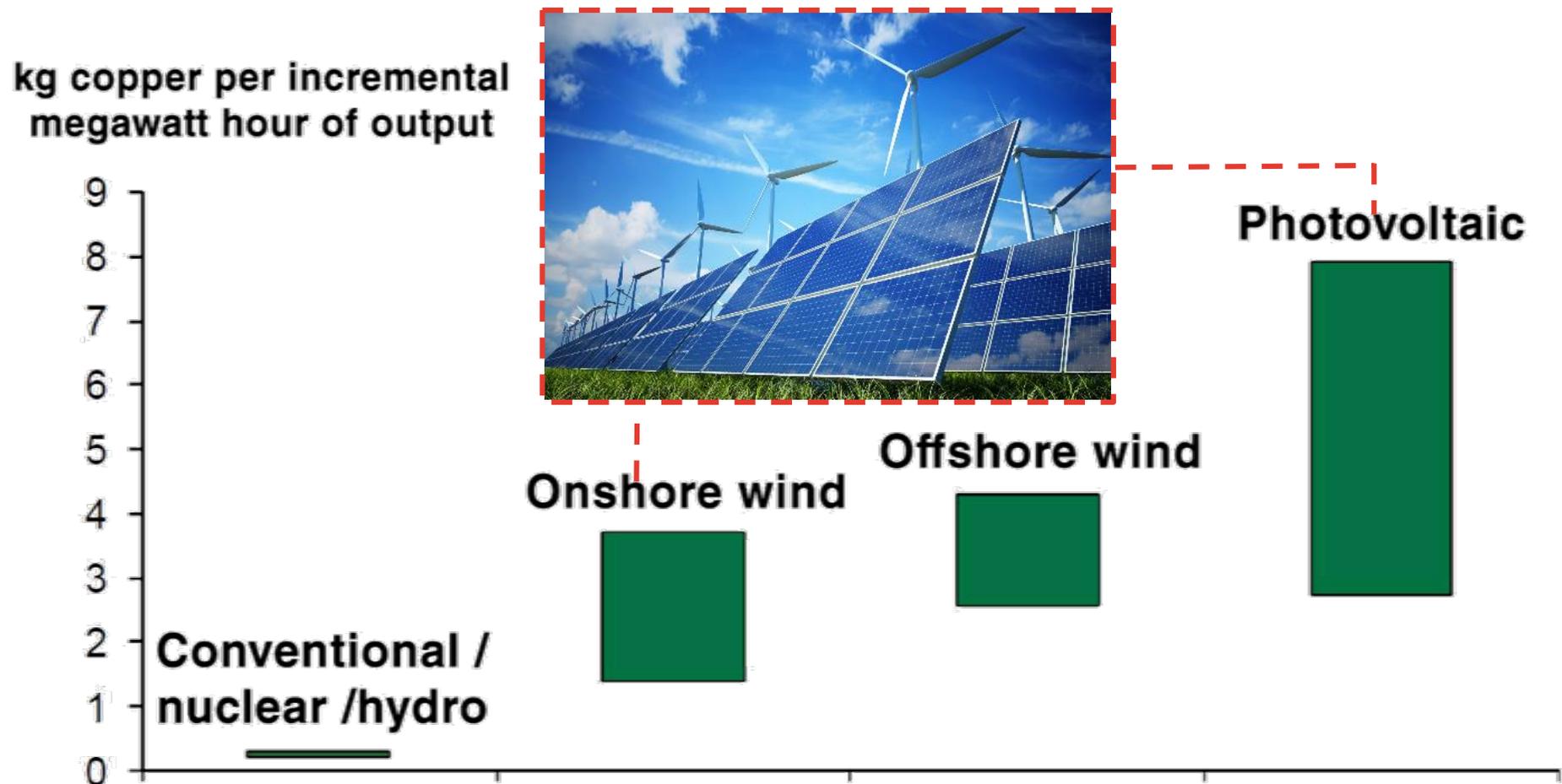
Fuel-cell power unit in Honda Clarity



Green energy demands greater copper use

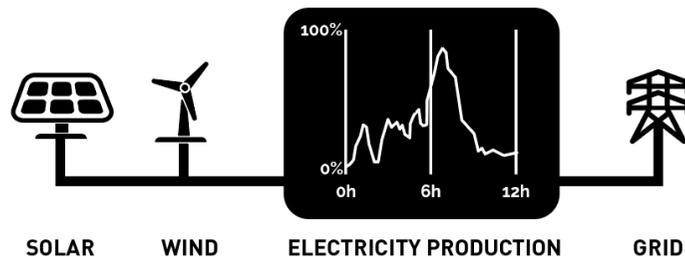
Renewable sources can be up to **37 times** more copper intensive than the same amount of energy generated conventionally.

China will plow \$361 billion into renewable power generation by 2020.



Storage is the missing link between renewables and grids

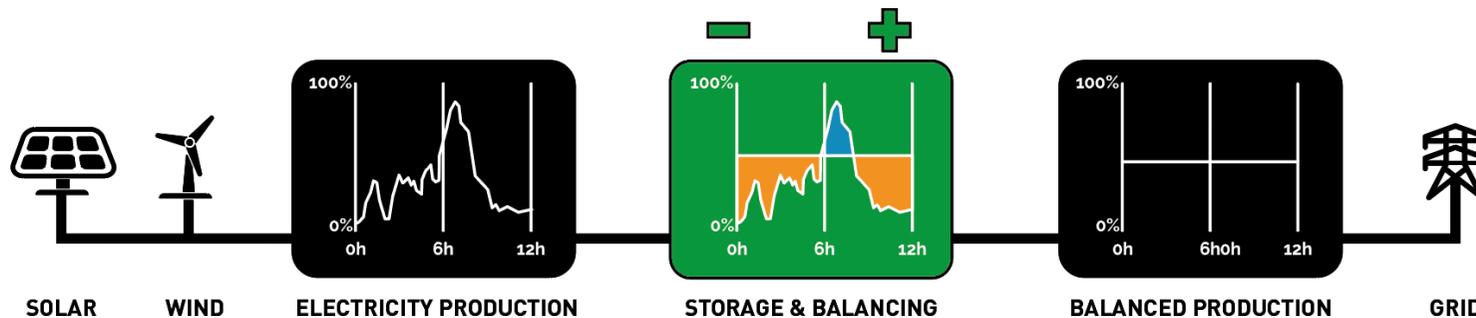
Renewable energy production depends on wind and solar conditions.



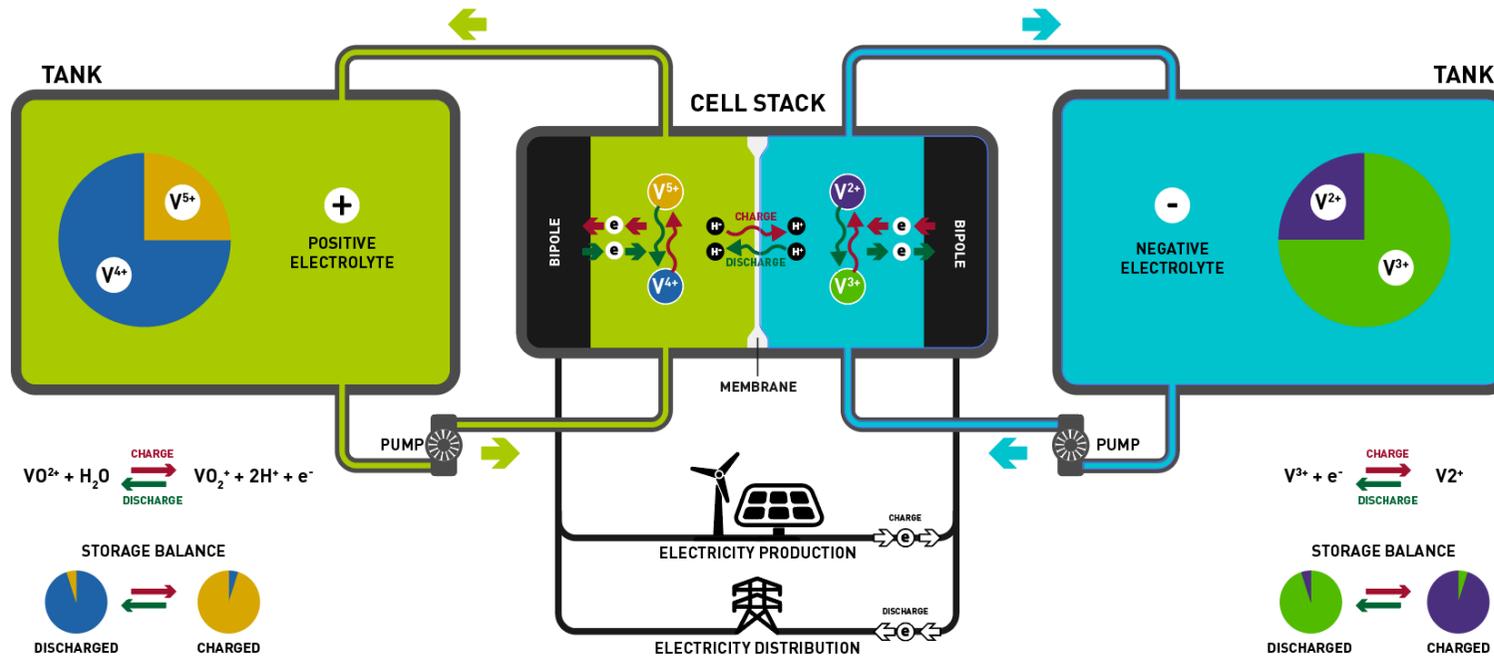
Renewable energy sector challenges

- **Inflexible:** Cannot increase power supply on demand.
- **Intermittent:** Requires storage or redundant capacity to stabilize supply.
- **Wasteful:** Energy waste has been increasing in line with the share of renewables.

Balancing is required for electricity generation to meet consumption on a consistent basis.



Vanadium redox batteries



MAIN ADVANTAGES



SCALABLE

Scalable energy capacity from four to eight hours or more by adding additional electrolyte



LONG LIFE

Can rapidly release and store large amounts of electrical energy



RECYCLABLE

Recyclable hardware and reusable electrolytes



SAFE

Electrolyte is non-toxic, non-flammable, and 100% reusable



LOW COST

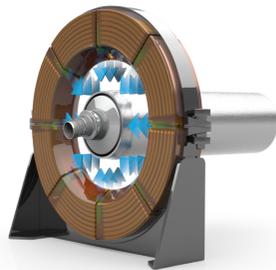
The lowest lifetime cost of electricity storage



Bmax : A revolution in metal shaping and welding



The metal manufacturing market is evolving to more complex shapes for design purposes & to lighter materials for transport applications.

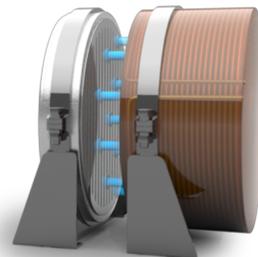


COLD WELDING

- WELDING OF DISSIMILAR METALS
- HIGH PERFORMANCE
- HIGHER PRODUCTION RATE
- DIFFERENT SHAPES
- NO HEAT AFFECTED ZONE



HIGH PERFORMANCE:
In testing, the mother material will surrender prior to the weld area



COMPLEX SHAPE FORMING

- COMBINED OPERATIONS
- LARGE RANGE OF SHAPES
- NO SPRING BACK AND GOOD MATERIAL DISTRIBUTION
- HIGHER FORMABILITY
- ULTRA HIGH SPEED PROCESS



JOINING

- MECHANICAL JOINING (NO GLUE)
- WIDE RANGE OF ASSEMBLIES
- HIGH CONDUCTIVITY
- HEAT-SHOCK RESISTANT



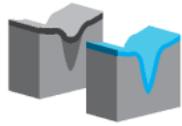
I-Pulse processes are fast, cost effective, flexible and easy to automate while enabling the assembly and welding of complex and thin parts

- Hyper-velocity processes cause the metal to act as liquid at cold conditions, enabling a degree of precision unattainable through traditional means
- Major improvements in the production of complex parts, materials challenging to form or weld
- Precision-forming of metal
- High quality assembling / welding of similar or dissimilar materials in planar or cylindrical geometries



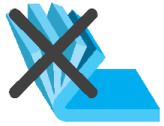
High velocity forming

High velocity forming has a number of advantages over traditional forming



Deeper formability

Due to the viscoplastic state and the lack of friction from the press, the metal can be deformed much further (up to 300% more) without tearing or breakage, when compared to traditional pressing methods



No springback

The high velocity process eliminates tension in the formed part, removing springback and ensuring the metal part conforms precisely to the shape of the die



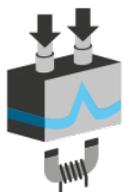
Extremely fine detail

The liquid-like viscoplastic state ensures that the metal part adopts even the finest details of the die. The horizontal scratch marks on the metal to the right are due to tiny imperfections in the die itself, which were reproduced on the finished part



Highly economical

Since only a single die is required to form a part, and only one side of the die is needed, the process is much more economical than traditional methods which could require as many as 7 different double-sided dies



Can be combined with other forming technologies

In applications to date, Bmax equipment has been combined with other technologies to provide either detailed features on pre-formed parts or to remove springback from parts formed through other means



Scandium

Scandium allows 3D printing with aluminum.

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



Syerston Project

FULLY PERMITTED DEVELOPMENT PROJECT LOCATED IN NSW

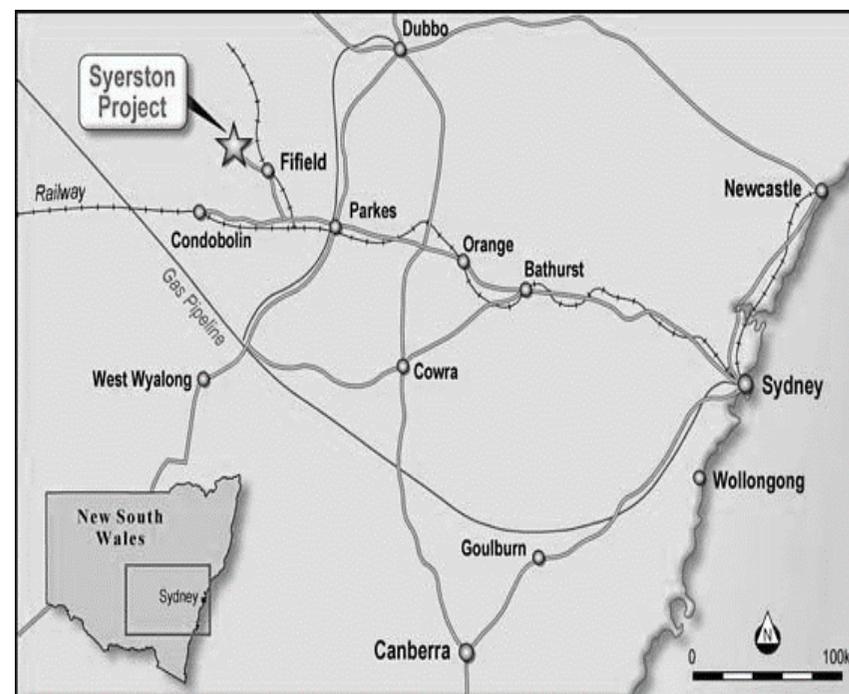
The Syerston Project is **100% owned by Clean TeQ** and located 350km west of Sydney

Laterite (iron-hosted) mineral resource, rich in **nickel, cobalt and scandium**

Uniquely positioned as one of the largest and highest grade sources of **cobalt outside Africa**

Fully permitted project targeting release of Bankable Feasibility Study in 4Q 2017

Seeking to directly supply the **lithium-ion battery industry** with high-purity nickel and cobalt sulphate, the key raw materials in the production of cathodes



Syerston is located in an **established mining region**; other major projects include Cadia Valley, Northparkes and Cowal

IVANHOE GROUP:

Worldwide solutions to provide critical metals and fulfil the needs of new urbans

- **Kamoa Copper Project** in the DRC and **Platreef Platinum Project** in South Africa.
- PuNeng Project in China to develop **vanadium** based electricity storage and ensure
- **CleanTeq Scandium Project** in Australia and **I-Pulse Bmax Project in France** for lightweight mobility solutions
- Clean TeQ's new project in Syerston in Australia for **Nickel and Cobalt**

THANK YOU

IVANHOE MINE *GROUP OF COMPANIES*
NEW HORIZONS

 WORLD
MATERIALS
FORUM

