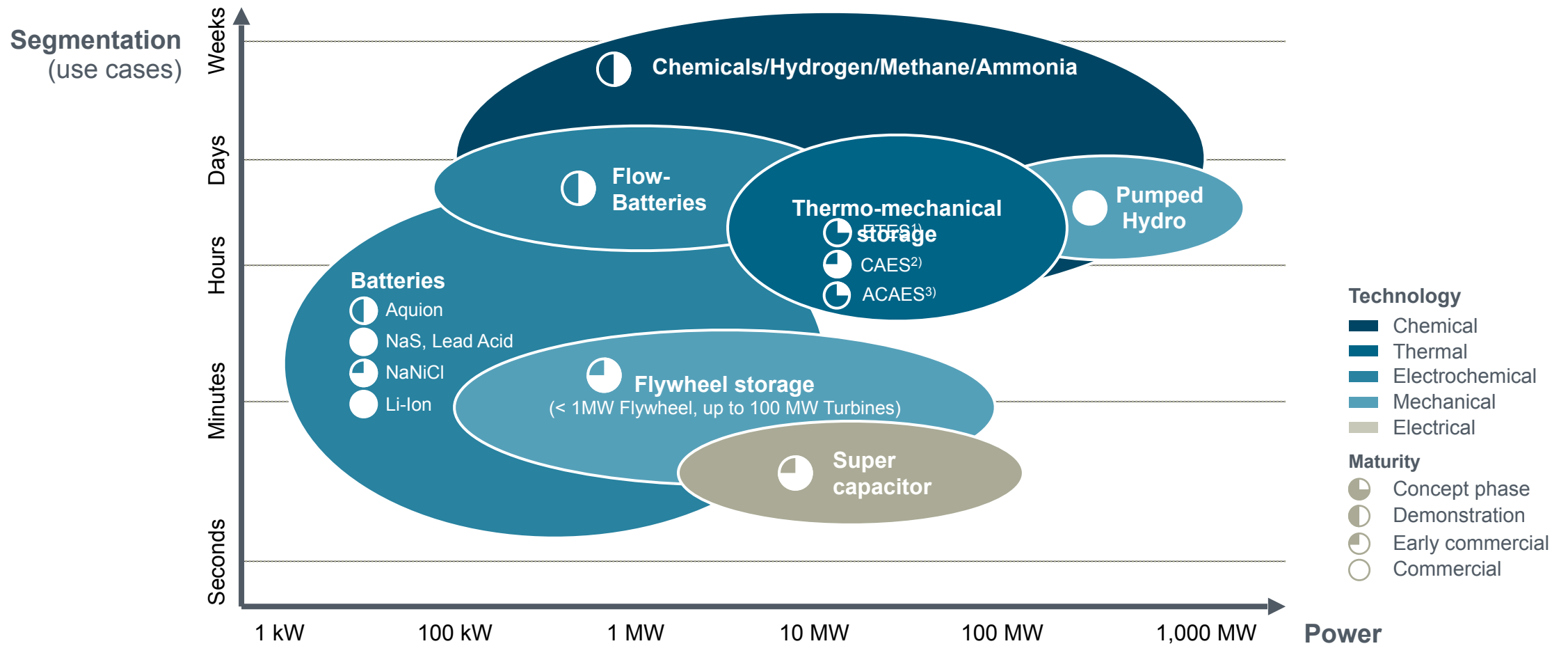


# How can Australia export its vast Renewable Energy resources?

# Energy Storage: Selecting the best technology depends on the Application



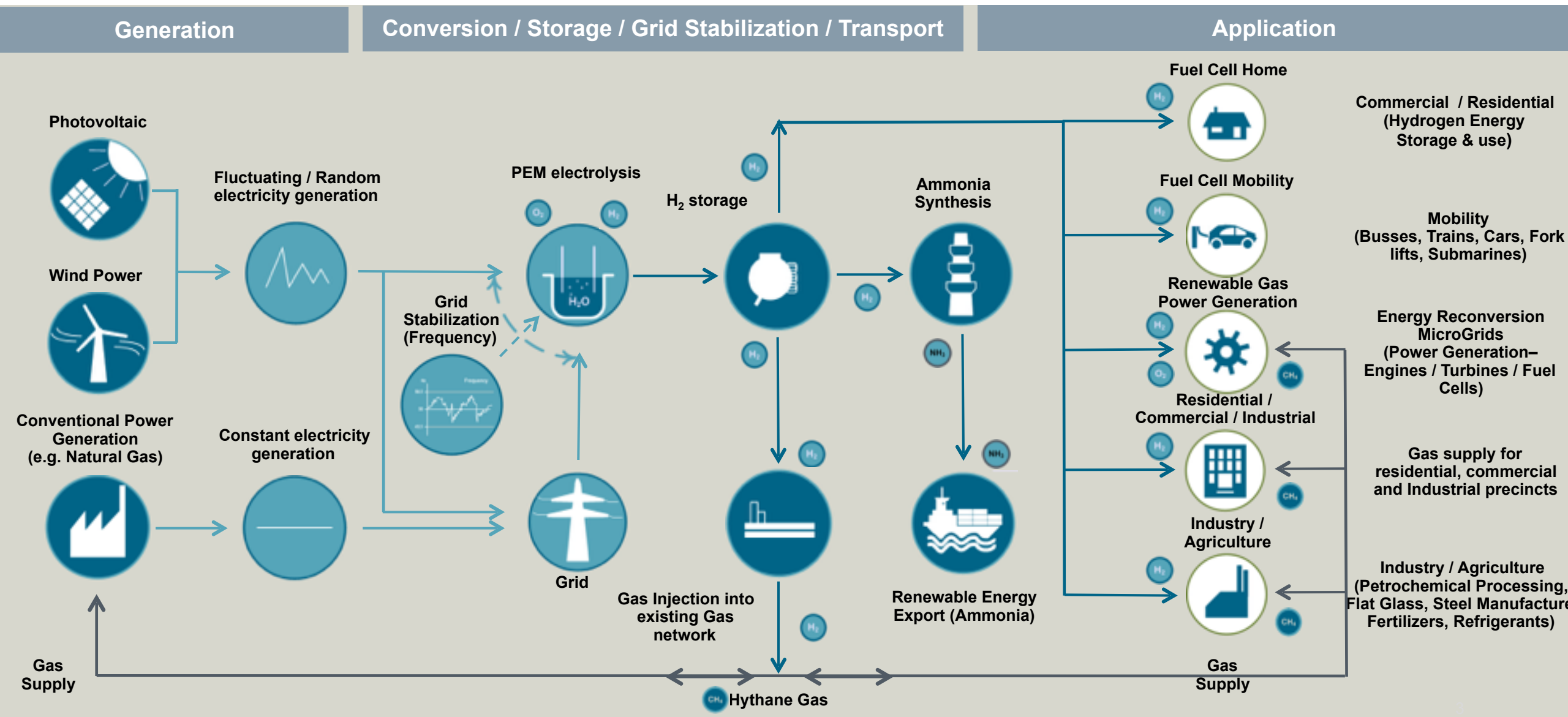
<sup>1)</sup> Electro-Thermal Energy Storage

<sup>2)</sup> Compressed Air Energy Storage

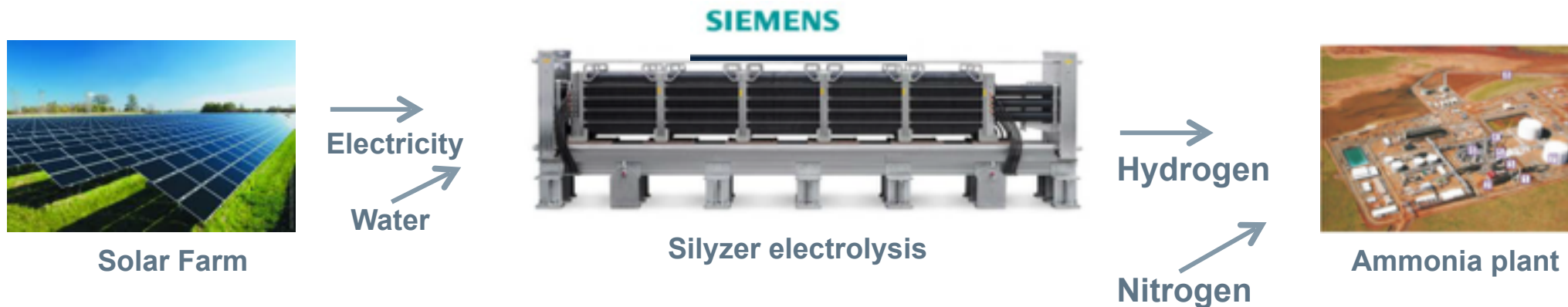
<sup>3)</sup> Adiabatic Compressed Air Energy Storage

# Converting renewables to stored energy for broad applications

Hydrogen facilitates the convergence between energy, industry and transport sectors



# How is Renewable NH<sub>3</sub> produced?



Currently it takes about 12 MWh of electricity to produce 1 tonne of renewable ammonia (containing 176 kg of H<sub>2</sub>)

Cost trends are very favourable for Renewable NH<sub>3</sub> following large declines in the cost of solar energy and emerging efficiencies in electrolysis

Source:  Renewable NH<sub>3</sub>

'Green' Ammonia

Green ammonia is key to



By 2050 there will be ten billion people on the planet.



Using ammonia as fertilizer makes land more productive. Increasingly vital as the population grows and living standards improve.

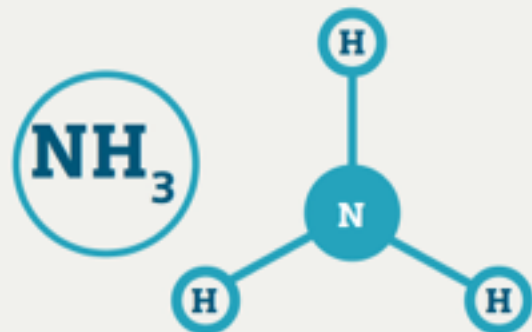
**Ammonia**

Ammonia is a compound made of nitrogen and hydrogen. Chemical formula  $NH_3$ . Ammonia's main use is in fertilizer.



**Nitrogen** is a harmless odourless gas that makes up 78% of the air around us.

**Hydrogen** is the most abundant element in the universe. There are 2 hydrogen atoms in every molecule of water.



By using water electrolysis and renewable electricity, ammonia production can be made completely carbon-free.

People need food and energy and it must be CO<sub>2</sub> free – that's where green ammonia comes in.

**Ammonia**

**180 Million Tonnes**



Ammonia feeds the world: 180 million tonnes were produced in 2015, mainly for use in fertilizers. Growing demand for food means this must rise 3% each year.



Today, ammonia is made using the Haber-Bosch process invented and perfected in the early 1900s. Its two inventors won Nobel prizes in 1918 and 1931.



In the Haber-Bosch process hydrogen and nitrogen are converted to ammonia using high temperature and a catalyst.



The global trade in ammonia means we already know how to transport and store it safely.

**But there is a problem**



Today the lowest cost way to get hydrogen is from natural gas but this produces carbon dioxide (CO<sub>2</sub>) which is a cause of manmade climate change.

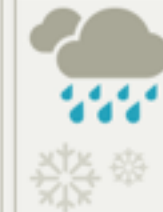


**Over 1%**

Ammonia production requires energy, and today this energy also comes from fossil fuels. Together with the fossil hydrogen feedstock, current ammonia production accounts for over 1% of global CO<sub>2</sub> emissions.



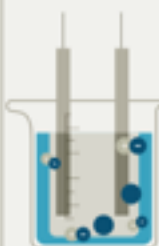
To keep under 2 degrees warming humans must emit no more than 600 billion tonnes more CO<sub>2</sub>. That's less than 25 years at the rate today.



Once CO<sub>2</sub> is released into the atmosphere it will change the climate for the next 10,000 years.

**The good news – innovating to create carbon free "green" ammonia**

We can make hydrogen from water using electricity – a process known as electrolysis. Passing an electric current through water separates the hydrogen and oxygen.



Green ammonia can support the business case for renewables, by providing an alternative revenue stream that is not dependent on a grid connection (particularly relevant in remote areas), and by being used for load-balancing.

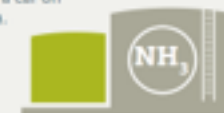


By switching to renewable electricity to make ammonia we could save over 40 million tons of CO<sub>2</sub> each year in Europe alone, or over 360 million tons worldwide. We can also burn ammonia to make electricity when the wind is not blowing.



When used in this way ammonia turns back into air and water, so doesn't pollute the atmosphere.

Ammonia can even be made to clean up after itself by 'scrubbing' any nitrogen oxides left after combustion. Ammonia is as easy to store safely as LPG. You can even run a car on ammonia.



## Yara Pilbara Fertiliser

Two ammonia tanks  
hold 80,000 tonnes

Equivalent to:

Approx 250,000 MWh electricity

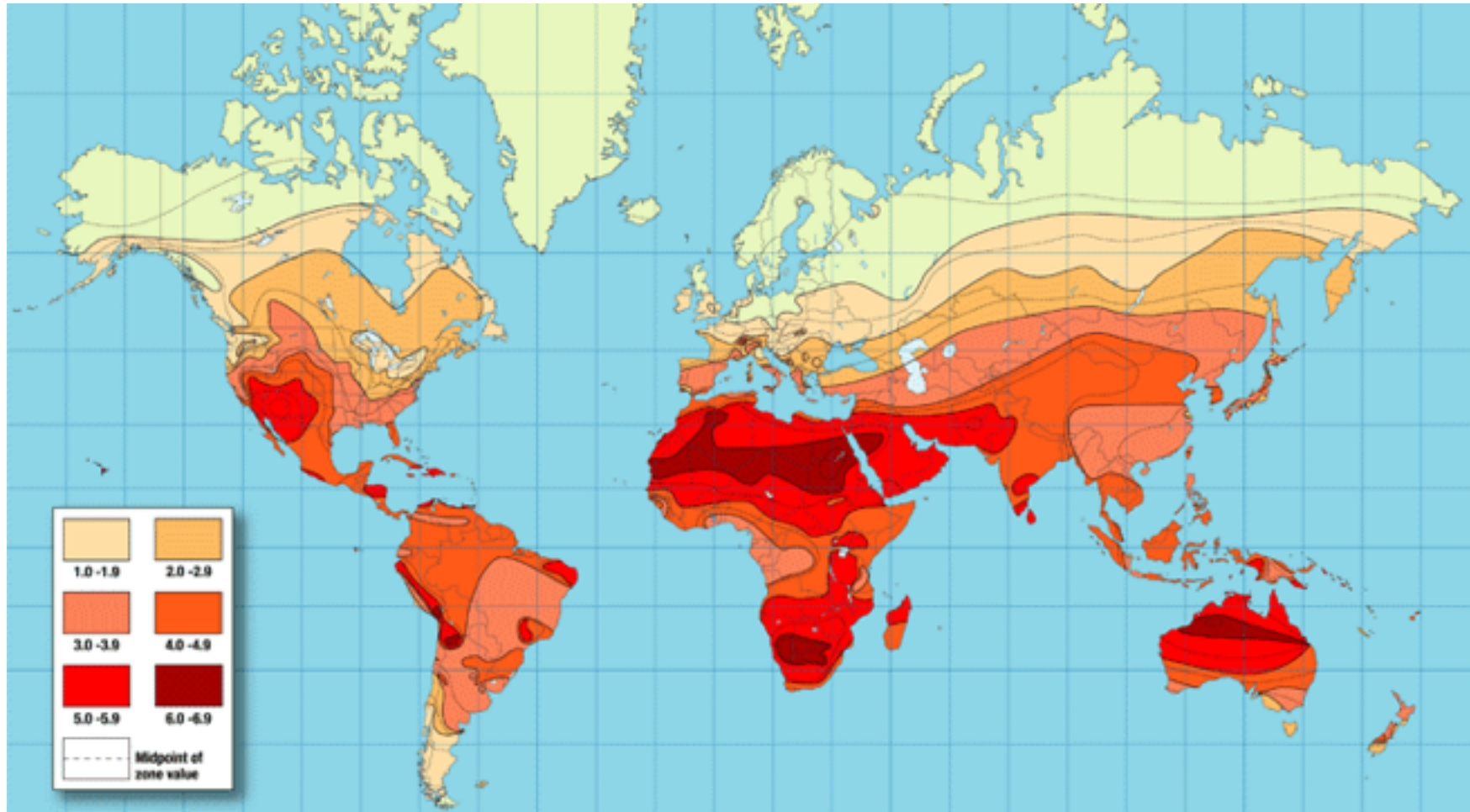
Or

Fuel for 60,000 Fuel Cell cars  
each travelling 20,000 km pa

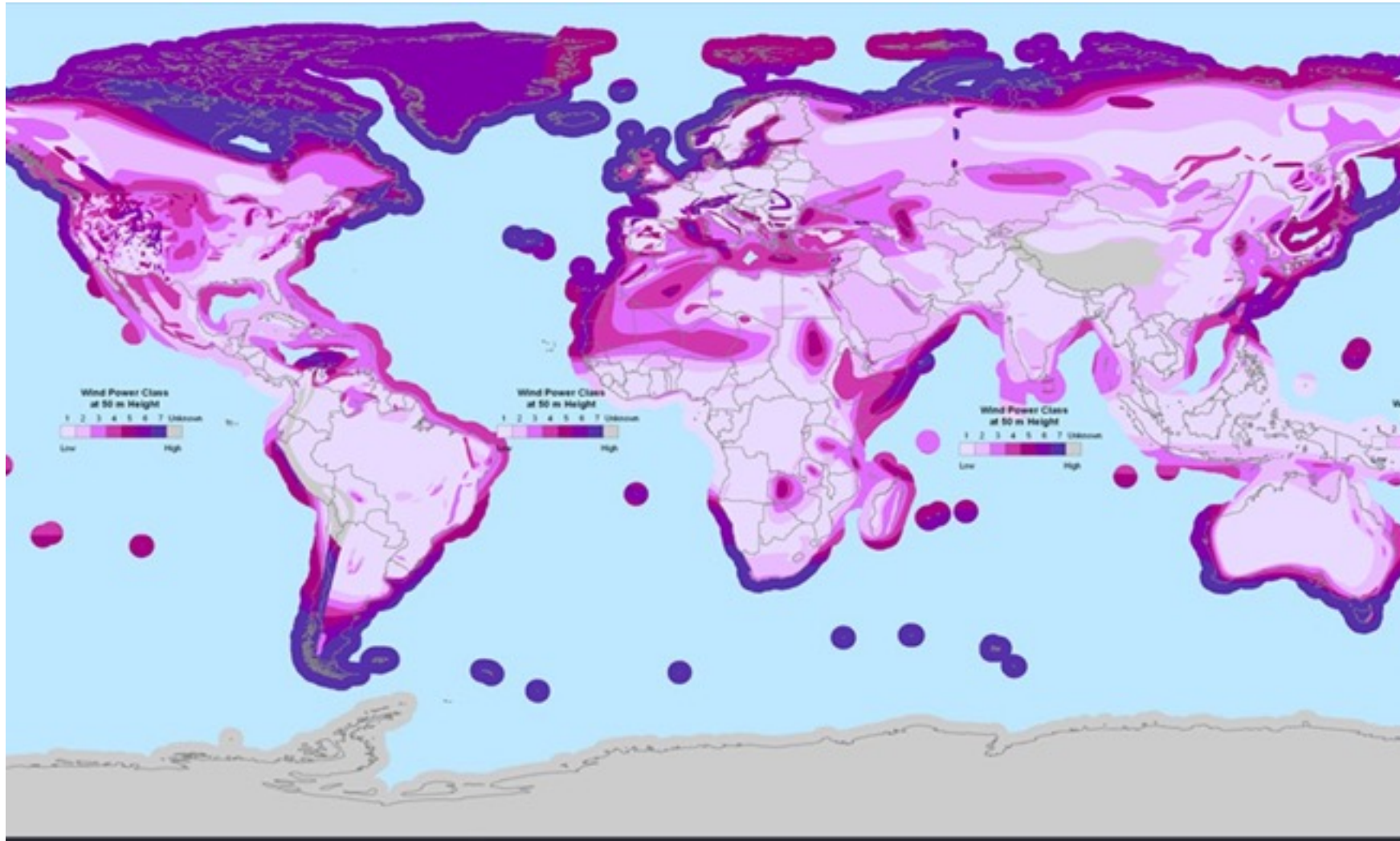


Source: Renewable NH<sub>3</sub>

## Australia has abundant solar resources



## Australia has abundant wind resources

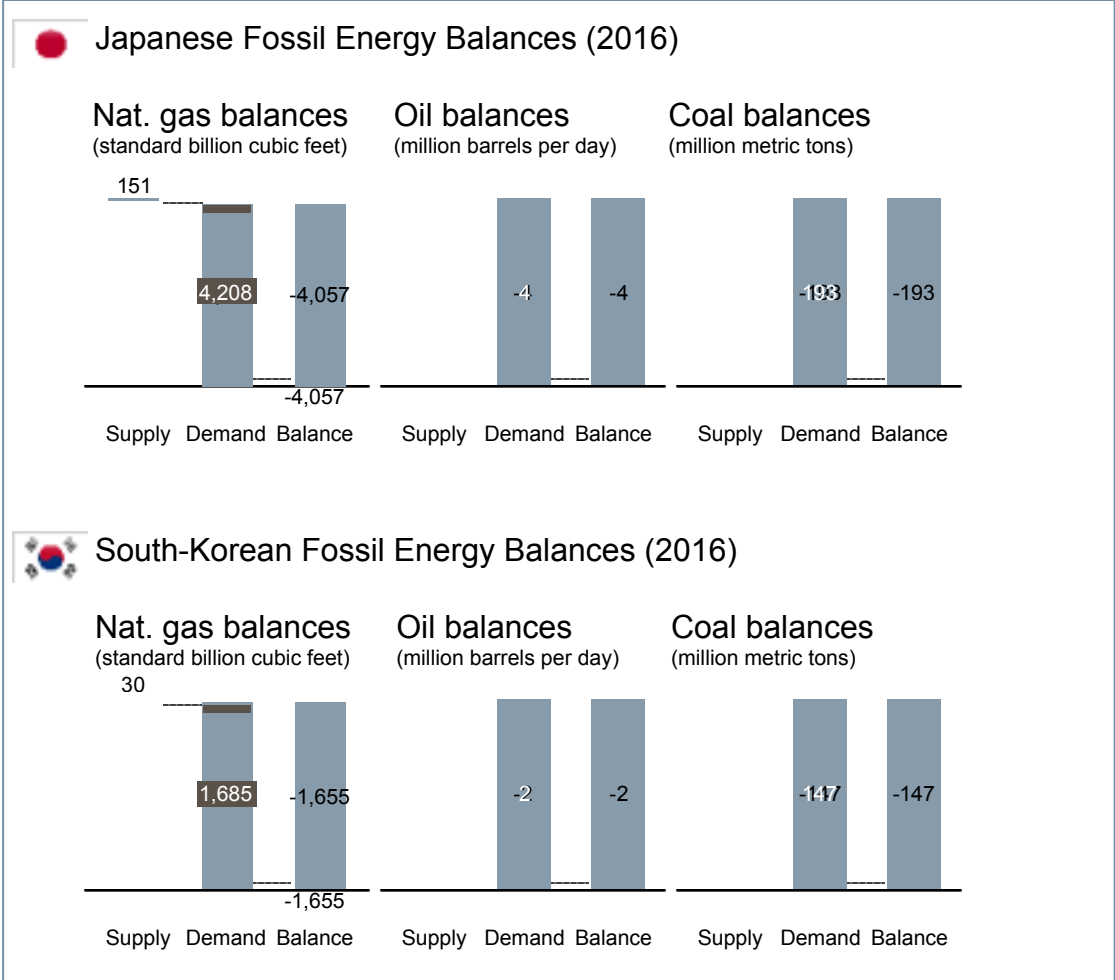




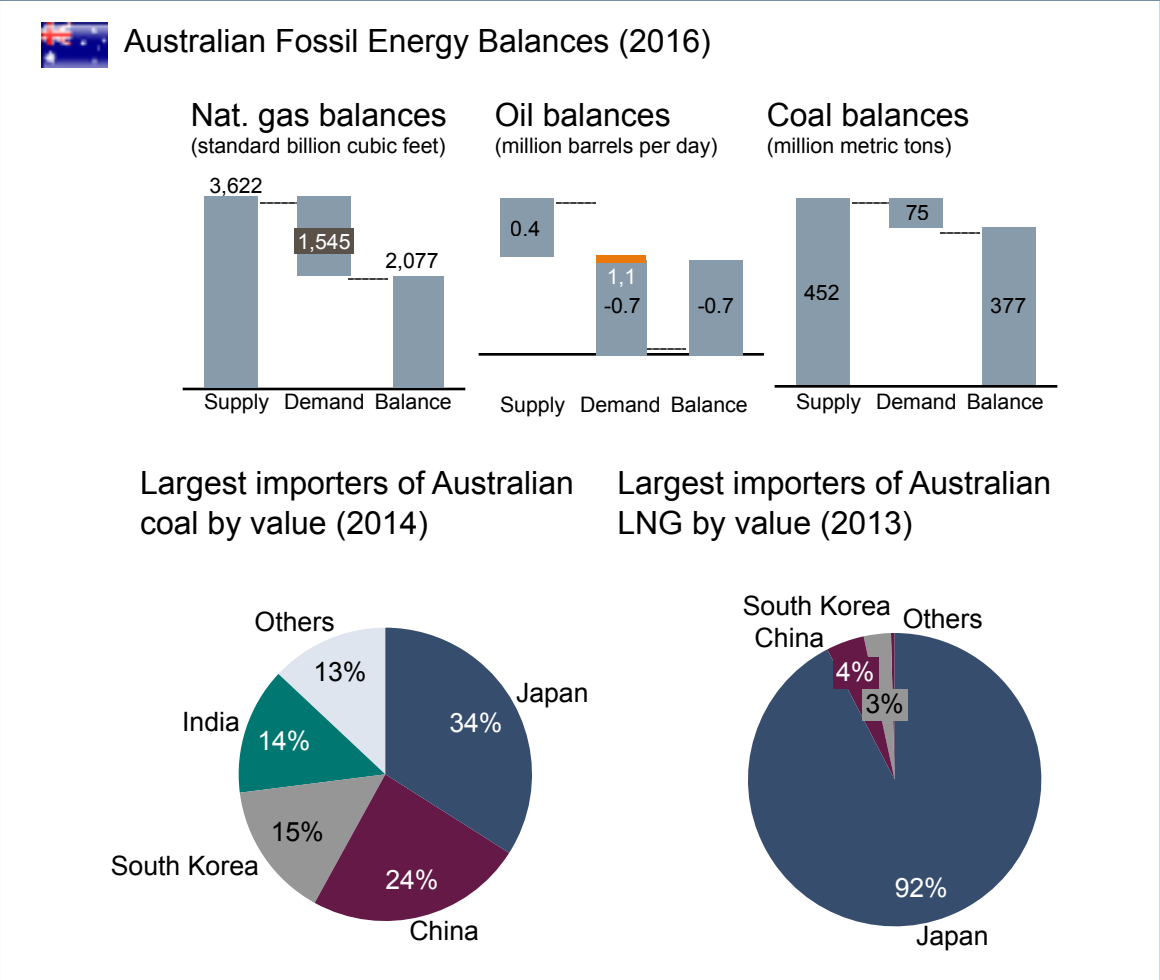
# Australia is a major energy trade partner for Japan and South Korea; what is the opportunity beyond coal and gas?



## Japan & South Korea importing all their fossil energy



## Australia a significant energy exporter



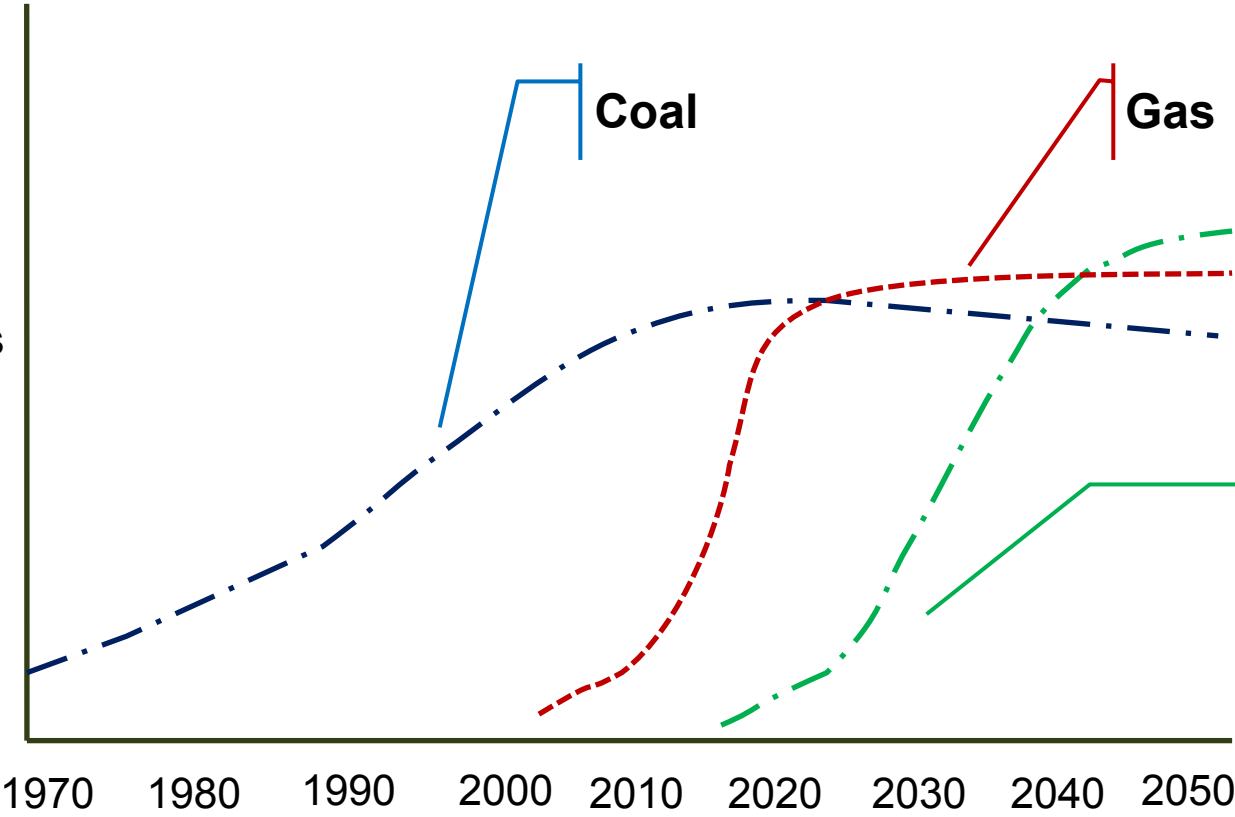
Source: Harvard's Center for International Development's Atlas of Economic Complexity, Australian Government (DFAT)

# Australia to continue its role as a Global Energy Superpower by exporting its vast renewable energy resources



## Development of Australian Energy Exports

Not scaled; indicative trend lines only



### Exportable Renewable Energy

Renewable energy is used to electrolyse water to make hydrogen; this can be directly exported or further processed to produce other renewable energy sources; a process known as power-to-gas or power-to-x