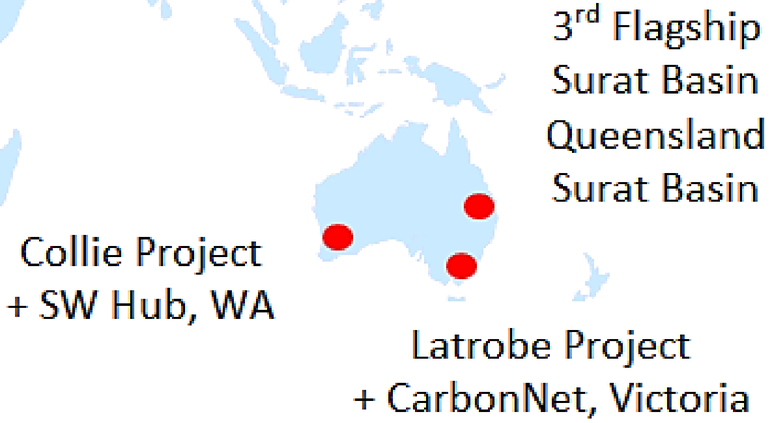
Collie Synfuels Pty Ltd

An Alternative Pathway to Australia's Hydrogen Economy

"Powering the Future of WA" - Critical Horizons Conference - 8th June 2018

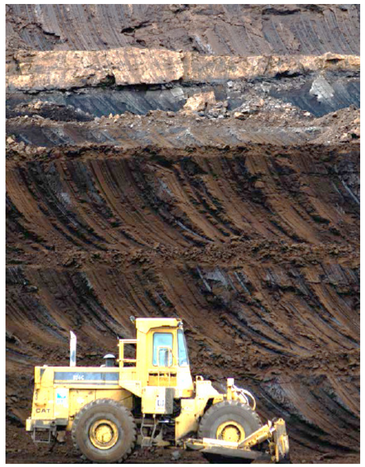
presentation by C.M. (Costa) Tsesmelis

Over the past 4 years Collie Synfuels have invested over $3 million to develop a modular, smaller-scale Coal-to-Fuel Cell Hydrogen technology with Carbon Capture & Storage - with end-to-end "off-the-shelf" proven technologies - for a commercial breakthrough in "Coal Value Add"



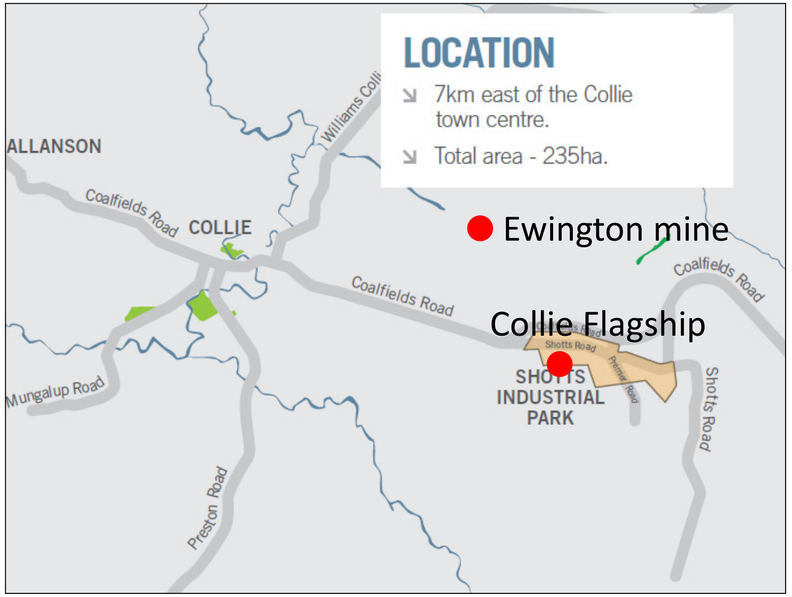
Flagship Projects

- **Collie Project**: Ideal site available at the approved Heavy Industrial Shotts Industrial Park - located 7 klms east of Collie. Supply of sub-bituminous coal with excellent gasification properties is available from Ewington mine next to Shotts. The Collie Project is linked with the South West Hub CO2 storage project.



- **Latrobe Project**: Abundant low cost lignite available in the Latrobe Valley 150 klms from Melbourne. It is the second largest lignite deposit in the world, estimated to total 430 billion tonnes, with a potential economic resource of 33 billion tonnes. An excellent site has been identified at the former BRIX site near Morwell. Our Latrobe Project is linked to the CarbonNet CO2 storage project.

- Potential 3rd Flagship in Surat Basin, Queensland. COAL21 have announced additional funding of $255 million to support the fund's objectives of building confidence in CCS and demonstrating CO2 storage capacity in Australia. Surat Basin CO2 storage potential is excellent and will receive particular support because of the abundant coal reserves in that region.



Project Partnerships developed over the past 4 Years

Most recently - CIVMEC Construction & Engineering have joined us as our exclusive Australian Construction Engineers

Strategic Petroleum Insights
(formerly Boston Petroleum Research, London, UK)
Specialist Consultancy - models simulate regional oil exploration and production, global oil supply, demand and price.

MAN Diesel & Turbo Germany
Fixed-bed Tubular Reactors Supply

FLUOR Australia and San Diego
Gasification Technology Centre-of-Excellence

Golden Nest / CCT
Pilot Plant Facilities at Baoji, Shaanxi Province, PRC

China Tianchen Engineering Corporation (TCC)
Main Engineering and Procurement Contractor

CIVMEC Construction & Engineering
Australian Construction Engineers

CSIRO Energy, Brisbane
Gasification Research Group

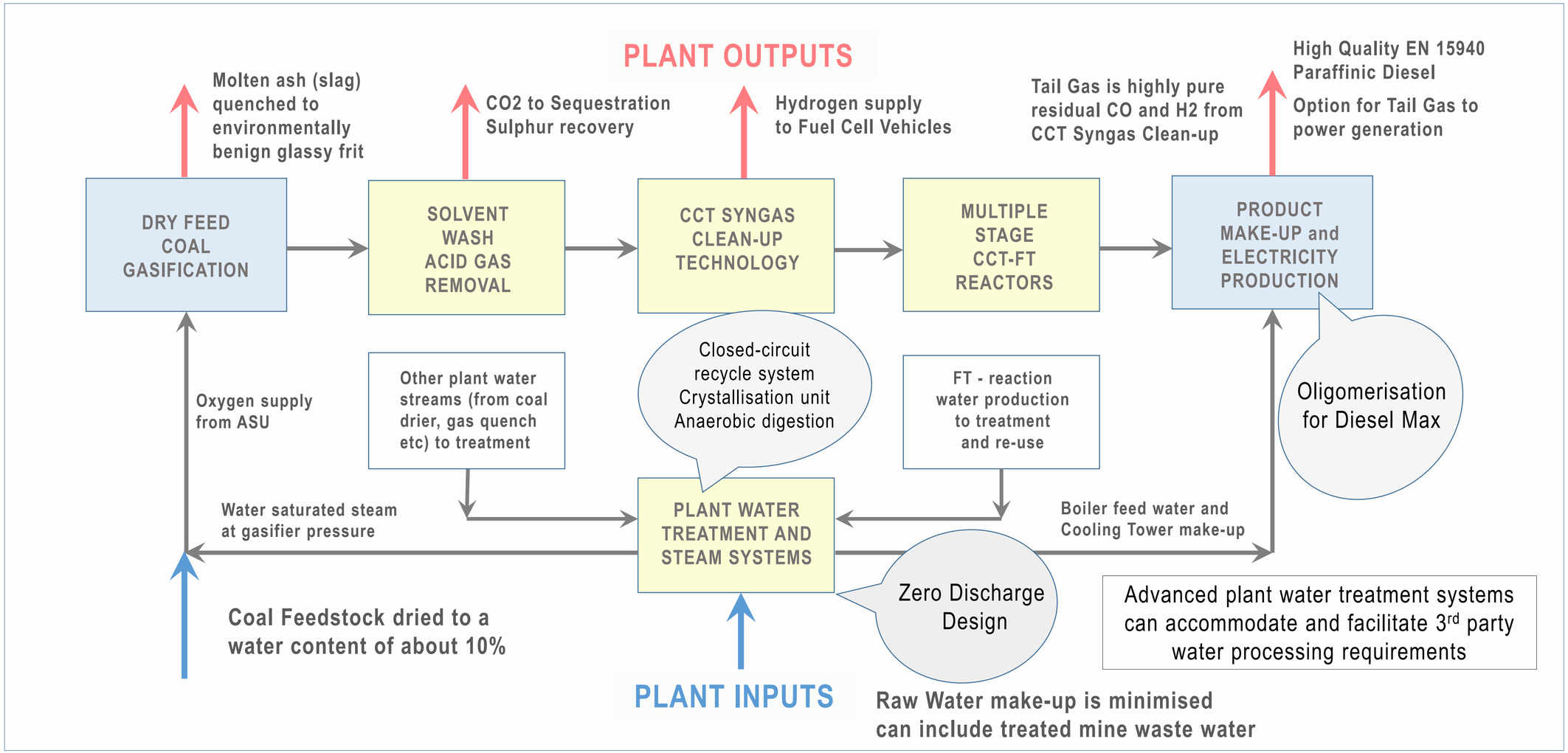
Clean Coal Technology (CCT) South Africa Pty Ltd
Fischer Tropsch & Syngas Clean-up Technology Licensors

Protos Consulting International Pty Ltd
Project Director - Perth WA
Owner's Management Team

Monash University
Lignite Gasification Consultants

Environmental Benefits - Innovative Australian IP

Flagship flowscheme - “Clean” FCV H2 - High Quality Biodegradable Diesel - Zero discharge liquids - No toxic emissions



Impact of Collie Synfuels Flagship Projects

Highlights of Major Benefits to the Australian Economy

EMPLOYMENT

The Collie Synfuels Flagship Projects when under construction will each account for approximately 1,500 jobs with over 100 permanent employees at each Flagship Project location for the operational phase

Collie Project: over 100 Permanent Jobs upon Start-up in 2022

INCOME

Employment during the operational phase of each Flagship Project is estimated to result in AUD$ 70 million Total Household Income per year, per project from both Direct and Indirect jobs created

OUTPUT VALUE

Total Product Sales resulting from yearly production from 2022 at least US$ 230 million per project (real 2017 dollars)
- new manufacturing and infrastructure benefits generate similar value

EXPENDITURE

Total installed cost + contingency for each Flagship Project estimated at approx US$ 735 million
- includes owners' costs for engineering and construction - estimate based on Western BFS at US$ 85m per Flagship Project - likely to be significantly less with Chinese Engineering partner

“Hydrogen Economy” Vision

Collie Synfuels Technology provides an Alternative Pathway to Australia’s Hydrogen Economy

- A “Hydrogen Economy” is an aspirational term for an economy based on systems that deliver energy using Hydrogen as an environmentally cleaner source of energy to end-users, with zero CO2 emissions and zero emissions of pollutants, such as NOX, CO, HC and particulate matter at point of end use.
- Hydrogen is attractive because whether it is burned to produce heat or reacted with air in a fuel cell to produce electricity, the only byproduct emission is water. Hydrogen can be produced from a diverse range of feedstocks and different technologies:
    - **Natural Gas Reforming -** or Steam Methane Reforming, produces a hydrogen and carbon monoxide “synthesis gas” from hydrocarbon fuels such as natural gas or biogas methane. This is achieved in a reformer which reacts methane with steam at high temperature over a nickel catalyst.
    - **Gasification -** a partial oxidation process where coal or biomass is converted into gaseous components in a closed pressure vessel by heating in the presence of air/oxygen and steam. With carbon capture and storage, hydrogen is produced from the process without CO2 emissions.
    - **Water Electrolysis** - uses an electric current to split water into Hydrogen and Oxygen. When the electricity used is from renewable energy sources (wind, solar, geothermal and hydroelectric power) the hydrogen is produced without CO2 emissions.
- Future potential Hydrogen production methods currently in research phases include:
    - High Temperature Electrolysis - using heat from industrial processes such as a nuclear reactor to improve efficiency
    - Solar Thermochemical Water-Splitting (STCH) - using high temperatures generated by solar concentrators
    - Photo-electrochemical (PEC) technology - using sunlight and a special class of semiconductors to produce Hydrogen directly
    - Biological - using certain microbes that produce Hydrogen in the presence of sunlight as a byproduct of metabolic processes

Hydrogen Production Technologies - US Dept of Energy

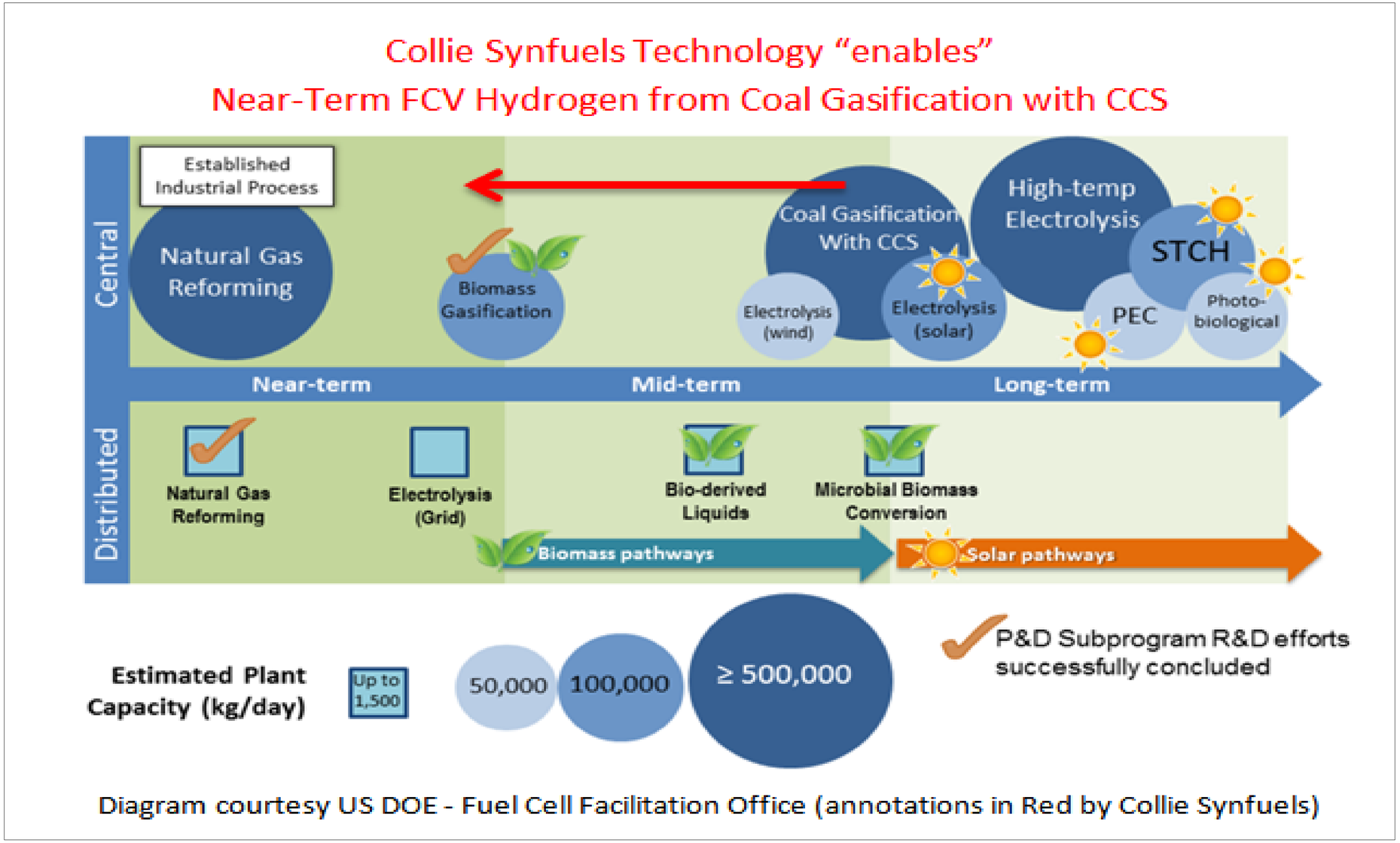
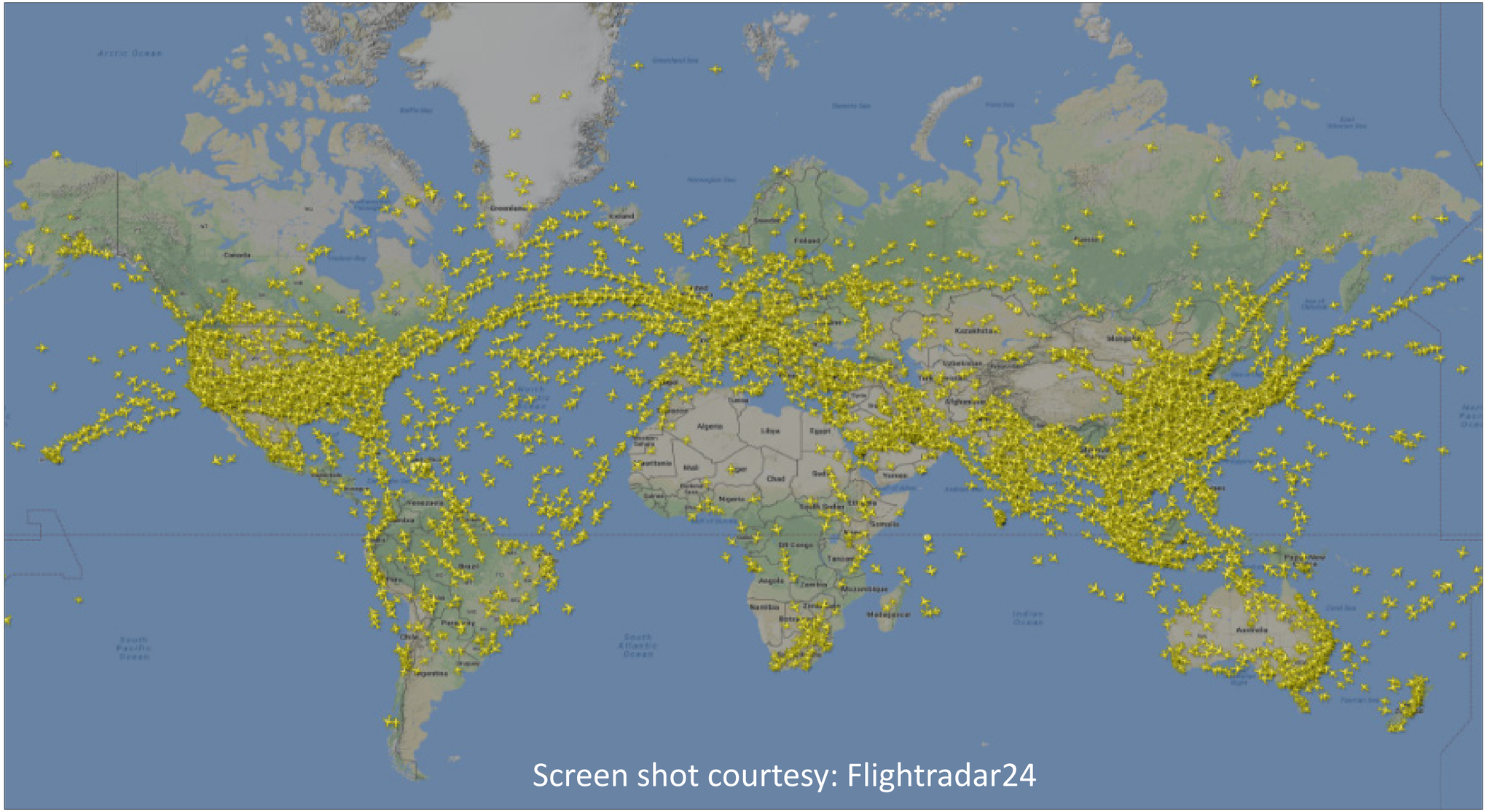


Diagram courtesy US DOE - Fuel Cell Facilitation Office (annotations in Red by Collie Synfuels)

Use of H2 for Global Air Transport - 100,000 flights every day



Jet A1 Kerosene Requirement

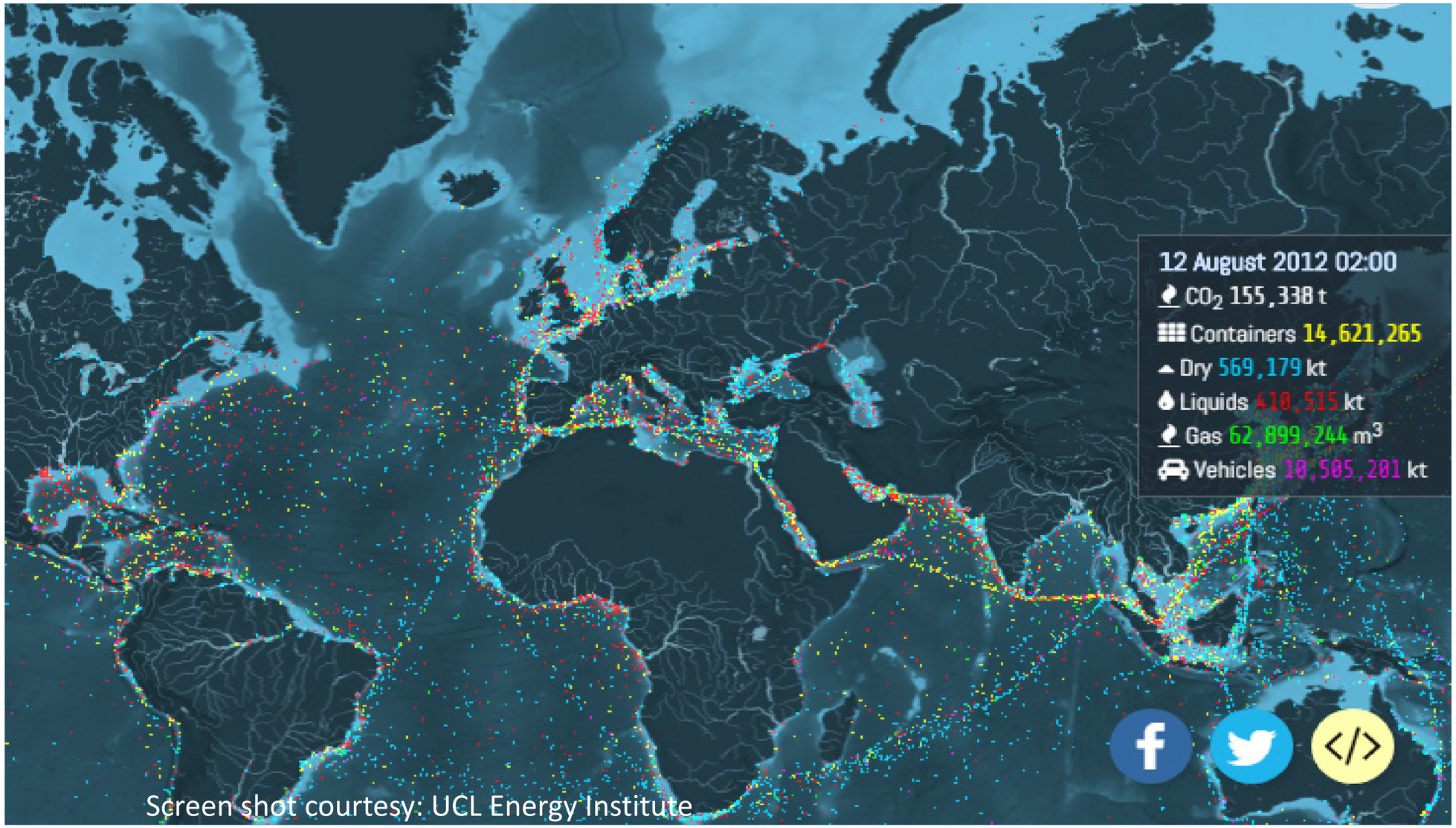
- **H2 FOR JET FUEL?** 1,000,000 people are in the air at any given time - with over 100,000 passenger flights criss-crossing the world every day. There are also about 10,000 important cargo-only freight flights daily.
- About 50 large passenger planes leave Frankfurt airport every day - each loaded with about 130 tonnes of Jet A1 Kero.
- To replace this on a 1:1 basis would require 50 tonnes of Liquid Hydrogen, with the daily needs at Frankfurt airport at 2,500 tonnes or 36,000 m3 of cryogenic Liquid Hydrogen. This would be enough to fill 18 Olympic-size swimming pools[1] .

Photo courtesy: BBC "City in the Sky" documentary

- Using Water Electrolysis to produce this Hydrogen without CO2 emissions would require the continuous output of about 8 (eight) 1 GW renewable energy power plants for electrolysis and liquefaction. At 10 Litres of water consumed per kg of Hydrogen produced, this would also require the daily consumption of 25 ML of water.
- **The magnitude of the task to use Hydrogen for Aviation as a future fuel produced from Electrolysis using renewable electricity is clearly immense.**

Note 1: Reference: Ulf Bossel, Proceedings of the IEEE Vol94, No.10, October 2006.

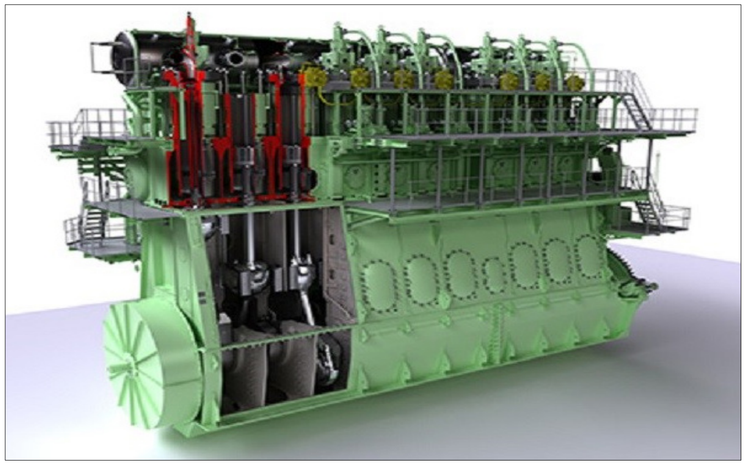
For Global Shipping - we have over 50,000 vessels



Screen shot courtesy: UCL Energy Institute

Marine Fuel Requirement

- **H2 FOR MARINE FUEL?** It is possible to build a two-stroke diesel engine to use Hydrogen in a similar way to the use of Liquefied Natural Gas (LNG). However cost and space requirements to store Liquid Hydrogen on-board are very high.
- MAN Diesel & Turbo - one of the world's leading marine engineering groups - do not see Hydrogen as a fuel for future shipping. Their focus is on Methanol as an alternative liquid fuel, which is a H2 carrier since Methanol is synthesised from Hydrogen.
- Total global marine fuel by 2020 is estimated at **450 million tonnes per year.** Even with H2 to Methanol the task is immense.



The 266,000-cbm Q-Max LNG tanker Rasheeda, shown above is one of the world's largest LNG tankers. The electronically controlled, gas injection MAN ME-GI diesel engine is state-of-the-art. Photos courtesy: Qatar Gas and MAN Diesel & Turbo.

Hydrogen Economy “Vision” applications are Land-Based

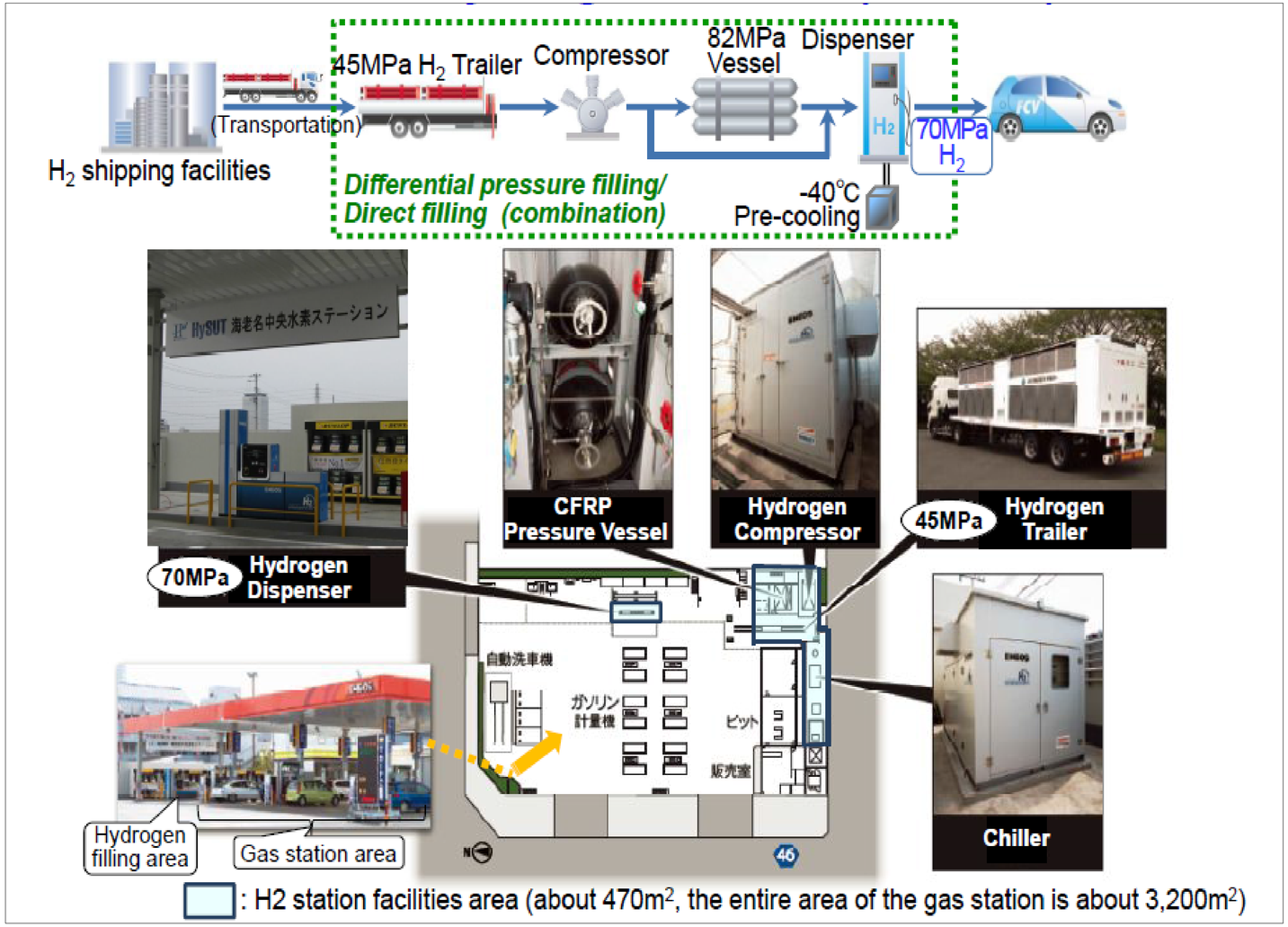
- **Main application is: Land-based Transportation** - using Proton Exchange Membrane (PEM) Fuel Cell Electric Vehicles (FCVs)
  - Other applications are combined heat & power generation for buildings - uninterruptable supply - including Solid Oxide Fuel Cells
  - Stationary power generation users with PEM and SOFCs include: Hospitals, Data Centres, Food Storage, Police/Fire Stations
  - Hydrogen as a fuel is used for Gas Turbine Power Generation (state-of-the art “H Class” Gas Turbines now achieve >60% efficiency)
  - Hydrogen can also be blended with Natural Gas and provide industry with alternative Hydrogen supply options
  - Also increasingly, an important use of Hydrogen is as a **storage medium for Renewable Energy**
- The Collie Project at the Shotts Industrial Park, planned for start-up in 2022, will “flexibly” supply from 1,500 kg/day to more than 10 tonnes/day of FCV H2 to meet the logistical needs of a growing network of H2 refuellers in Perth metro and the South West.
- We aim to vertically integrate our Fuel Cell Hydrogen production facilities with H2 refuellers to be installed at retail outlets through our HyCoFuels distribution company - together with partnerships for H2 refuellers installed at existing independent petrol retail outlets.
- Our “Flexible” H2 supply means H2 refuellers can be installed incrementally with commercial roll-outs of FCVs - as “clusters” of refuellers are built to match FCV and H2 demand.

- We see a tremendous opportunity for Fuel Cell trucks, buses and cars to be supplied with our low cost Fuel Cell Hydrogen meeting the SAE J2719 Hydrogen Fuel Quality standard - to provide an **Alternative Pathway for Australia’s Hydrogen Economy “vision”.**

Collie Synfuels current work: Hydrogen Refueling Station Infrastructure

Latest H2 refueller - Newport Beach - Liquid H2 supply
Photo courtesy: California Fuel Cell Partnership

Toyota Mirai 2017 - photograph courtesy Green Cars Magazine

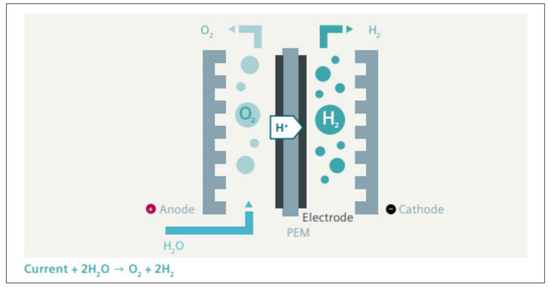


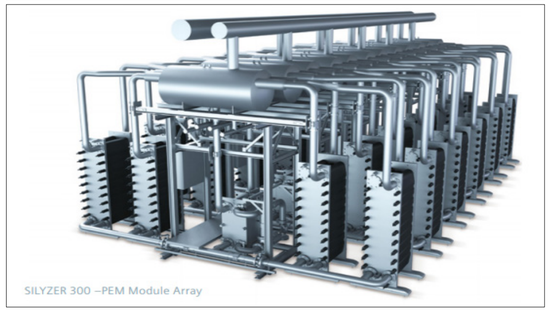
Collie Synfuels following the JAPANESE MODEL (Slide courtesy: IEA Hydrogen Roadmap (Asia Workshop) presentation June 26, 2014)

Hydrogen Economy developments

- **Regions and countries around the world that have endorsed and are progressing a Hydrogen Economy "vision" include:**
  USA - California / Northeast - over 50 FCV Hydrogen refuelling stations in operation - $100M through 2023 is planned for H2 infrastructure
  EU - A Pan-European hydrogen fuelling station network in progress with over 29 state-of-the-art refuelling stations being deployed
  Japan - currently has about 90 stations, with another 10 in the planning or construction stage
  Korea - the government has announced ambitious plans to increase investments in H2 refuelling stations - with a target of 310 by 2022
  China - only 4 stations at present - however major state development plans are in progress to rapidly expand FCV production & refuellers
- **Australia** - only 1 refueller at present located in Sydney and a mobile electrolyser from Toyota to advertise their Mirai FCV sedan.
  A Siemens Electrolyser for a fleet of 20 Hyundai Nexo FCVs is being progressed by the ACT. The French firm NEOEN have been funded by the SA Government for a feasibility study to develop a 50 MW renewable energy Hydrogen Superhub to produce 25,000 kgs/day of H2

Photo courtesy: Hydrogen Mobility Australia

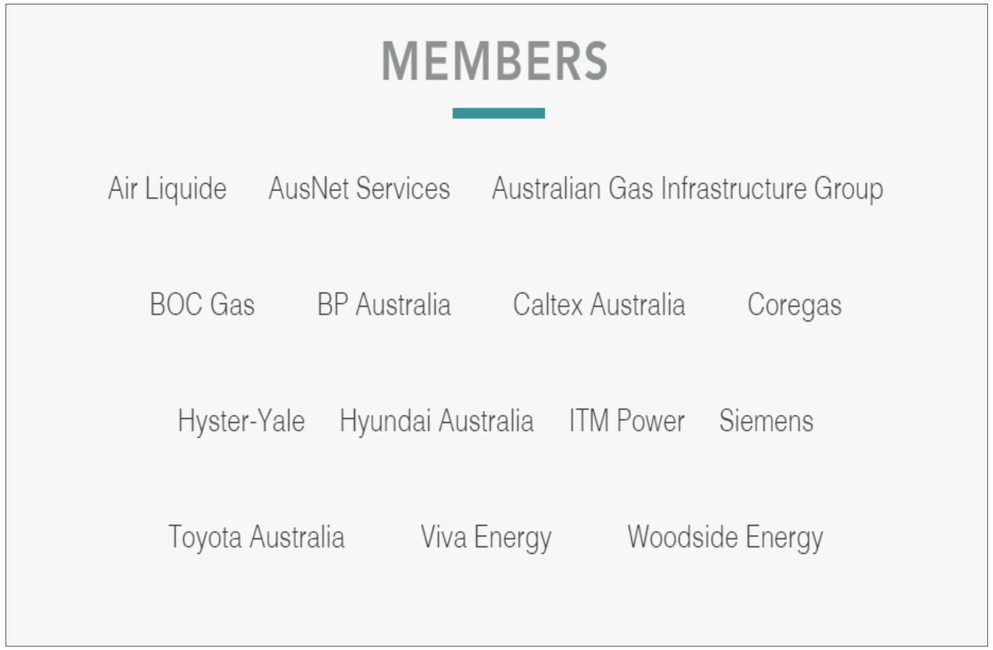




Hydrogen Mobility Australia

We are far behind in Australia with our own Hydrogen Economy Vision - however the CSIRO are developing a roadmap this year and an industry lobby group has been announced

Hydrogen Mobility Australia (HMA) was officially announced in February 2018 with a vision of a “Hydrogen Society” for Australia built upon clean and renewable energy technology, including hydrogen powered transport. HMA is a collection of vehicle manufacturers, energy companies, infrastructure providers, research organisations and governments with a mission to make this hydrogen vision a reality. Founding members are Toyota and Hyundai.



The objectives of Hydrogen Mobility Australia are:

- To accelerate the commercialisation of new hydrogen and fuel cell technologies for transportation, export, storage and stationary applications in Australia

- To provide a forum for effective communication and collaboration of all stakeholders in the hydrogen and energy community

- To progress Australia’s shift towards a future hydrogen society built upon clean and renewable energy technologies

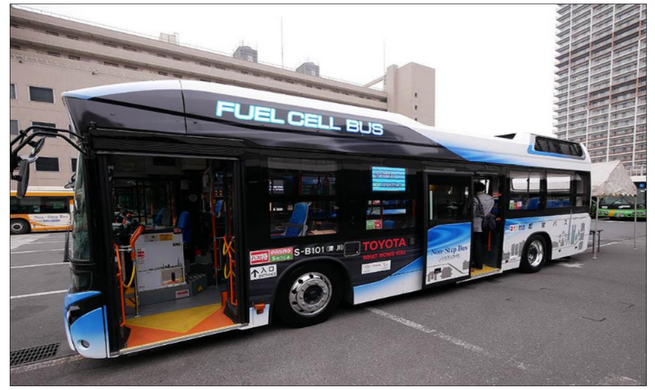
Given the emphasis on renewable energy technologies HMA are likely to follow the EU CertifHy program that provides EU-wide **Guarantees of Origin (GO)** for **Premium Hydrogen** (defined as “Green Hydrogen” from renewables and “Blue Hydrogen” for Low or Zero Carbon Hydrogen from non-renewables).

Fuel Cell Vehicles are here - what's needed in the H2 production & refuelling infrastructure which Collie Synfuels is well placed to meet

Toyota's Project Portal hydrogen fuel cell Class 8 truck. (Photo: Toyota)

Toyota's Fuel Cell - Class 8 Truck - currently on trials at Los Angeles port

Hyundai Nexo - Fuel Cell sedan



Toyota's Fuel Cell bus - Made by Hino
(photos: courtesy Bertel Schmitt, March 2017)

Military SUV - low temp Fuel Cell operation undetected by infrared monitoring

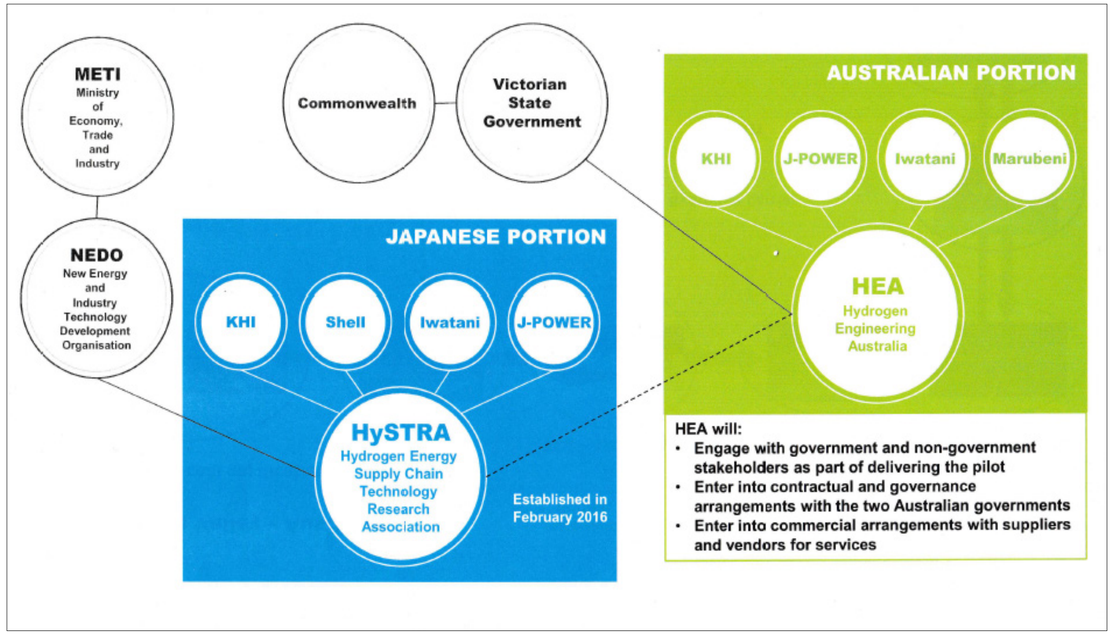
China SAIC - Roewe 950 FCV sedan

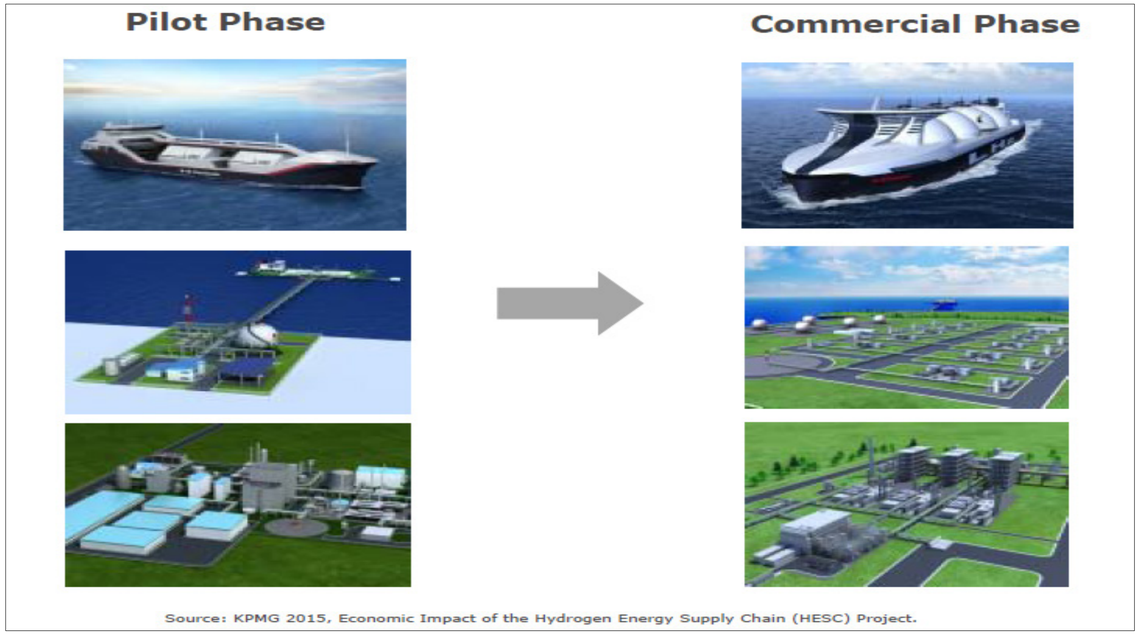
California - Fuel Cell Bus

Federal / Victorian Government support for Lignite-to-Liquid H2

Significant support for Coal-to-Hydrogen with CCS with $100m committed to Japanese consortium

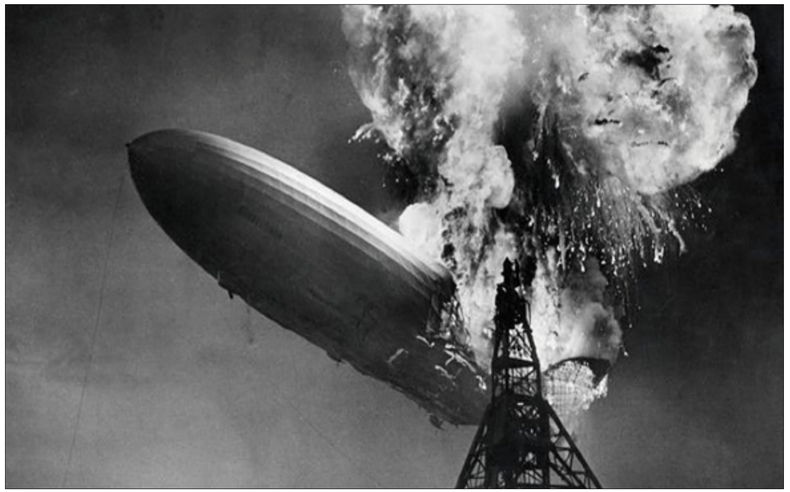
- Coal Gasification to produce Liquid H2 is part of Japan's "Hydrogen Economy Program" with the design of a stand-alone 2 t/d H2 Pilot Plant being built in the Latrobe Valley Australia by a Japanese consortium. The $500m Pilot Phase Trial is co-funded and supported with $100m from the Commonwealth and Victorian Governments as part of the "Hydrogen Energy Supply Chain (HESC) project".
- Hydrogen produced at the 2 t/d H2 Pilot Plant will be transported by high-pressure tube trailer truck to Liquefaction facilities at Pt. Hastings. Liquefaction of H2 to -253 DegC ensures potential coal contaminants are removed to meet the SAE J2719 standard. The Pilot Phase "Trial" will test the entire H2 supply chain for Liquid H2 from Pt Hastings to Japan via 2 x 2,500m3 specially built Liquid H2 vessels - for FCV H2 supply possibly in time for the Tokyo 2020 Olympics. If successful, a commercial size plant will be constructed around 2030.



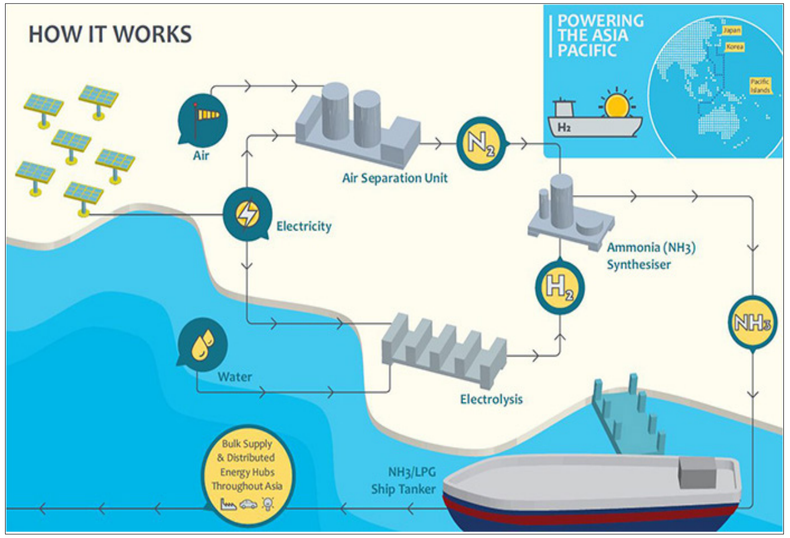


Unwarranted Safety Concerns

- Hydrogen is non-toxic. It is no more or less dangerous than other flammable fuels, including petrol, natural gas and LPG. All flammable fuels must be handled with care and Hydrogen can be handled safely when simple guidelines are observed.
- Hydrogen's explosive limits in air cover a wide range from 18.3% - 59.0 % however it's very unlikely that Hydrogen could ever explode in open air due Hydrogen's high diffusivity which means it rises very fast when released, and it dilutes rapidly into a non-flammable concentration. This is the opposite with propane or petrol fumes which hover near the ground, creating a greater danger of explosion. Petrol presents a much more dangerous explosion potential than Hydrogen with potential explosion occurring with petrol at much lower concentrations from 1.1% to 3.3%.
- Safety concerns for Hydrogen as a gas by non-experts are however very common. A Professor of Robotics & Automation for example was recently quoted in the RAC Horizons magazine review of the Hyundai Nexo that Hydrogen is *"highly explosive".*
- The Head of the CSIRO in his National Press Club talk last year promoting Ammonia as a carrier of renewable H2 with the CSIRO membrane cracker said *"…so the problem with Hydrogen if you store it as a gas, is… it's explosive, we all remember the Hindenburg… "* . The Hydrogen in the Hindenburg did NOT explode. The surface of the Hindenburg started to burn and the Hydrogen in the airship then caught fire and burnt for roughly one minute. Of far greater safety concern is the use of Anhydrous Ammonia as a renewable Hydrogen carrier - it is highly toxic and extremely hygroscopic and will seek out moisture sources. Eyes, lungs and skin are attacked first upon exposure.



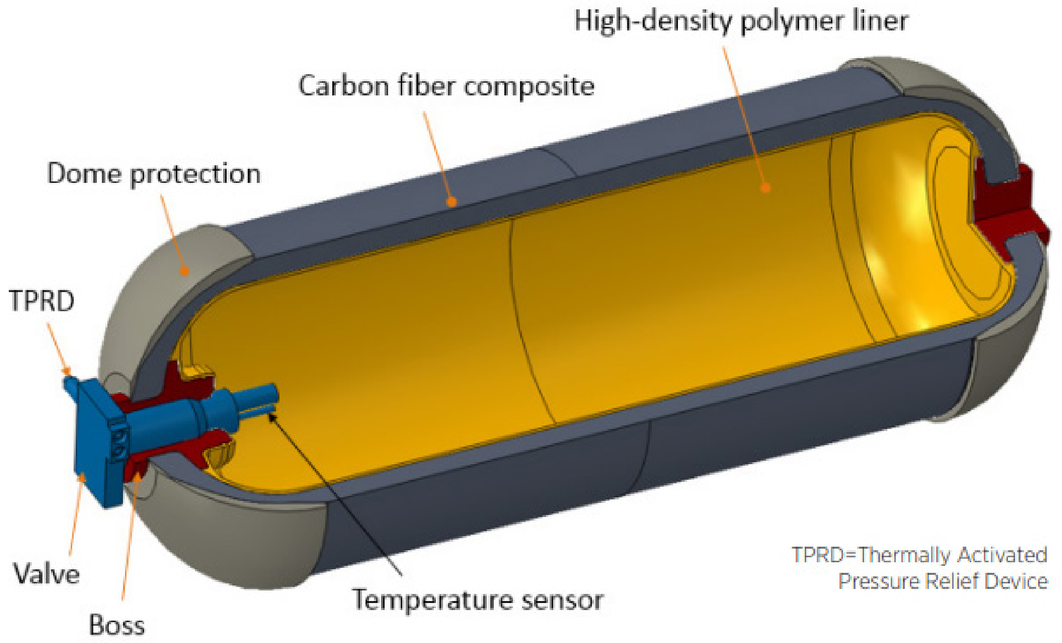
Hindenburg Airship Fire 1937



ABC News: Renewable Hydrogen to Ammonia Project in the Pilbara

Safe and Reliable Hydrogen storage

- Hydrogen itself is not explosive. As a pure gas stored in high pressure cylinders, such as those that deliver H2 by truck to retail outlets in California and Japan, and H2 storage cylinders on-board Fuel Cell Vehicles, Hydrogen is perfectly safe and stable.
- An explosion cannot occur in a pressurised tank that only contains Hydrogen. The manufacture of pressurised Hydrogen tanks used in FCV cars, trucks, buses and other vehicles, meet stringent ISO standards covering all safety features.
- Pressurised hydrogen tanks with compressed H2 gas stored on-board are safe and reliable for use by the public.



Schematic: courtesy of Argonne National Lab

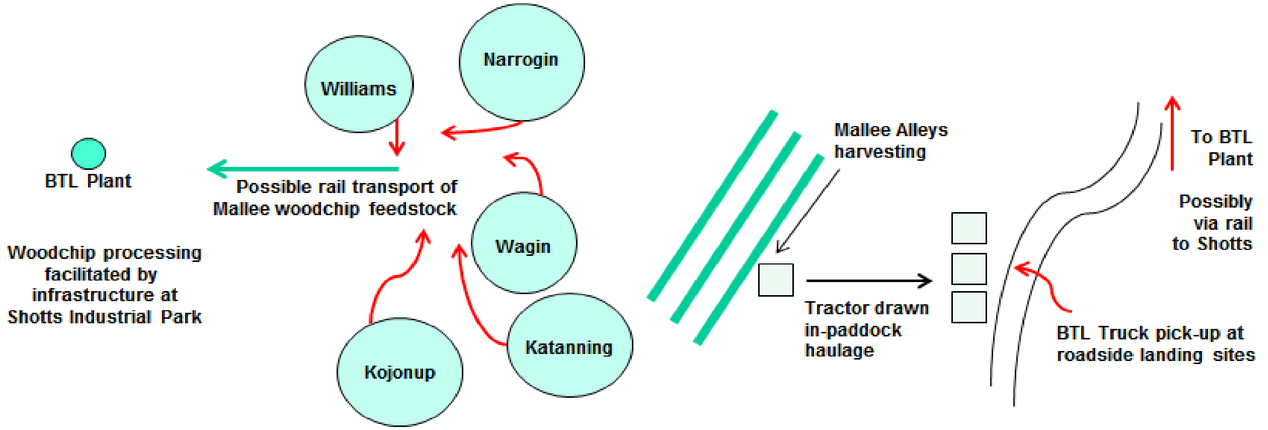
- FCVs typically employ two state-of-the-art hydrogen fuel tanks, made from a polyamide liner wrapped in a carbon fiber epoxy composite. The polyamide resin delivers superior performance for hydrogen permeation prevention and excellent durability and mechanical performance. The tanks are able to withstand sudden changes in tank temperature from filling and discharging hydrogen, and they provide excellent shock resistance characteristics in extreme cold. So excellent safety and consumer protection features are built into the roll-out of FCVs for the public. Hydrogen refuelling stations being rolled out in the USA, Japan and Europe dispense compressed hydrogen gas at 35 MPa and 70 MPa pressure. The higher pressure is preferred giving a superior fill time of only a few minutes.

The Collie Project offers Synergies with Biomass processing

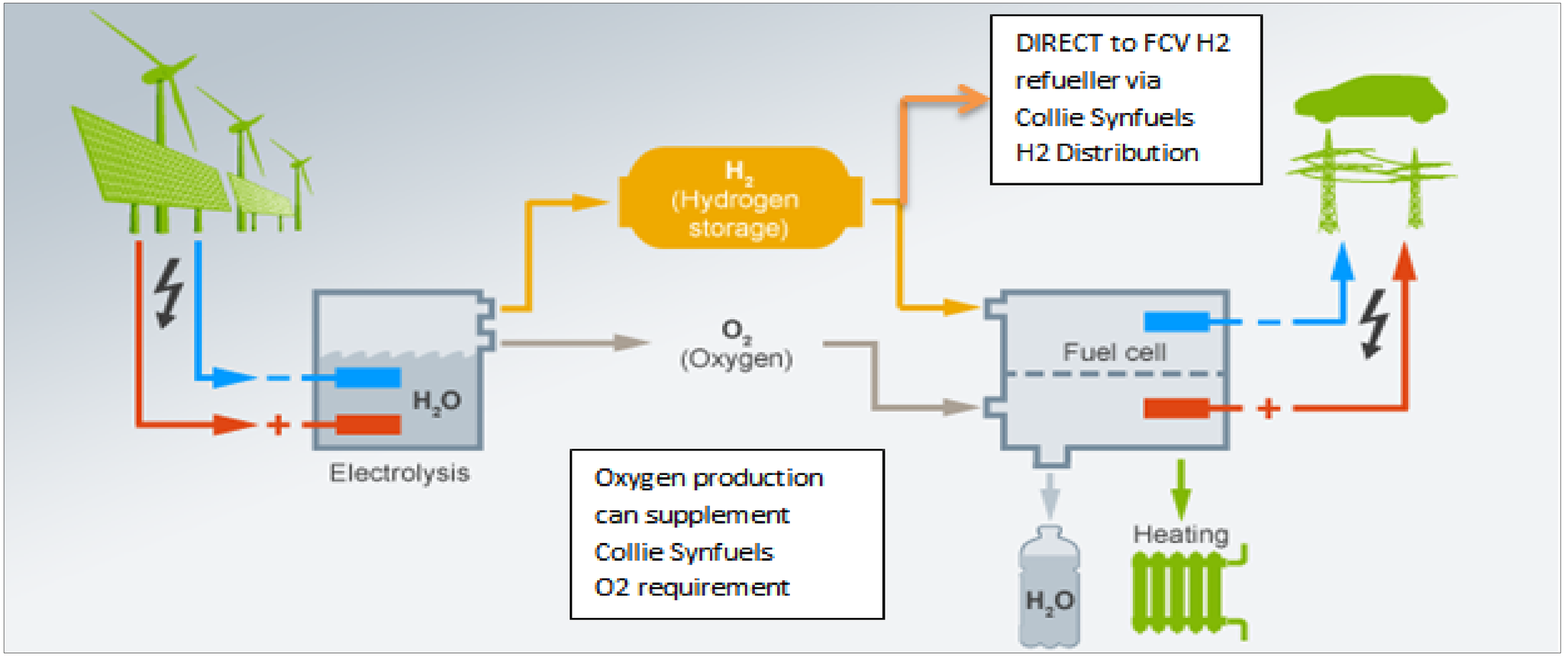
- Katanning, Kojonup, Narrogin, Williams, Wagin mallee belts present an opportunity for sustainable woodchip feedstock production for a potential target Biomass-to-Liquids (BTL) Plant site at the Shotts Industrial Park.
- A core group of 180 farmers with average property size in region of 2,000 Ha would be needed with existing mallees integrated into Mallee Plan to ensure feedstock supply. Perhaps 6 Bulk Contracts are needed - with farmers in each group to determine amongst themselves optimum harvesting - taking into account geography, land form, soil factors when wet, the impact on crops and farm track conditions.
- The Collie Project can co-feed mallee woodchips and also provide infrastructure for Biomass processing to liquids, pyrolysis oil, and power from a range of technologies, including Waste-to-Energy projects.

Photograph from May 2012 report compiled by CSIRO, WA DEC and the CRC for Future Farm Industries, titled - Management of Mallee Belts for Profitable and Sustained Production - reproduced with permission from John Bartle

South West WA - Mallee Belt regions



Synergies with H2 generation at Shotts with off-peak wind farm generation



PEM technology is ideally suited for use with harvesting energy generated from off-peak wind farm generation - because it can be quickly switched on and off without any need for preheating. The electrolyser hydrogen fuel tanks can also be integrated with Collie Synfuels Hydrogen distribution infrastructure as Green Hydrogen for FCV refuellers. In addition Oxygen produced from the electrolysis can also potentially supplement Collie Synfuels Oxygen requirements.

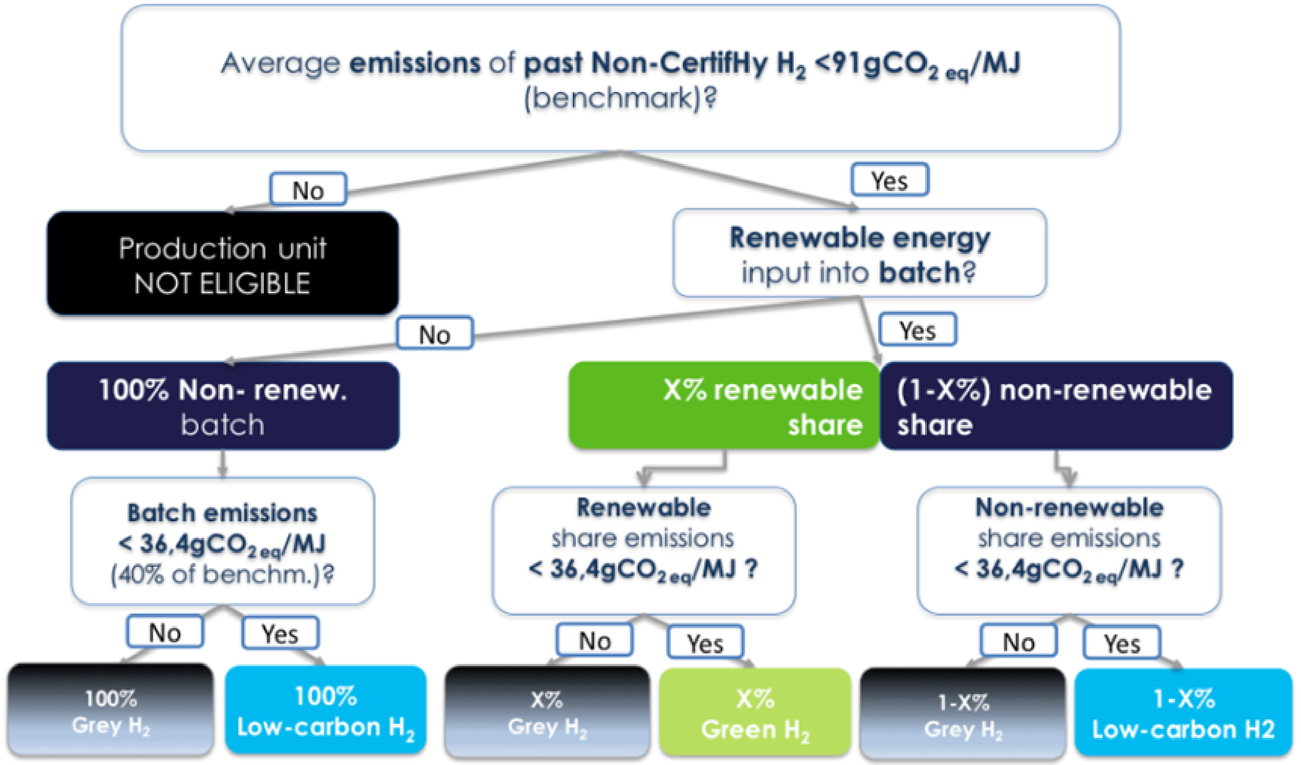
HMA are likely to follow the European Union CertifHy program

The CertifHy project provides a EU-wide **Guarantees of Origin** (GO) for **Premium Hydrogen** (defined as "Green Hydrogen" from renewables and "Blue Hydrogen" for Low or Zero Carbon Hydrogen from non-renewables).

The aim of the project is to initiate a GO Trading system which will assist the European Union achieve its goal of 85-90% Renewables by 2050.

The HMA vision of a Hydrogen Society for Australia built upon "clean and renewable energy" by its founder members Toyota and Hyundai in Australia - is likely to follow the EU program and its definitions of Green, Blue and Grey H2.

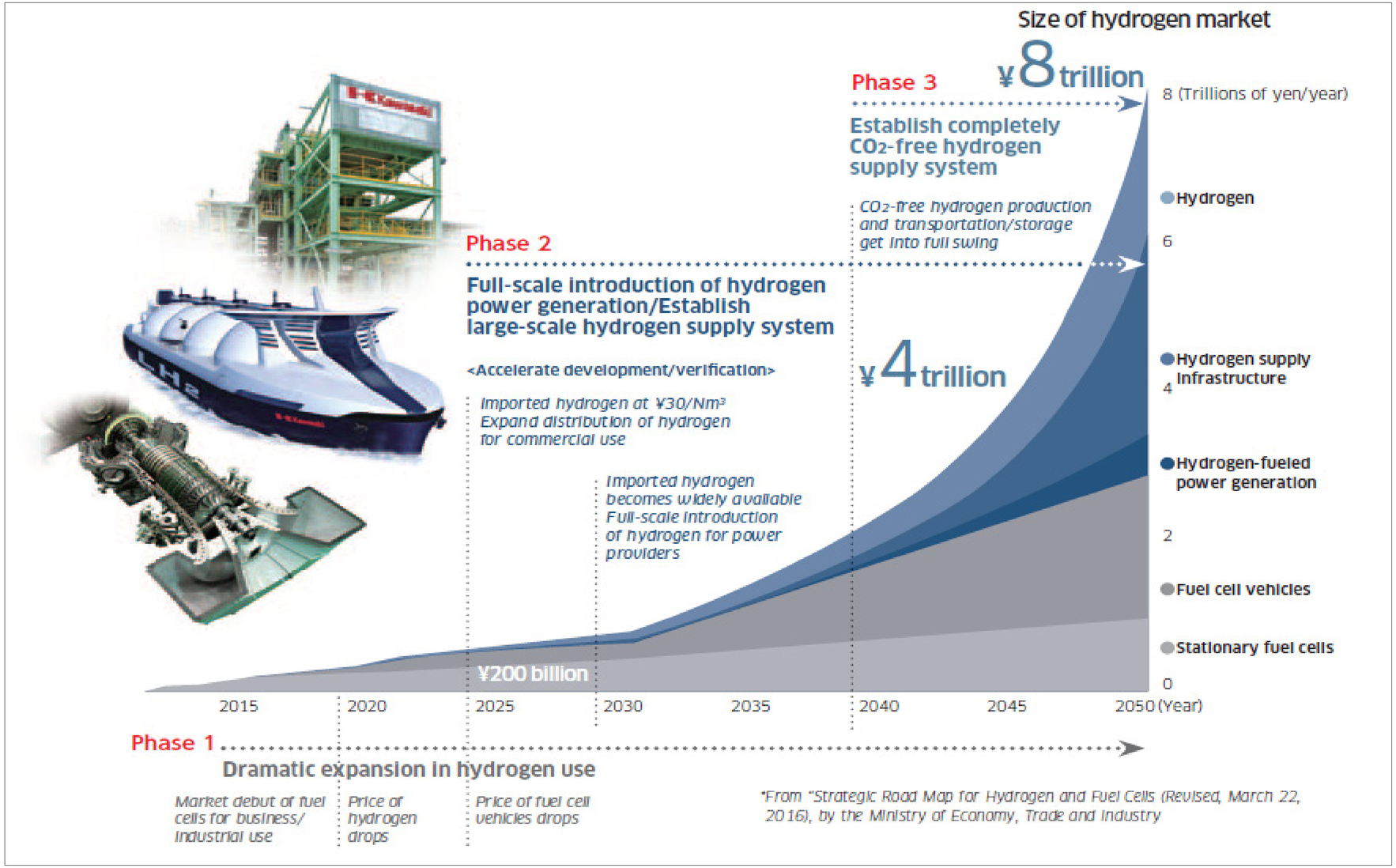
Both Green and Blue H2 Certificates will be priced by Hydrogen Producers and traded in Europe in a similar manner to Renewable Energy Certificates.



Collie Synfuels low cost "clean" Fuel Cell Vehicle Hydrogen meets the SAE J2719 H2 standard with no unlisted contaminants. Our gasification system can co-fire Biomass renewable feedstock (eg forest residues and/or mallee tree woodchips).

Both **Green H2** and **Blue H2** in the European Union receive **Premium Hydrogen** "Guarantee of Origin" Certificates. If a similar market developed in Australia, Collie Synfuels' low cost "clean" FCV H2 would have significant competitive advantage on pricing its certificates since all of Collie Synfuels production is low cost Premium Hydrogen (100% BLUE and GREEN).

Japan's Hydrogen Economy Program



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