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JAS-ANZ

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QUALITY MANAGEMENT

TECHNICAL WEBINAR:

ROLE OF PIPELINES IN CLIMATE CHANGE

PRESENTED BY SOUMEN GUHA

APGA - JULY 2022

WHAT NEEDS TO CHANGE TO ADDRESS CLIMATE CHANGE

- Globally, in an effort to address climate change 195 countries adopted the Paris agreement in 2015.
- This agreement is a universal and legally binding climate deal that seeks to limit the rise of global temperature below 2°C with an aspirational goal to **cap this increase to 1.5°C**.

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TARGET SETTING

- EU has set a target to cut greenhouse gas emissions by 80-95% and as a result move to a low carbon economy.
- **Australia's new Federal Government's target of 'net zero' is by 2050, with 43% emissions reduction by 2030.**

EU Targets	2020	2030*
Cut greenhouse emissions **(compared to 1990 levels)**	20%	55%
Energy coming from renewables	20%	32%
Improvement in energy efficiency	20%	32.5%

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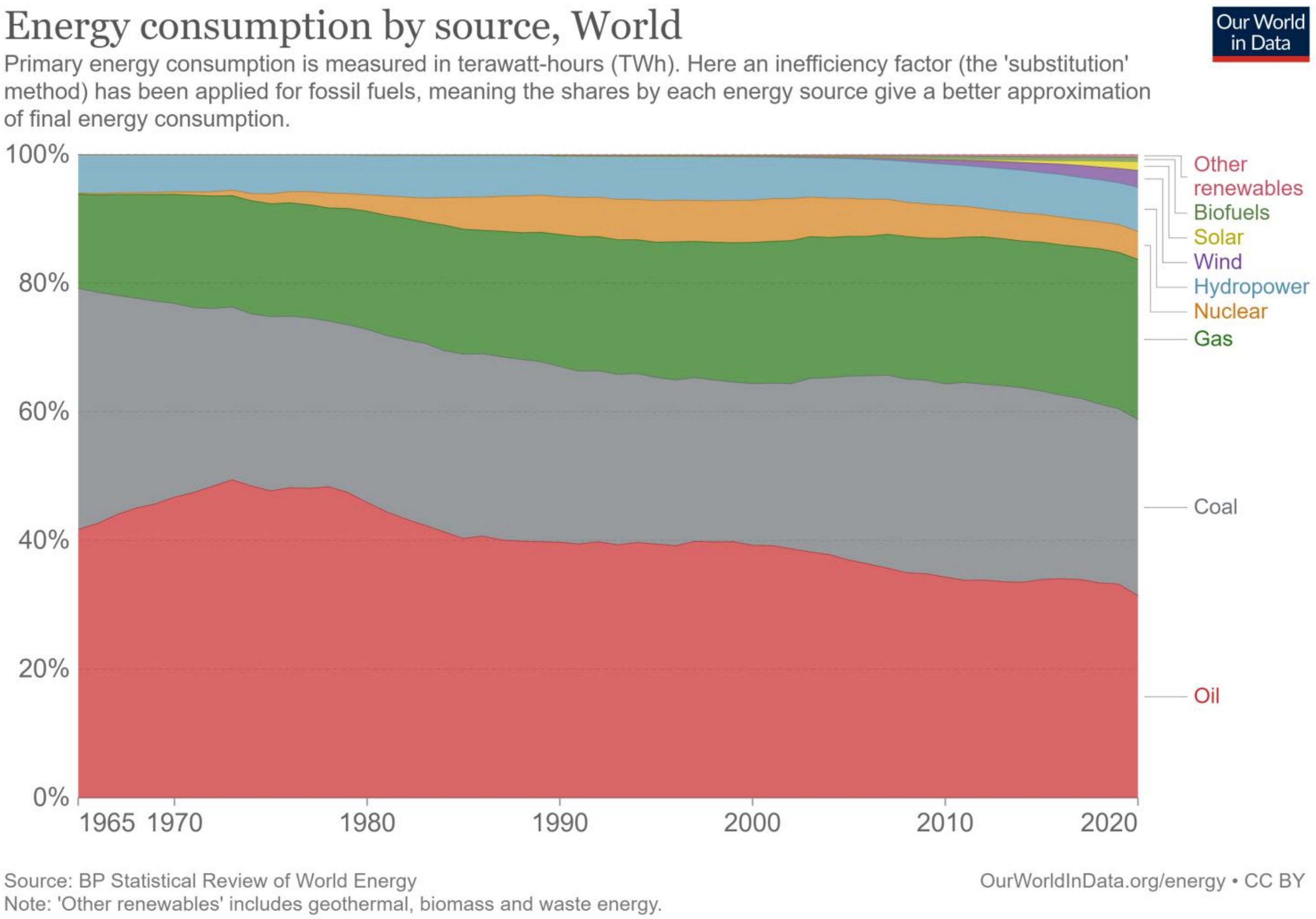
SITUATION OF ENERGY CONSUMPTION



https://ourworldindata.org/energy
https://ourworldindata.org/energy-gdp-decoupling

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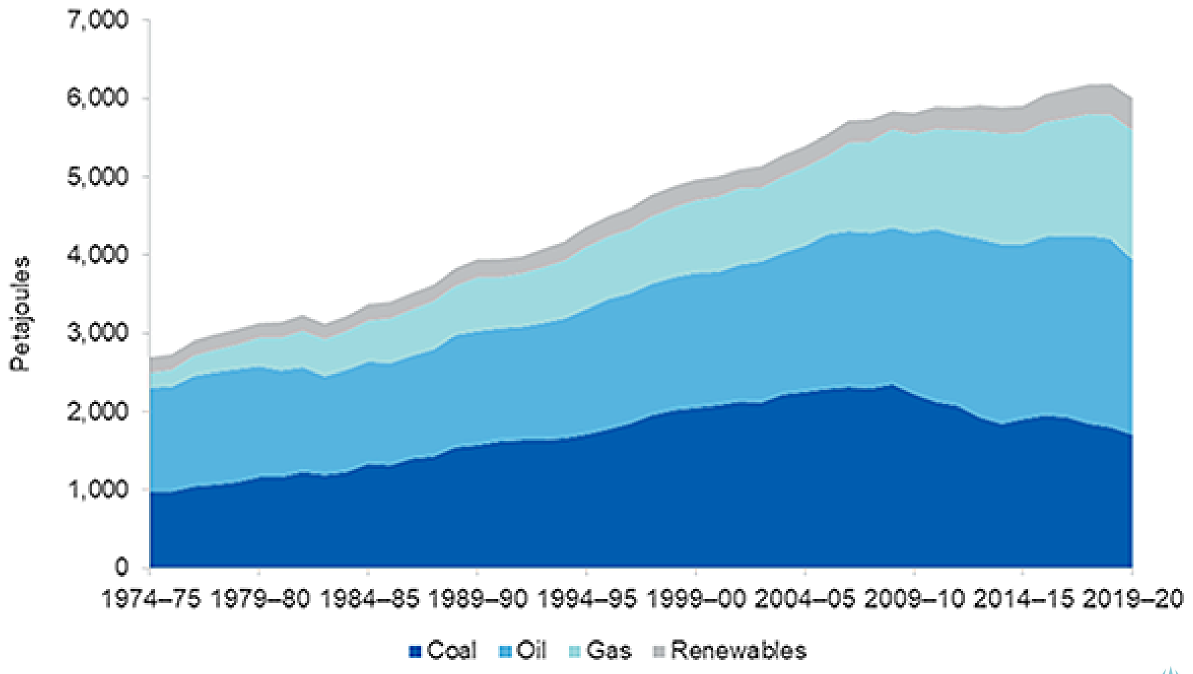
AUSTRALIAN ENERGY CONSUMPTION

- Energy consumption comparison 2000 - 2018
  - Fossil fuels (coal, oil and gas) accounted for 93% of Australia's primary energy mix in 2019-20.
  - Oil accounted for the largest share of Australia's primary energy mix in 2019-20, at 37%

	2019-2020		Average annual growth	
	PJ	Share (%)	2019-20 (%)	10 years (%)
Oil	2,241.2	37.3	-6.9	0.1
Coal	1,706.6	28.4	-5.3	-2.4
Gas	1,647.2	27.4	3.8	2.9
Renewables	418.8	7.0	4.6	4.0
Total	6,013.8	100.0	-2.9	0.2

- Oil (37%) coal (28%) and gas (27%) is followed by Renewable energy sources accounting for 7%.



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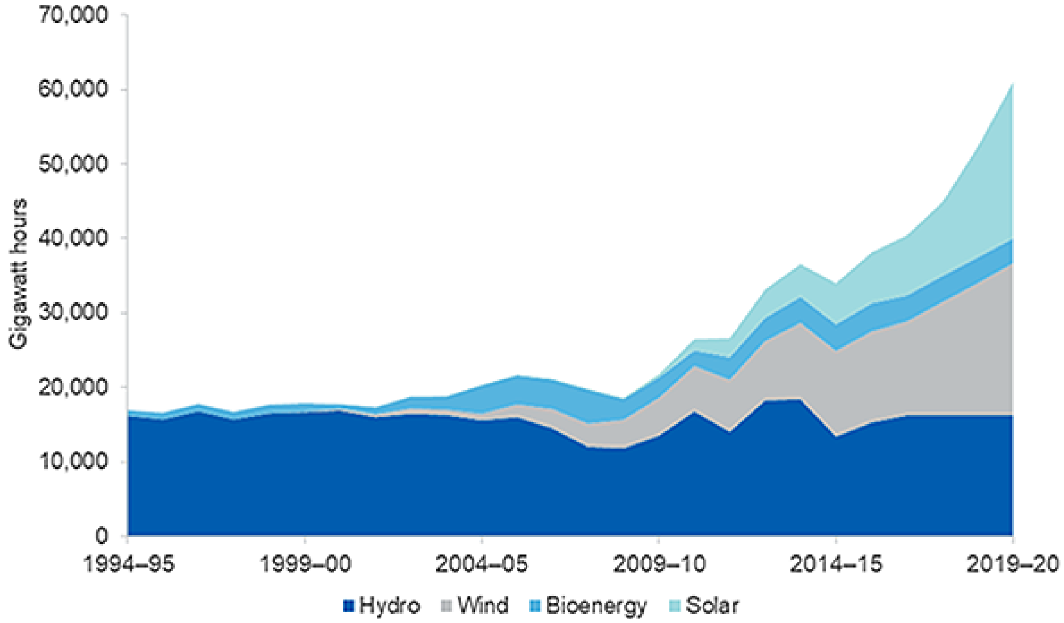
AUSTRALIAN RENEWABLES IN ELECTRICITY REPLACEMENTS TRENDS FOR SOLAR, WIND AND OTHERS

- In 2020, 24% of Australia’s overall electricity generation was from renewable sources,
  - Wind and solar account for 9% each
  - Hydro accounts for 6%.
- Solar and wind have drivers in doubling the expansion into the sector as in 2020 small scale increased by 27% and wind generation by 16%. Recently large solar expansion has occurred as it has reached 3% of total electricity generation in 2020.

Australia electricity generation from renewable sources:



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COMPARISON OF LEVELIZED COST OF ELECTRICITY [LCOE]

- Levelized cost of electricity - “LCOE is a metric which measures all expenses in producing on MWh from a new project. This is inclusive of the costs of development, construction, equipment, financing, feedstock as well as operation and maintenance”

LCOE	Onshore Wind	Utility Scale PV	Battery Storage	Natural Gas CCPP
Cost per MWh	$44	$50	$150	$56
Percentage decrease since 2019	9%	4%	~50%	~9%

		LCOE
Alternative Energy	Solar PV - Rooftop Residential	$160–$267
	Solar PV – Rooftop Commercial	$81–$170
	Solar PV - Community	$73–$145
	Solar PV - Crystalline Utility Scale	$40–$46
	Solar PV - Thin Film Utility Scale	$36–$44
	Solar Thermal Tower with Storage	$98–$181
	Battery Storage	$150
	Fuel Cell	$103–$152
	Geothermal	$71–$111
	Wind	$29–$56
Conventional	Gas Peaking	$152–$206
	Nuclear	$112–$189
	Coal	$60–$143
	Gas Combined Cycle	$41–$74

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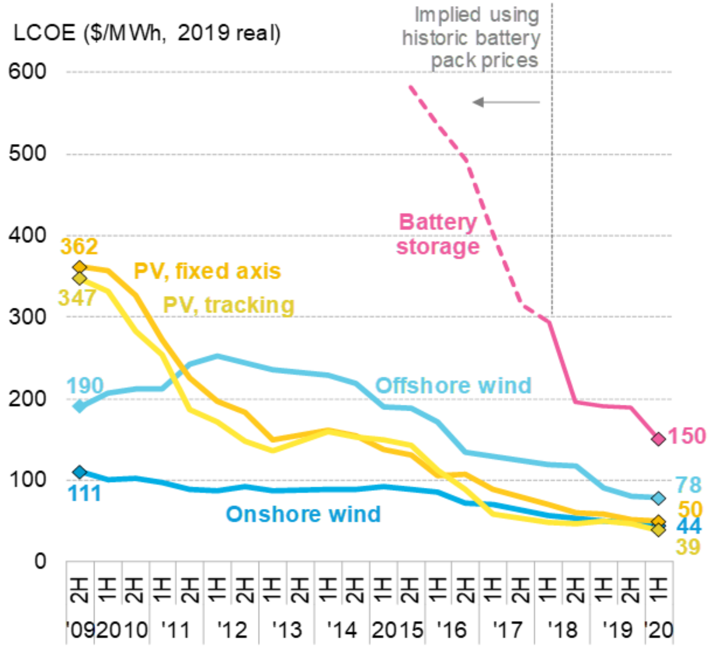
DOWNWARD LCOE TRENDS OF SOME ELECTRICITY SOURCES

- LCOE of renewables have fallen at much higher rate than traditional sources
- But battery as a power storage has its limitations. Time duration of storage and decay being one important factor of those.
- Hence the need for other technologies like green hydrogen and green ammonia

Figure 2: Global LCOE benchmarks – PV, wind and batteries



Source: BloombergNEF. Note: The global benchmark is a country weighted-average using the latest annual capacity additions. The storage LCOE is reflective of utility-scale projects with four-hour duration, it includes charging costs.

Levelized cost of electricity (LCOE) for US natural gas–fired combined cycle plants:

Year	LCOE ($/MWh)
2009	83
2010	96
2011	95
2012	75
2013	74
2014	74
2015	64
2016	63
2017	60
2018	58
2019	56

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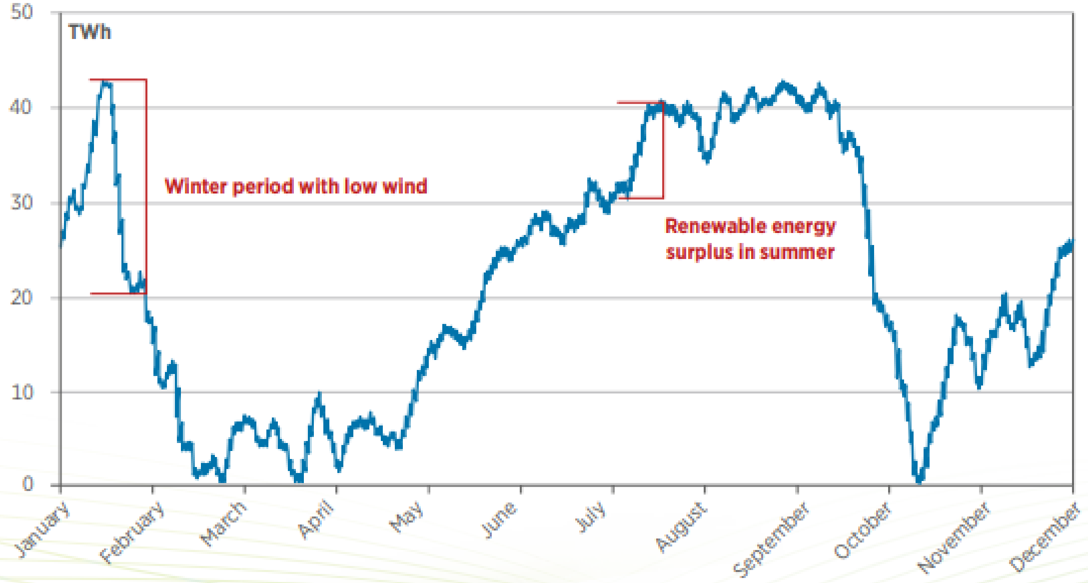
NEED FOR CONVENTIONAL ENERGY SOURCES REPLACEMENTS WITH AMMONIA, HYDROGEN AND CARBON CAPTURE

- Pipeline opportunities in replacement of oil and coal by new energy involving fluids
- Hydrogen can be used, stored and moved in different ways including existing infrastructure can be developed for it i.e. it can be transported via pipelines or by ship

Hydrogen can play a key role for seasonal storage in power systems with a high share of variable renewable energy.

Figure 6: Role of hydrogen in electricity storage, Germany: 95% decarbonisation scenario, 2050



Source: LBST, 2019

- This brings us to fluid based storage of power and energy which can be used and transported when needed during different times of the day or night also different times of the year

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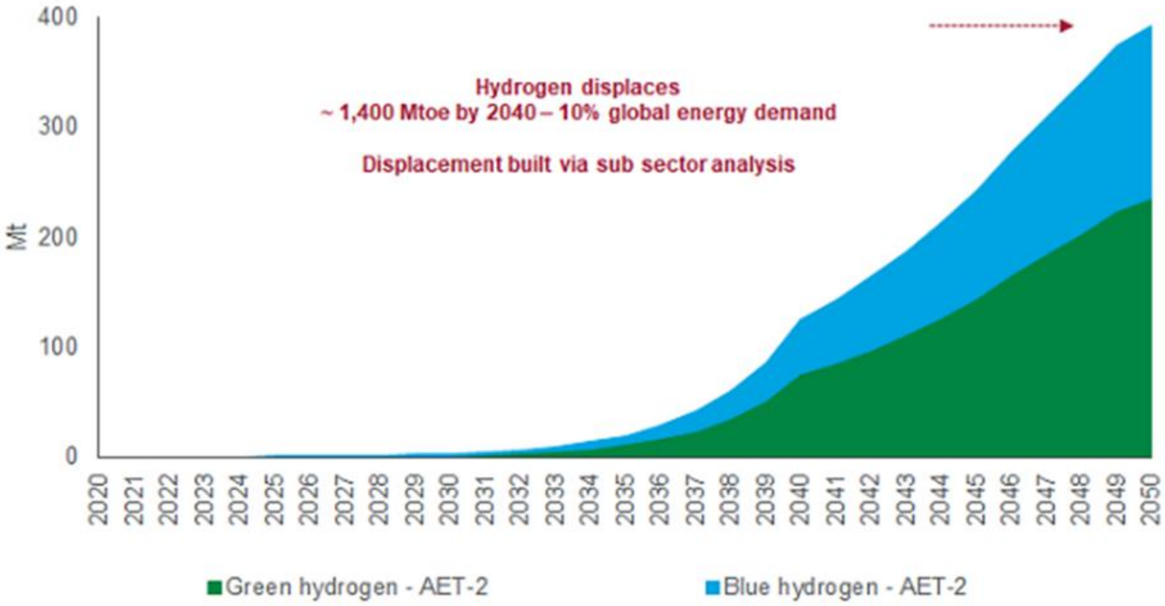
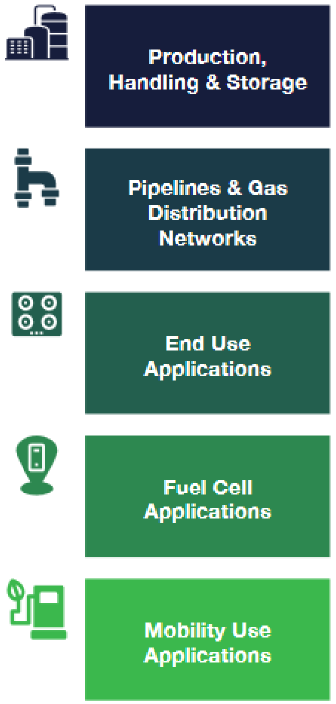
IN 2020 GREEN HYDROGEN ACCOUNTS FOR 0.1% OF GLOBAL HYDROGEN PRODUCTION

- They also quote that the CAPEX should fall by one third by 2030 as electrolyser production moves to automation, feedstock costs reduce by 5% and electrolyser efficiency improves by 8%.
- "Today green hydrogen is tiny, with only around US$365 million invested in 94 MW of capacity, though the pipeline of new projects is 3.2 GW and growing fast. That shows the interest the technology is attracting in China, Japan, the US, Europe and Australia"



https://www.woodmac.com/news/the-edge/future-energy-green-hydrogen/



Taken from the ME-093 Hydrogen Technologies Strategic Work Plan

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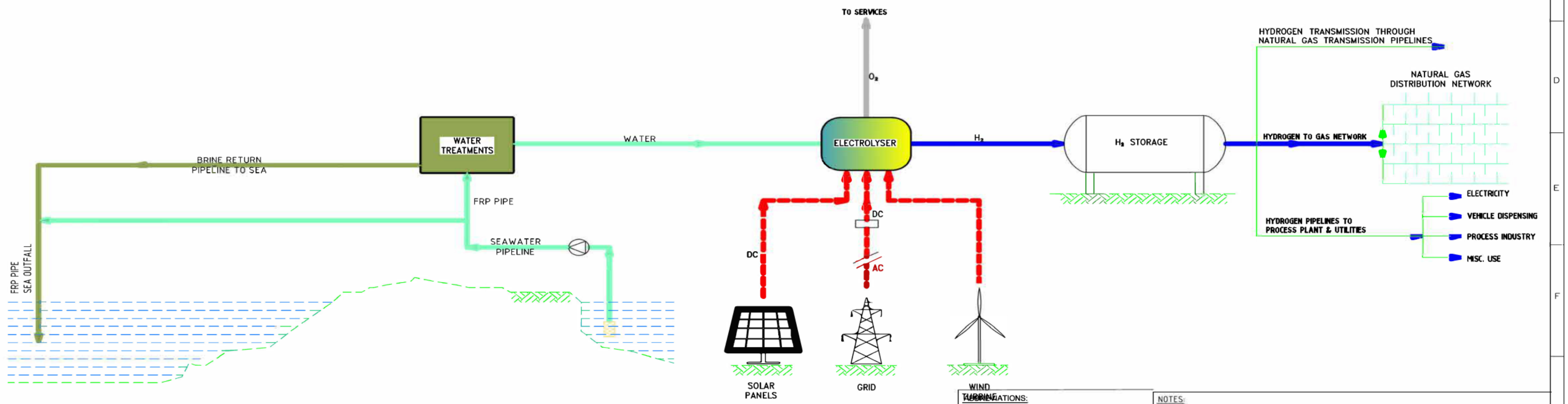
GREEN HYDROGEN PRODUCTION SCHEMATIC DIAGRAM

INDICATIVE ONLY, FOR CONCEPT PURPOSES



ABBREVIATIONS:

FRP	:	FIBRE GLASS REINFORCED PIPE
H_2	:	HYDROGEN
O_2	:	OXYGEN
NG	:	NATURAL GAS
DC	:	DIRECT CURRENT
AC	:	ALTERNATING CURRENT

NOTES:

REF. No.	REFERENCES	REV	DATE	DESCRIPTION	BY	CHKD.	APPD.
TBC	TBC	0	14.07.2021	INDICATIVE CAPACITY	I.C	S.M	S.G

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A1

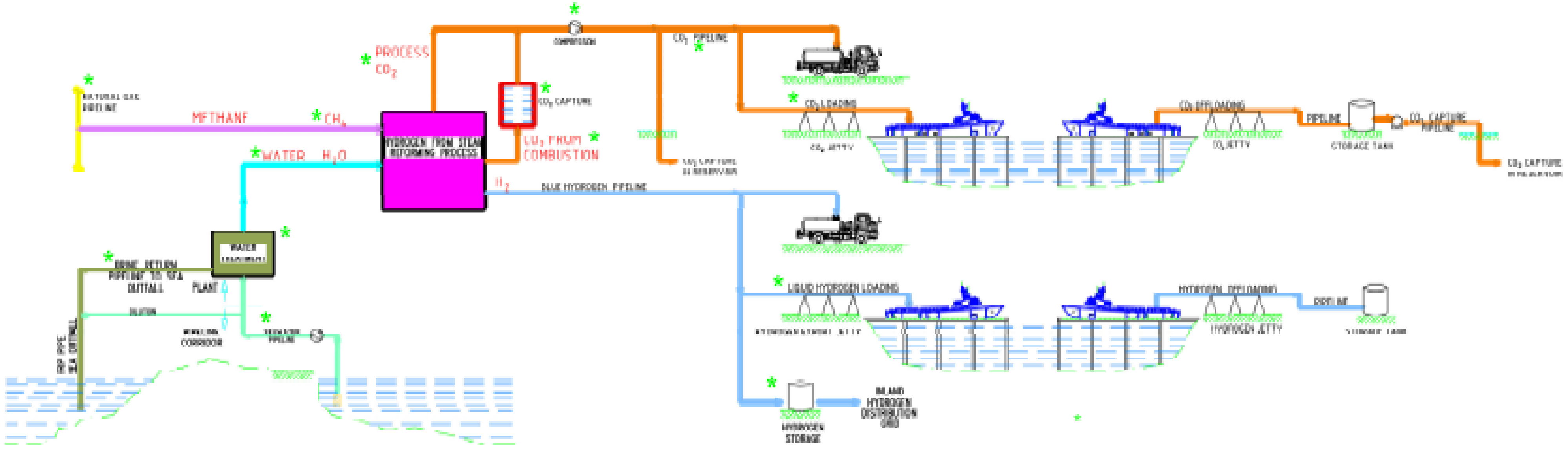
DRG TITLE
GREEN HYDROGEN GENERATION AND ASSOCIATED PIPILINES
PROCESS FLOW DIAGRAM
SUSTECH CAPABILITIES AND EXPERTISE PRODUCTION SCHEMATIC

DRG NO. Q20611079-001

REV. A

BLUE HYDROGEN AND ASSOCIATED PIPELINES

INDICATIVE ONLY, FOR PRELIMINARY CONCEPT PURPOSES



ABBREVIATIONS:

CH_4	:	METHANE
CO_2	:	CARBON DIOXIDE
FRP	:	FIBRE GLASS REINFORCED PIPE
H_2	:	HYDROGEN
H_2O	:	WATER
N_2	:	NITROGEN
NH_3	:	AMMONIA

NOTES:

1. NOTES TO BE ADDED HERE

* THESE ITEMS ARE SUSTECH'S DEMONSTRATED CAPABILITY & EXPERTISE

REF. No.	REFERENCES	REV	DATE	DESCRIPTION	BY	CHKD.	APPD.
TBC	TBC	0	18.06.2021	INDICATIVE CAPACITY	LE	SH	S.G

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DRG TITLE: BLUE HYDROGEN & ASSOCIATED PIPELINES SCHEMATIC DIAGRAM SUSTECH CAPABILITIES AND EXPERTISE

DRG NO. Q19611056-BDV SCD-003

REV. B

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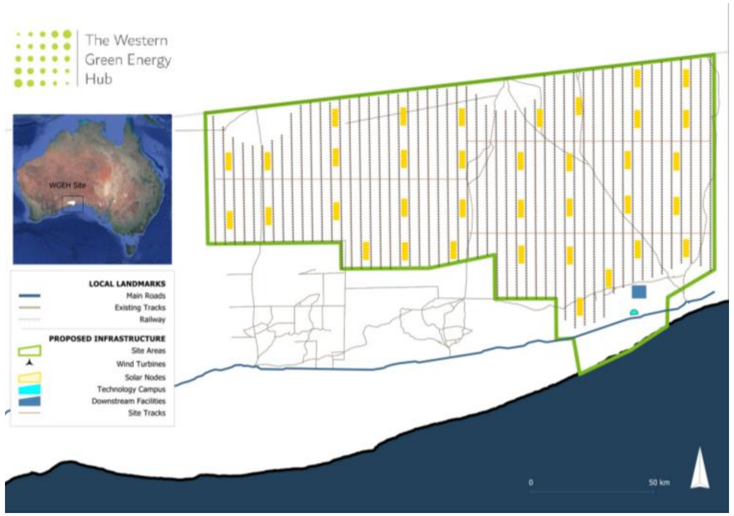
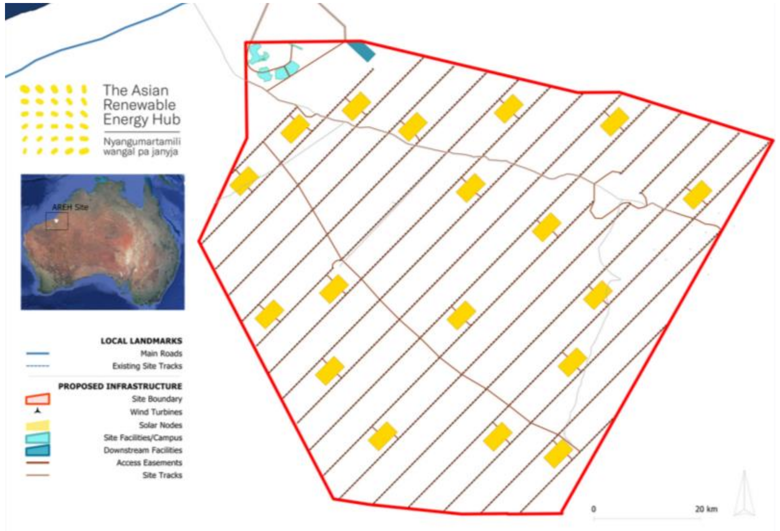
AUSTRALIAN POTENTIAL HYDROGEN/AMMONIA PROJECTS



https://intercontinentalenergy.com/western-green-energy-hub

- One such potential project is the Western Green Energy Hub located in western Australia in the Kalgoorlie region. This project is green hydrogen and ammonia project. It will be built in phases and eventually reach 50GW of upstream solar/win which equates to around 3.6 MTPA of green hydrogen downstream. The capital cost estimation of this project will be $70B (USD), making it one of the worlds largest energy projects. This project has a FID target of 2028.
- Another potential project will be the Asian Renewable Energy Hub located in WA, the project aims to capture 26GW of upstream wind and solar. This will be used to produce 1.8 MPTA green hydrogen and up to 10 MPTA of green ammonia. The project has an FID target of 2025 and is estimated to cost $36B (USD) (15).



https://intercontinentalenergy.com/asian-renewable-energy-hub

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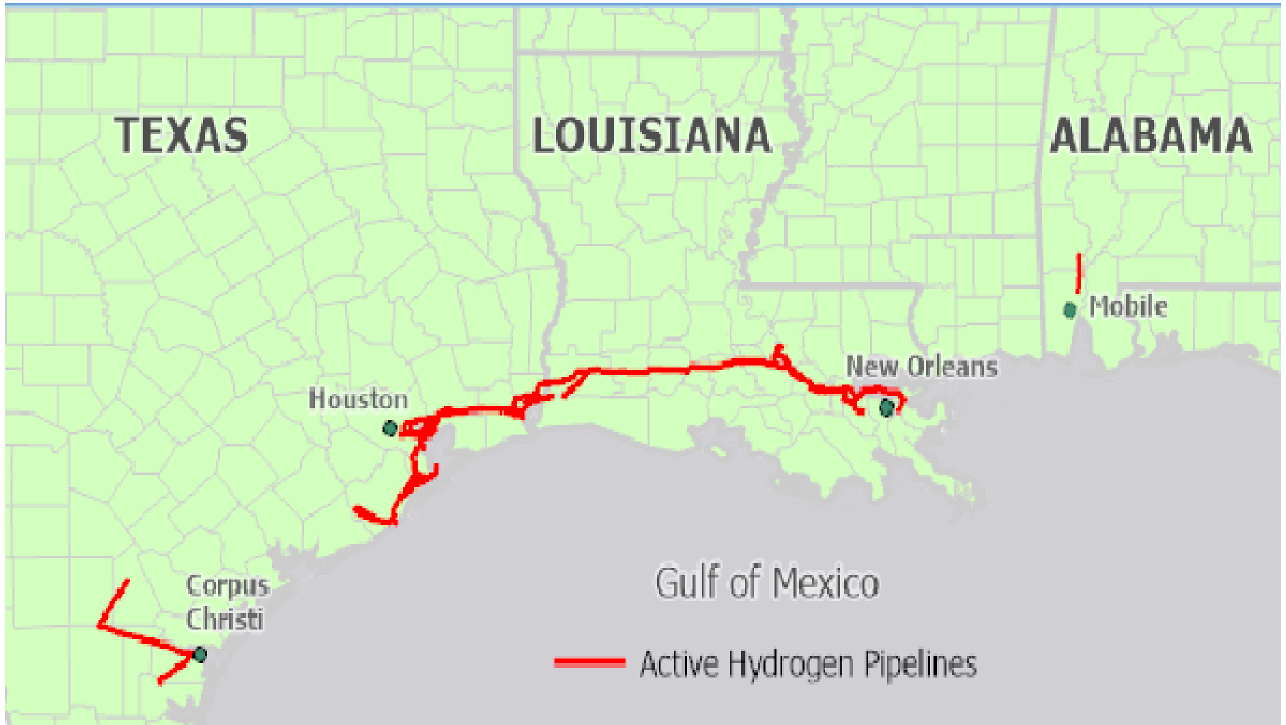
EXISTING HYDROGEN PIPELINE INSTALLATIONS AND FUTURE POTENTIAL



Taken from the "Pipeline Transportation of Hydrogen: Regulation, Research, and Policy" report (March 2 2021)

- Approximately 1,600 miles of hydrogen pipelines are currently operating in the United States, 90% of these are located along the Gulf coast
- One possibility for expanding hydrogen delivery is to adapt existing infrastructure to accommodate hydrogen. Conversion of natural gas pipelines to carry blends of natural gas and up to 15% hydrogen may only require modest modification to pipelines
- Hyblend, a US based project aims to examine the long term effects of these blends on pipeline materials. This project aims to create a publicly available model for industry use which should help further develop understanding of the costs of upgrading existing networks

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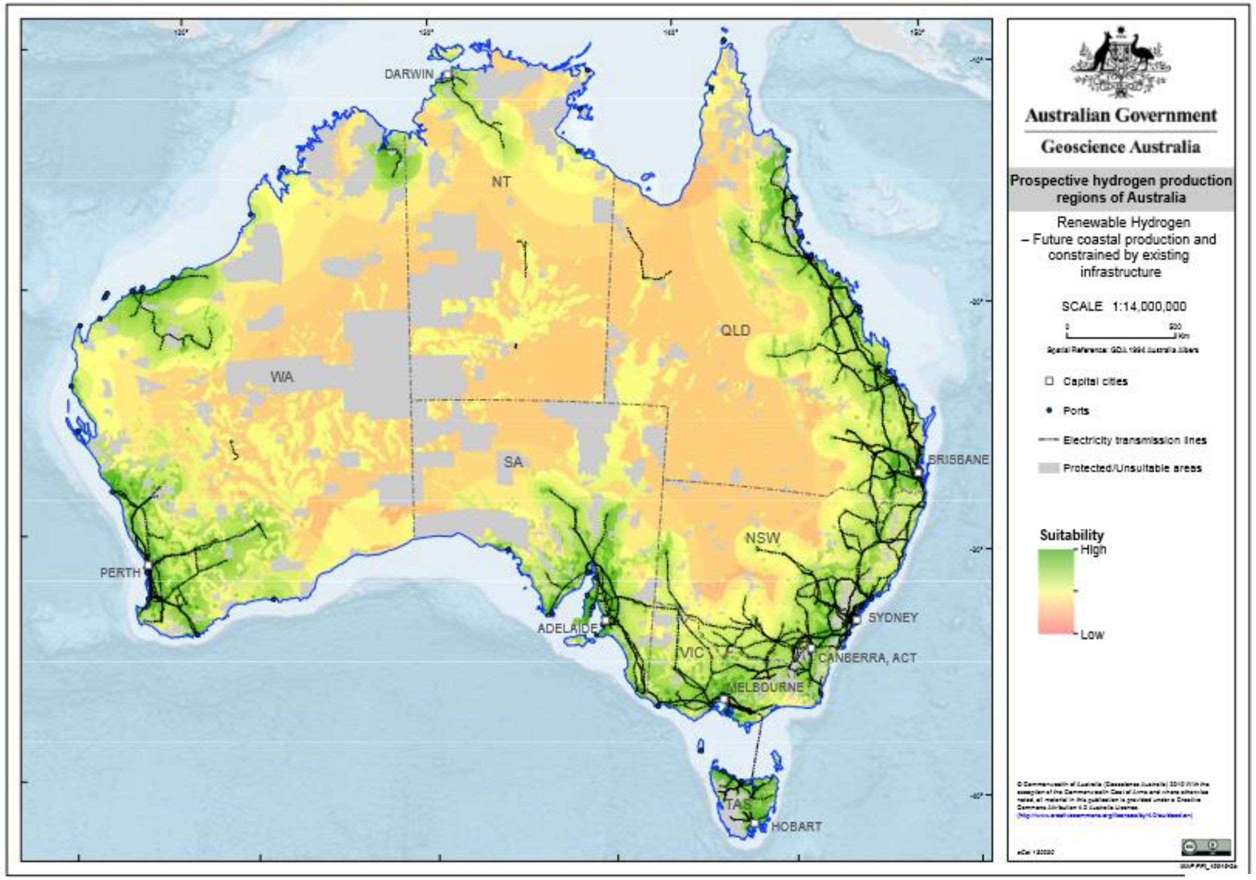
WATER PIPELINES FOR GREEN HYDROGEN

- Through Australia’s National Hydrogen Strategy assessment of site criteria only 11% of Australia’s land is suitable for green hydrogen production
- The demand of water of the correct quality would create a demand of transportation from a location to the plant.
  - Hydrogen scaled up could create demand for a year-round source of water that has been processed in a desalination facility and therefore would need to create pipelines for transport to and from the facility
  - Recycled water from wastewater facilities can have lower logistic costs due to close proximity of wastewater processing facilities to urban centres



Taken from “AUSTRALIA’S NATIONAL HYDROGEN STRATEGY”

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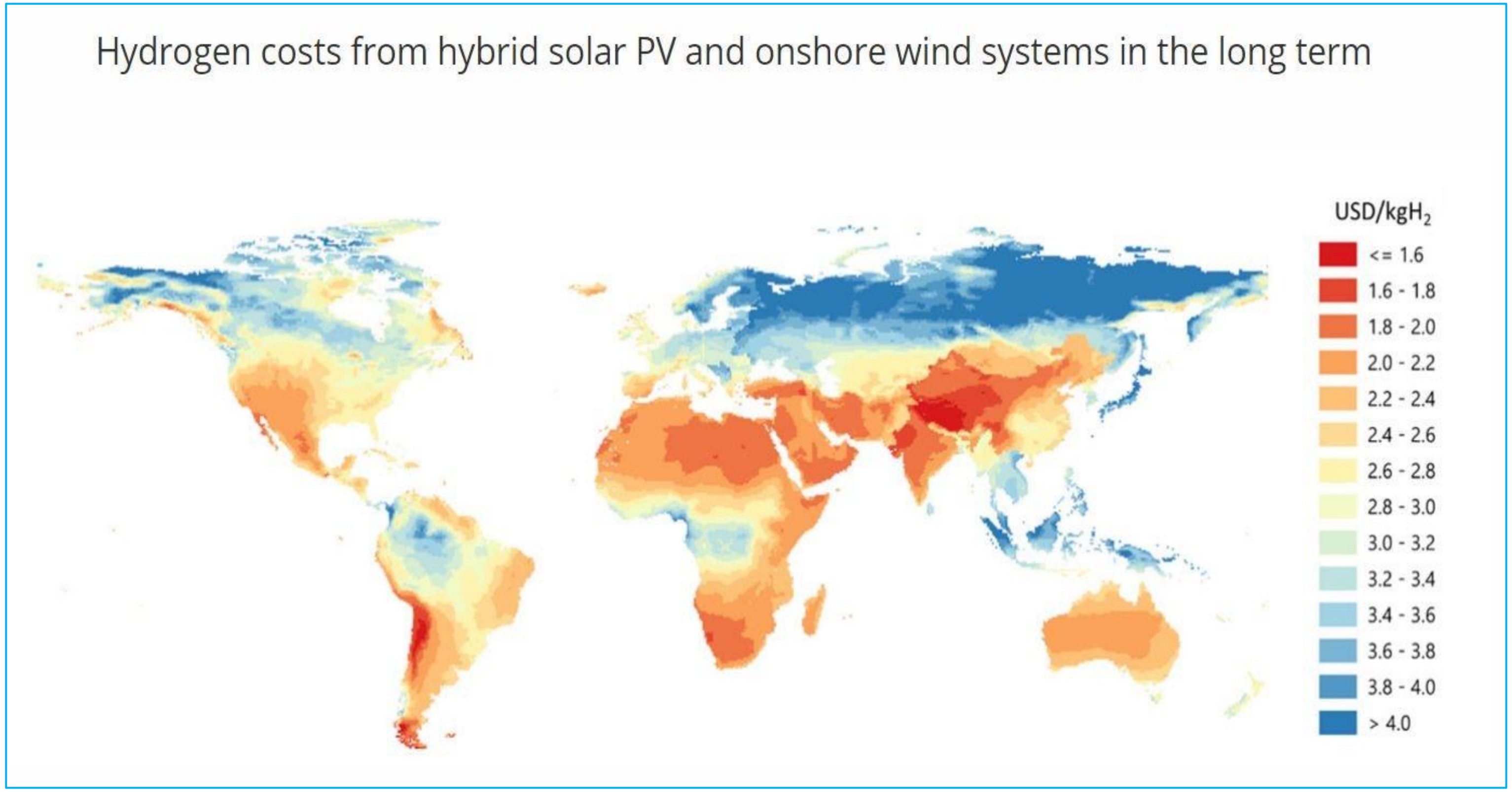
HYDROGEN

- From the report "The Future of Hydrogen" released by the IEA in 2019
  - the cost of green hydrogen at $3 to $7.50 per kilo, compared to $0.90 to $3.20 for production using steam methane reformation.
  - When compared to per GJ basis green hydrogen prices are thrice to double that of natural gas prices across Australia???
  - This is going to break even with falling LCOE of renewable sources



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AMMONIA

- Liquid hydrogen also has more stringent storing conditions as it must be kept at -253°C while ammonia can be stored at a less energy intensive conditions at -33˚C
  - ammonia is much less flammable than hydrogen – so safe intermediate hydrogen carrier
  - Directly used as fuel in shipping

Energy Density	
Ammonia (MJ/L)	Liquid Hydrogen (MJ/L)
12.7	8.5

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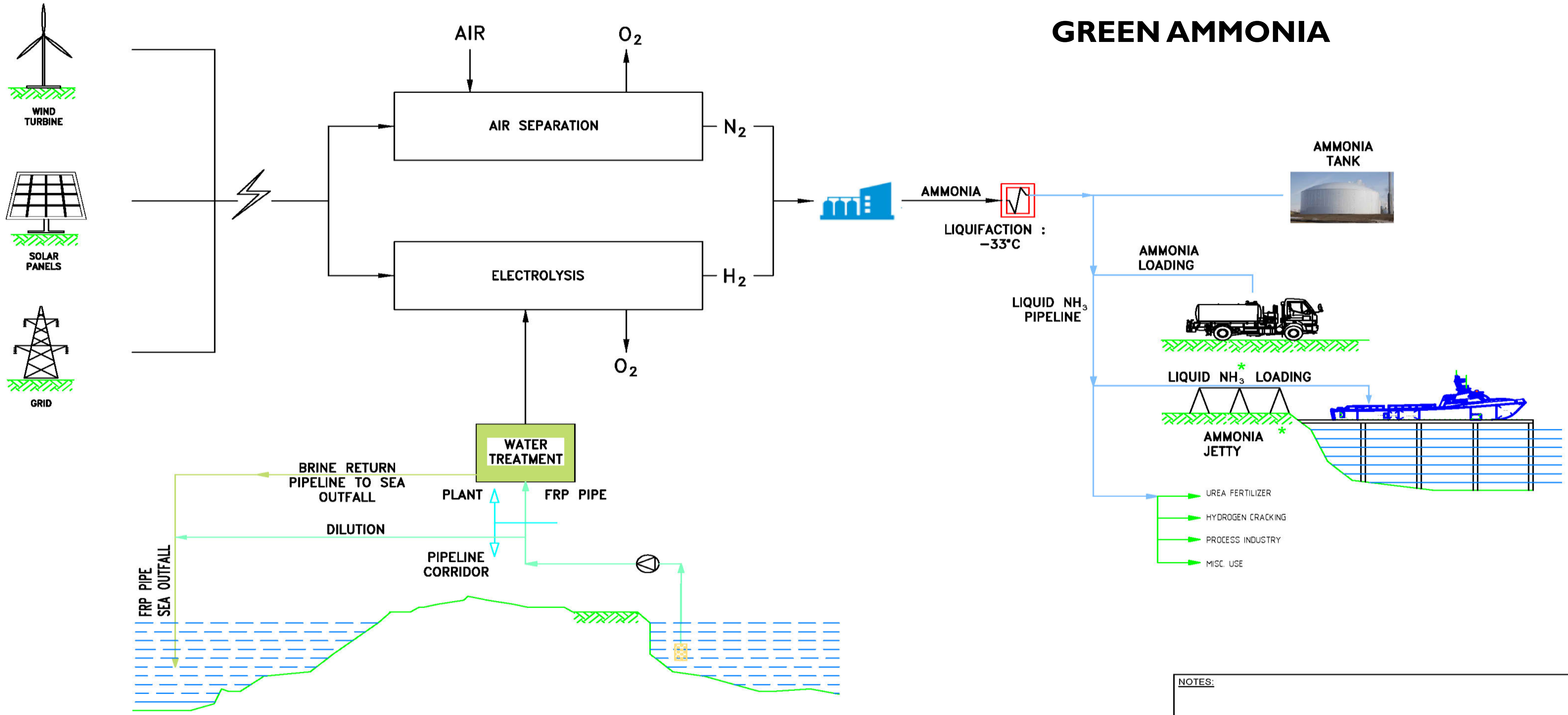

NOTES:

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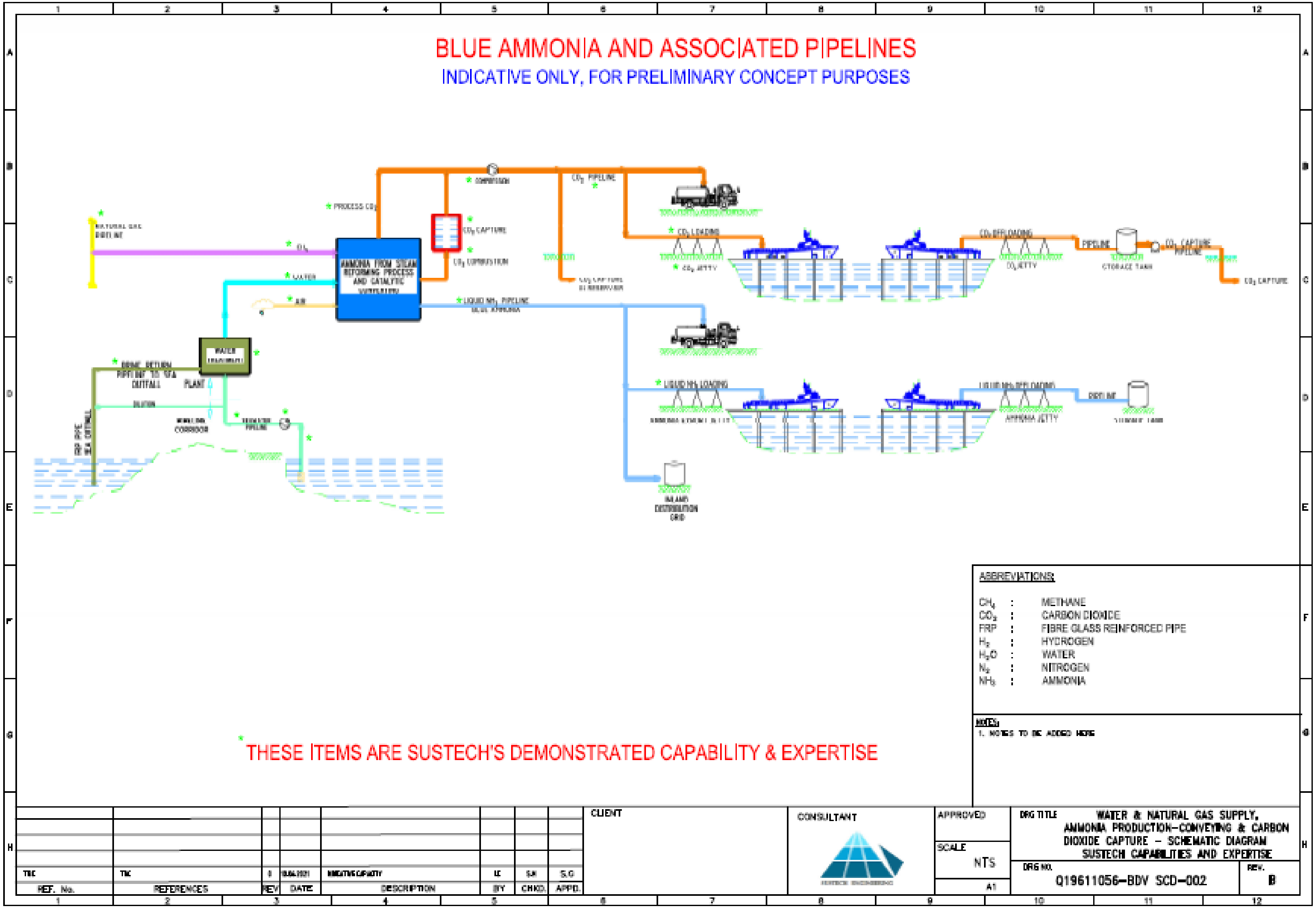
DRG TITLE
GREEN AMMONIA AND ASSOCIATED PIPELINES SCHEMATIC DIAGRAM SUSTECH CAPABILITIES AND EXPERTISE

DRG NO. XXXXXX

REV. A



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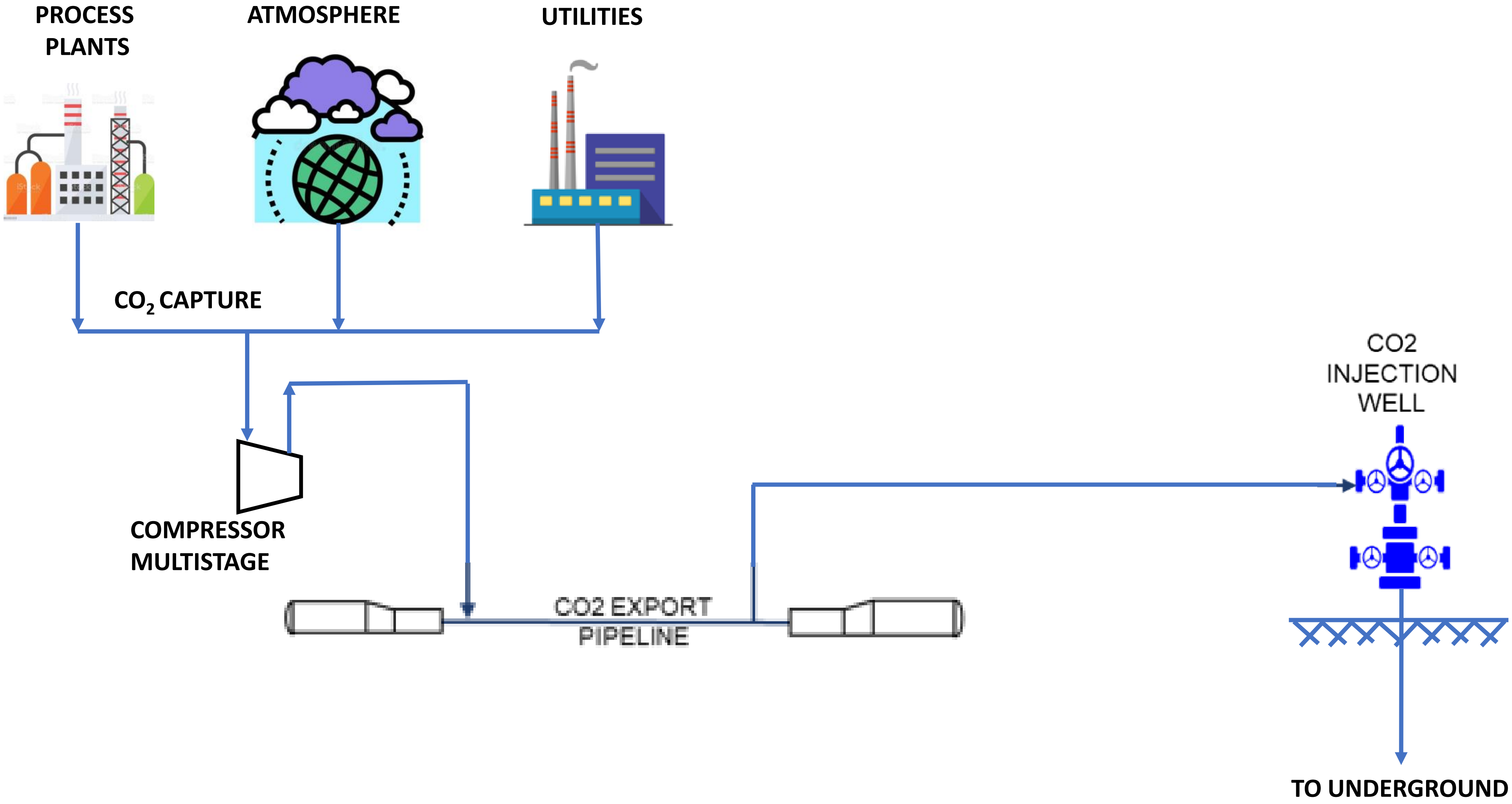
AMMONIA INSTALLED CAPACITY

- In the US pipelines carrying liquid ammonia have been in reliable operation of decades. The US is home to around 5000km of mild carbon steel pipelines, with a delivery capacity of 2 million tpa
- Main branches can have diameters of 200mm and 250mm
- A 2000-mile pipeline by Nustar Energy which transports 1.5 million tonnes of anhydrous ammonia per year. This method is cost effective, efficient and has a low carbon footprint

Name	Length (km)
Gulf central	3057
MAPCO (Mid America Pipeline System)	1754
Tanoa	132

CO_2 CAPTURE AND STORAGE SCHEMATIC

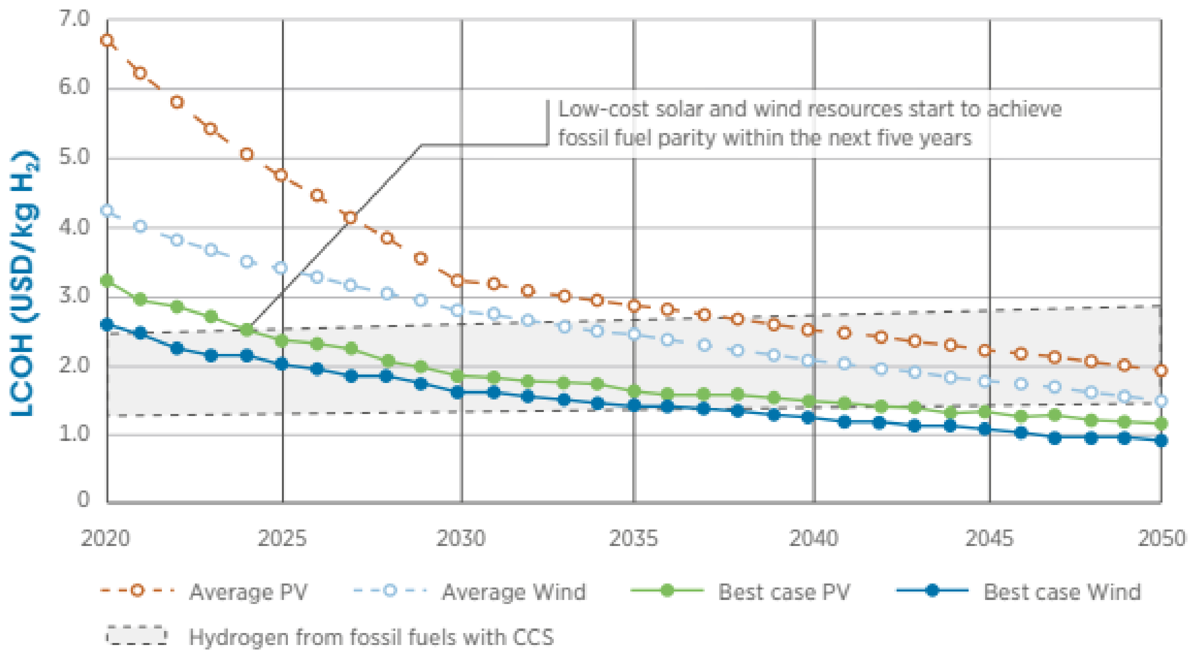


BLUE VS GREEN HYDROGEN & AMMONIA

- While industry moves towards solely producing green ammonia, pipeline opportunities for CCS in blue ammonia will exist.

Future costs of green hydrogen will be below those for blue hydrogen fossil fuels. By 2035, average-cost renewables also start to become competitive. Pricing of CO_2 emissions from fossil fuels further improves the competitiveness of green hydrogen. In the best locations, renewable hydrogen is competitive in the next 3-5 years compared to fossil fuels.

Figure 14: Hydrogen production costs from solar and wind vs. fossil fuels



Note: Remaining CO_2 emissions are from fossil fuel hydrogen production with CCS.
Electrolyser costs: 770 USD/kW (2020), 540 USD/kW (2030), 435 USD/kW (2040) and 370 USD/kW (2050).
CO_2 prices: USD 50 per tonne (2030), USD 100 per tonne (2040) and USD 200 per tonne (2050).

HYDROGEN:

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HYDROGEN PIPELINES CODES AND FUTURE STANDARDS

ASME B31.12 Standard on Hydrogen Piping and Pipelines:

- General requirements for hydrogen pipeline. These include definition and requirements for material, welding, heat treating, brazing, testing, forming, examination, inspection, maintenance and operations
- Industrial piping requirements for component, design, fabrication, assembly, inspection, erection, examination, and testing of piping
- Pipeline requirement for component, design, installation and testing on hydrogen pipelines

As Hydrogen is an emerging technology within Australia, standards have yet to be fully established, as such the Australia standards committee ME-093, hydrogen technologies in May 2020 established five working groups to develop guidance in the below areas:

- Production, Handling and Storage
- Pipeline and Gas Distribution Networks
- End Use Utilisation
- Fuel Cell Applications
- Mobility Applications

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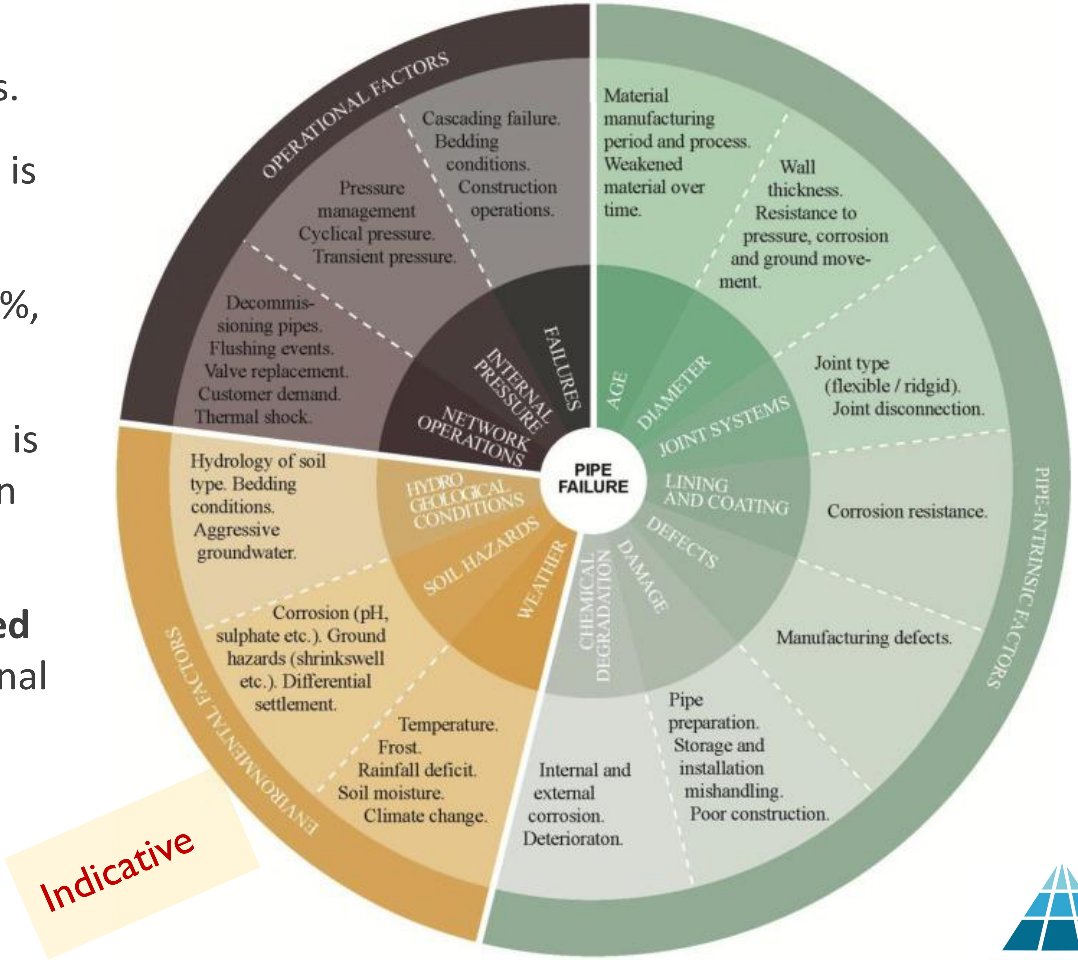
AMMONIA PIPELINES CODES

- ASME B31.4 Pipeline Transportation Systems for Liquids and Slurries
  - Contains the requirements for design, material, construction, assembly, inspection, testing, operation and maintenance of liquid pipeline systems between delivery and receiving points. This is inclusive of ammonia plants.
  - Operation and maintenance of liquid pipeline systems in relation to safety and protection of the general public, operating company personnel, environment, property and the piping system themselves

HYDROGEN PIPELINES – FAILURE MODES AND FUTURE MATERIALS

Main concerns for failure:

- **Hydrogen embrittlement** can weaken metal or polyethylene pipes.
- This increases risk of leakage and maintenance/upkeep costs. This is particularly an issue in high pressure pipes.
- Embrittlement can reduce a pipeline's overall service life by 20-50%, this is due to the acceleration of propagation of cracks
- This is likely in situations where pipeline has existing fractures and is subject to dynamic stresses due to fluctuating internal pressures in the presence of hydrogen
- Potential remedies for this could include the **use of fibre reinforced plastic (FRP) pipelines**, these pipelines cost 20% less than traditional steel pipelines as they can be obtained in longer sections (up to lengths of 0.5 mile) which minimises welding requirements. **ISO 14692** is one of the standards being followed in this area.
- There will be other material solutions also



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FAILURE MODES OF AMMONIA PIPELINES

- The European Gas Pipeline Incident Data Group (EGIG) states that during the periods 190-2004 in Europe 1123 incidents have occurred in regard to ammonia pipelines. This has been adapted into the table, where it should be noted that near half are from external interference.

Cause of incident	% Of all incidents	Description
External interference	49.8	Digging, pilling, ground works, anchor, bulldozer, excavator, plough, protecting casing/ sleeves
Construction defects/material failures	16.7	
Corrosion	15.1	
Ground movement	7.1	Dyke break, erosion, flood, landslide, mining, river
Hot-tap made by error	4.6	
Other and unknown	6.7	
Total	100	

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INCIDENTS IN THE US

- Liquid ammonia pipelines in the US have had 9 occurrences of incident. The incidents can be summarised as below.
  - 1x overpressure
  - 2x external corrosion
  - 1x maintenance work
  - 1x metal fatigue cracking
  - 1x seam failure
  - 1x an unforeseen freeze thaw cycle
  - 2x malicious act
- As a note the two failures via malicious act, makes clear that these fuel pipelines can potentially be subject to terroristic attack.
- Another note is that no failure was the occurrence of accidental excavation and as such, this may be due to the practice of installing sufficient line markers.

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ROLE OF PIPELINES IN RESPONSE TO CLIMATE CHANGE

- Pipeline opportunities in replacement of oil and coal by new energy involving fluids

1. Redefining Redefining existing natural gas pipelines for energy storage
2. Repurposing existing natural gas pipelines for natural gas – hydrogen mixture transportation
3. New green hydrogen pipelines
4. New green and blue ammonia pipelines
5. New Carbon Dioxide Pipelines
6. Pipelines for anything conveyable to cut on oil fueled transportation; e.g. different slurry and air conveying pipelines
7. New Sea Water Pipelines
8. New Brine Pipelines
9. New Water Pipelines
10. New Wastewater Pipelines
11. Distribution network of resource and product pipelines
12. Repurposing Oil Pipelines

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- Challenges of each type of pipelines
- How much in use as installed capacity of each
- Failure modes of each
- Hazards and safety
- Codes and standards in place for each
- New codes to write – **Free the standards**
- New material challenges and innovation opportunities
- New technology evolving and increasing viability
- Risks of investment

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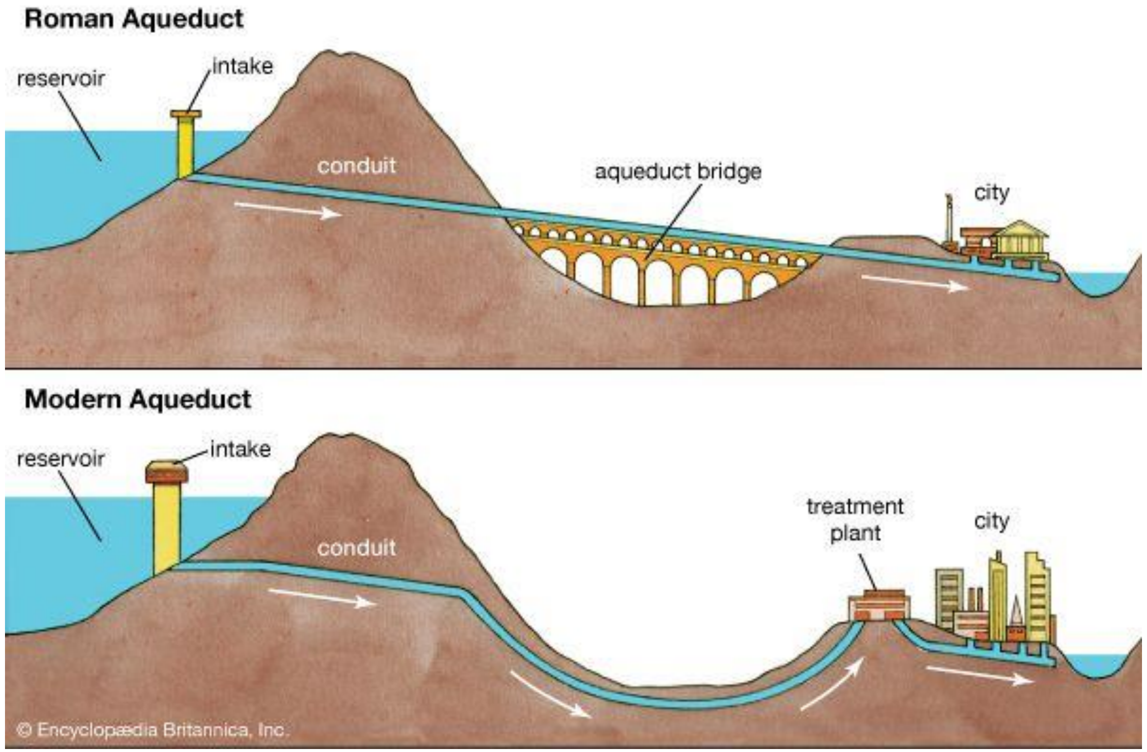
- Wheels - Transporting

- Pipes - Conveying



From dawn of human time, two fundamental inventions – wheel and pipes

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THANK YOU

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