Renewable hydrogen for the Pacific Islands

Workshop
Suva, 7 September 2023
slido.com enter #3283346

Workshop context

Numerous stakeholders – governments, utilities, researchers, donors - investigating opportunities for renewable hydrogen to assist the Pacific Island Countries and Territories achieve their ambitious clean energy and climate goals

And a recent regional call for action

FIFTH PACIFIC REGIONAL ENERGY AND TRANSPORT MINISTERS' MEETING

Warwick Hotel, Port Vila, Vanuatu, 08 – 12 May 2023

"Accelerating decarbonisation in the Blue Pacific".

EFATE OUTCOME STATEMENT

Port Vila, Vanuatu, 11-12 May 2023

Energy Official Resolution - ***Fuelling the Pacific Through Green Hydrogen***

Energy Officials:

- **Called for a dramatic deepening of** decarbonisation efforts in PICTS through the recognition of potential contribution of green hydrogen and its derivatives;
- **Recommend** to further examine the potential role of green hydrogen in the region and expected timeframe with a view to developing a Pacific regional green hydrogen strategy.

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Welcoming remarks

The Fiji Department of Energy

Introductory remarks

Dr Kelly Strzepek

Australian Government

Department of Climate Change, Energy, the Environment and Water

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Introductory remarks

Mr Inia Saula

Introductory remarks

Mr Peceli Nakavulevu

Introductory remarks

Mr Gordon Chang

Introductory remarks

Dr Atul Raturi

Introductory remarks

Dr Rahman Daiyan and Dr Iain MacGill

Todays agenda

RENEWABLE HYDROGEN FOR ENERGY TRANSITION FOR THE PACIFIC ISLANDS

SOUTHERN CROSS HOTEL, Suva, Fiji 5-8th September 2023

Day 3 Agenda: Renewable Hydrogen for the Pacific Islands

Start Time	Finish Time	Topic	Chair
8.30am	**9.15am**	**Registrations**	
9.15am	9.35am	**Welcome, introductions, stakeholder perspectives on hydrogen for the region**	**Iain MacGill**
		Fijian Department of Energy	
		Dr Kelly Strzepek - Australian Government Department of Climate Change, Energy, the Environment and Water (DCCEEW)	
		Ms Florence Ventura - Pacific Community (SPC)	
		Mr Peceli Nakavulevu - International Renewable Energy Agency (IRENA)	
		Mr Gordon Chang - Pacific Power Association (PPA)	
		Dr Atul Raturi - University of the South Pacific (USP)	
		Dr Iain MacGill and Dr Rahman Daiyan - UNSW Sydney	
9.35am	9.45am	Dr Iain MacGill - establishing a hydrogen strategy for the Pacific Island Countries and Territories	
9.45am	11am	Dr Daiyan Rahman - Masterclass into Hydrogen and Derivatives	
11:00	**11:30**	**Morning Tea**	
		Regional perspectives	**Atul Ratui**
11:30am	11.45am	Mr Peceli Nakavulevu - International Renewable Energy Agency; IRENA work and projects in the region	
11:45am	12 midday	Ms Florence Ventura - Pacific Community (SPC) perspectives	
12 midday	12.15pm	Dr Ali Mohammadi - Engineering and Physics - University of the South Pacific; hydrogen based research at USP	
12.15pm	12.35pm	Dr Rahman Daiyan - other hydroge project proposals for the region Iain MacGill and Shayan Naderi - Renewable energy potential for hydrogen production in the region	
12.35pm	1pm	Regional challenges and opportunities - perspectives from Governments and Utilities (Vanuatu, Solomons, Fiji), other stakeholders	
13:00	**14:00**	**Lunch**	
		Early progress on roadmapping, possible ways forward	**Iain MacGill and Rahman Daiyan**
2pm	2.30pm	Dr Rahman Daiyan - Early progress on a regional hydrogen roadmap - some preliminary findings, and possible ways forward	
2.30pm	3pm	Stakeholder reflections on key issues for roadmap development including from project partners; Fiji, Vanuatu, Solomon Islands - government, utilities, regulators, industry	
3pm	3.10pm	**Thanks, workshop close**	
		Workshop ends	

Establishing a hydrogen strategy for the pacific island countries and territories

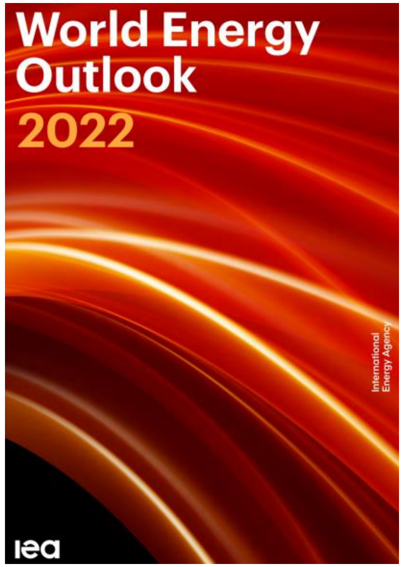
Dr Iain MacGill

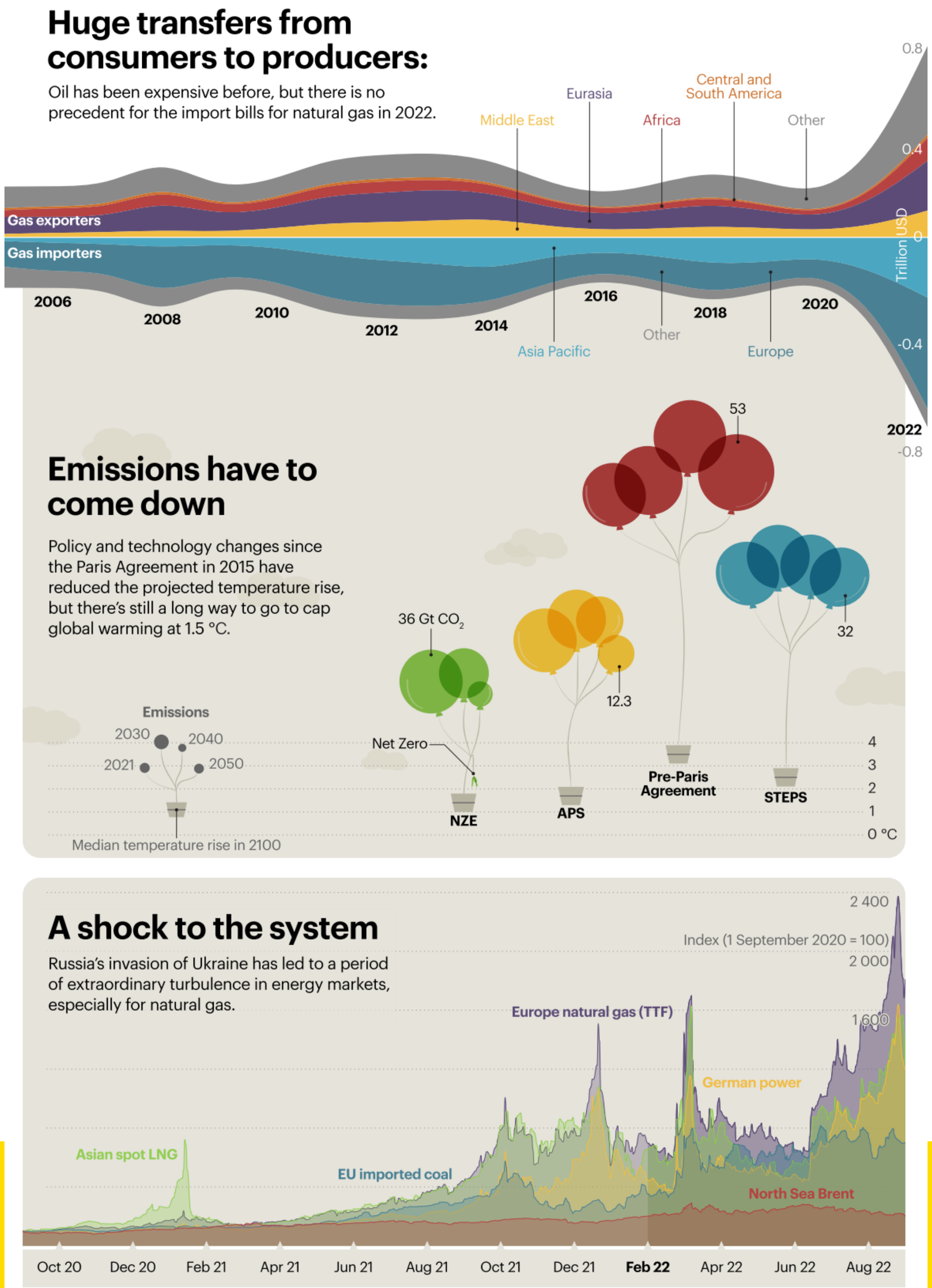
Collaboration on Energy and Environmental Markets

IRENA
International Renewable Energy Agency
USP
THE UNIVERSITY OF THE SOUTH PACIFIC
Pacific Community
Communauté du Pacifique
Australian Government
Department of Climate Change, Energy, the Environment and Water

Three global energy crises to navigate

- Recent inprecedented gas + coal prices, high + volatile oil prices
- Enormous wealth transfers, adverse impacts on societal progress in developing + emerging economies, recession risks in industrialised nations
- Growing climate change impacts, inadequate efforts to date avoid dangerous warming





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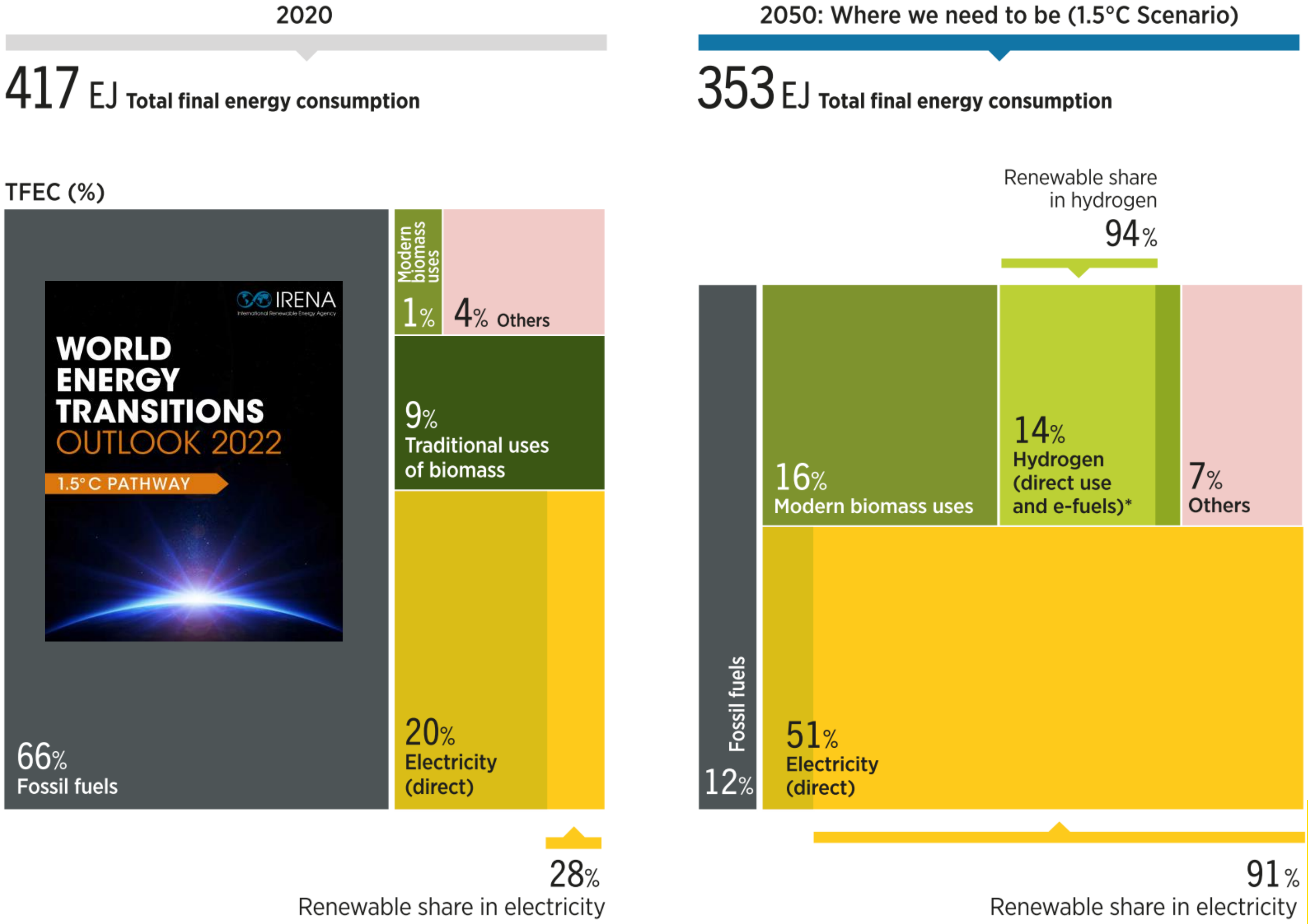
General agreement on desirable global energy pathways but also uncertainties

- Electrification of current non-energy sectors
- Greatly expanded, mostly renewables electricity sectors
- Key uncertainties – what role for fossil fuels, biomass, **hydrogen**



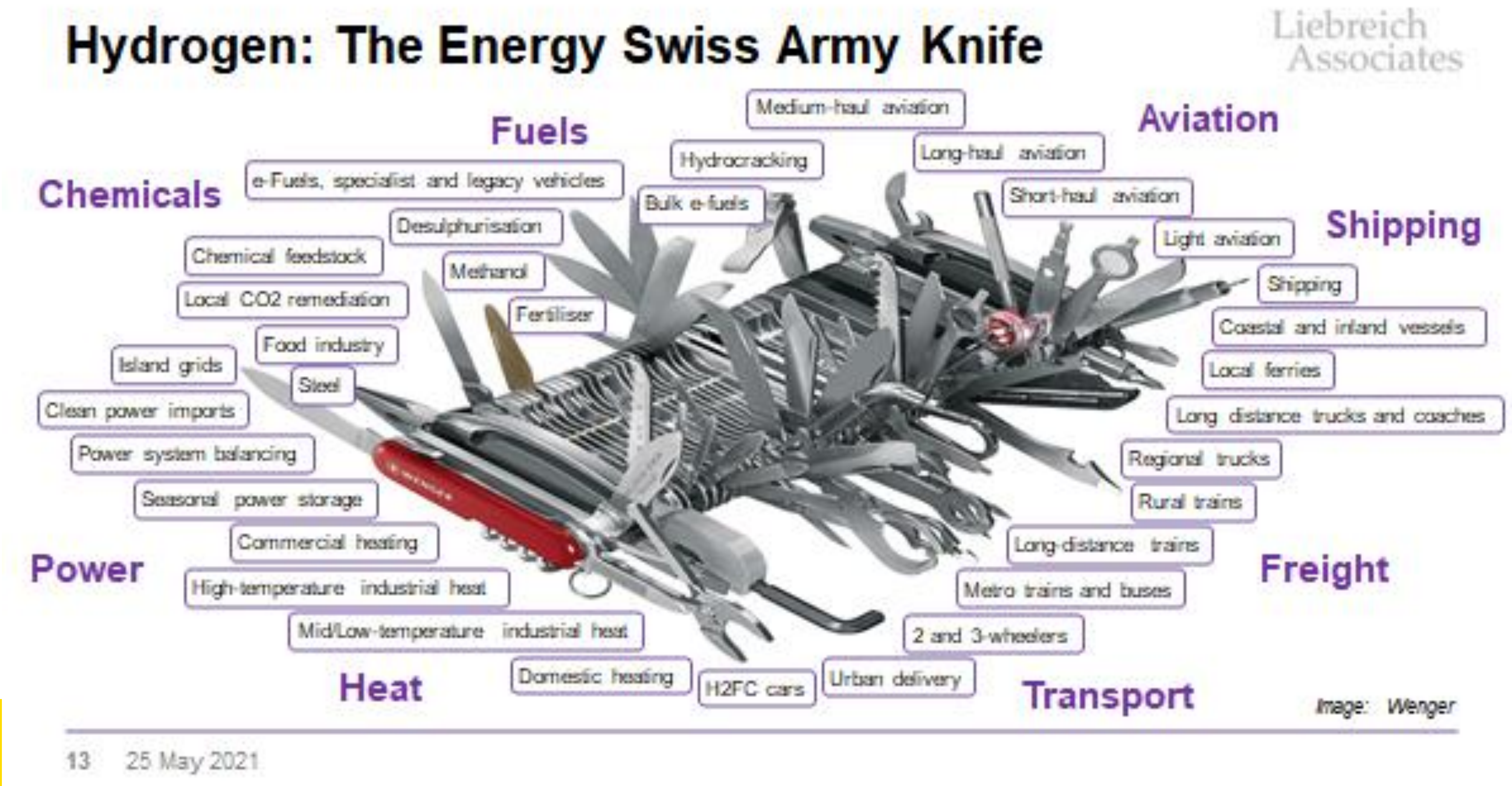
What role can hydrogen play, or perhaps must play in achieving our clean energy an climate goals?

Globally?

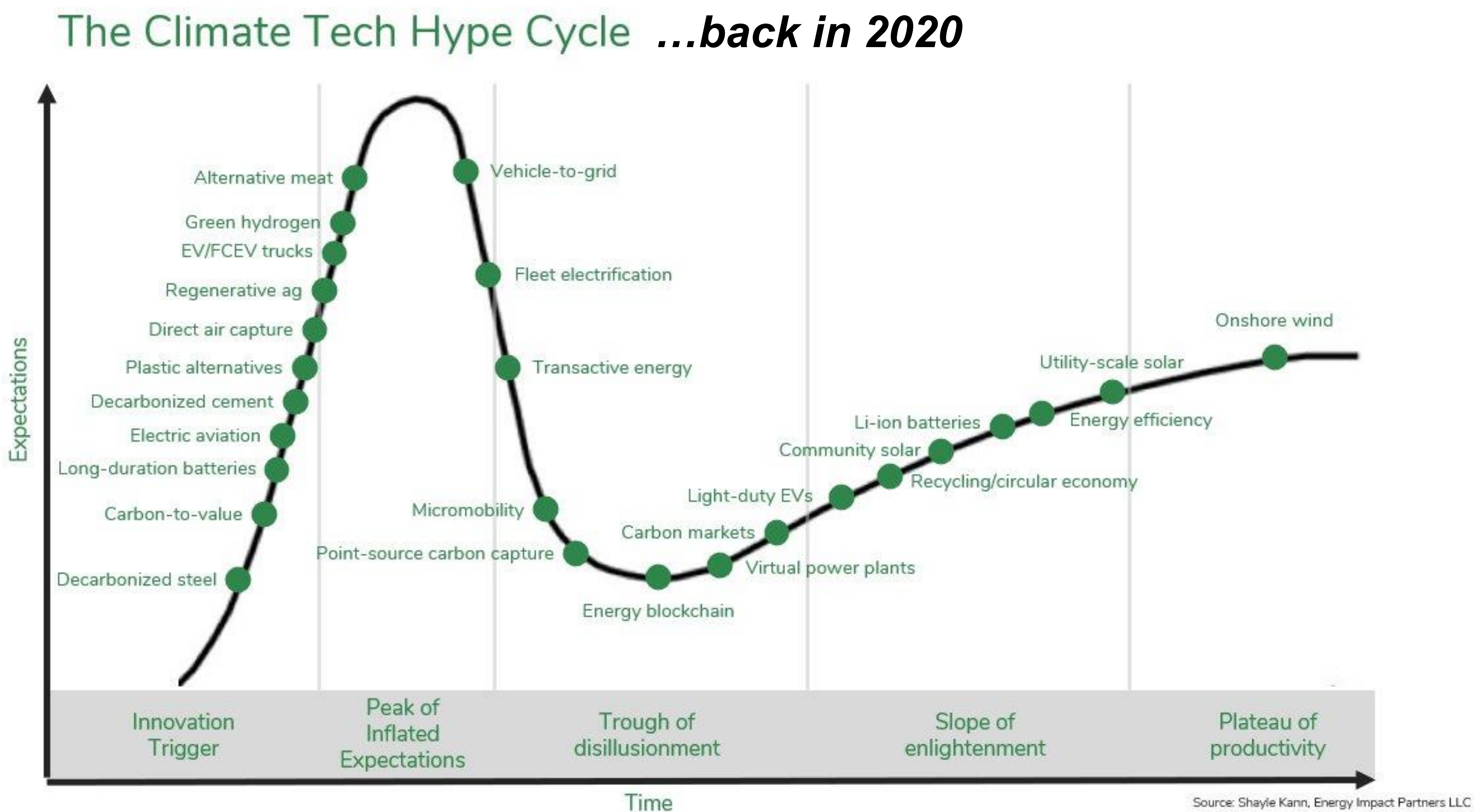
Regionally?

Jurisdictionally?

Hydrogen can do just about everything ....
but what does it do better than other options?



Where are on the renewable h2 hype cycle?



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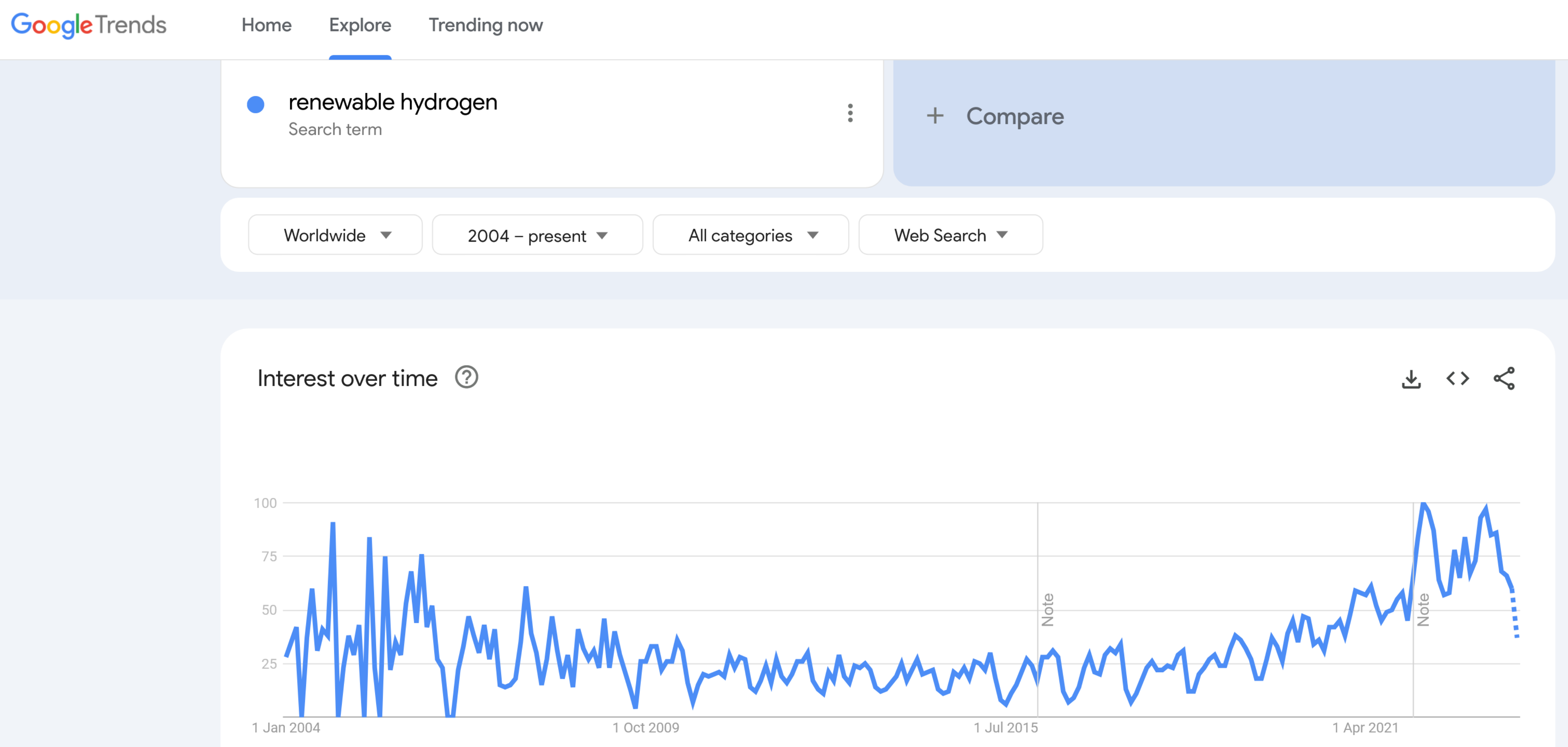
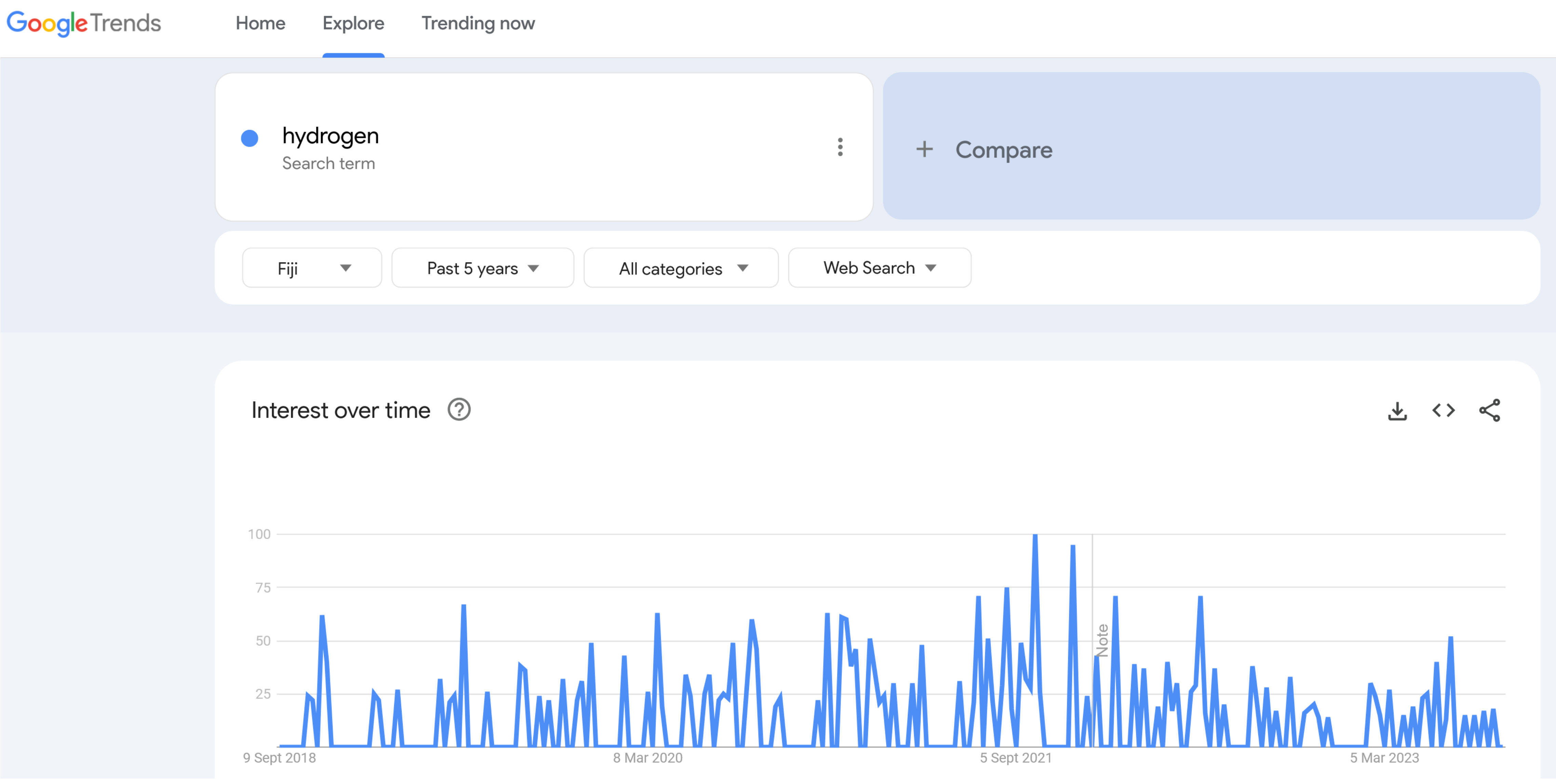
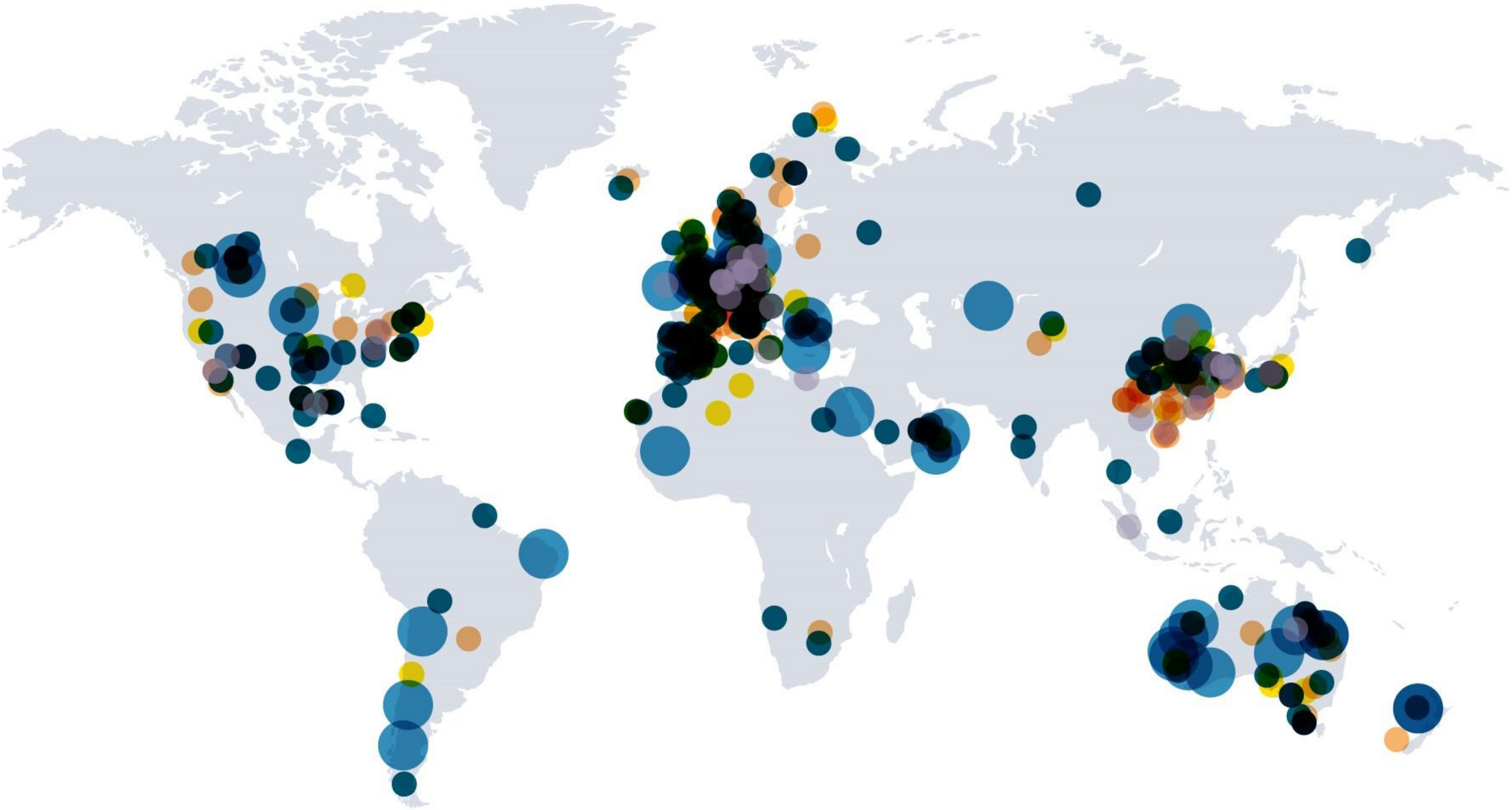
Where are we on the renewable h2 hype cycle?



Where are we on the hype cycle? Fiji



Growing global interest in major hydrogen and derivative projects…. *although only limited progress to date*



221 large-scale industrial usage
Refinery, ammonia, methanol, steel and industry feedstock

133 transport
Trains, ships, trucks, cars and other hydrogen mobility applications

74 integrated H_2 economy
Cross-industry and projects with different types of end uses

51 infrastructure projects
H_2 distribution, transportation, conversion and storage

43 giga-scale production
Renewable H_2 projects >1 GW and low-carbon H_2 projects > 200 ktpa

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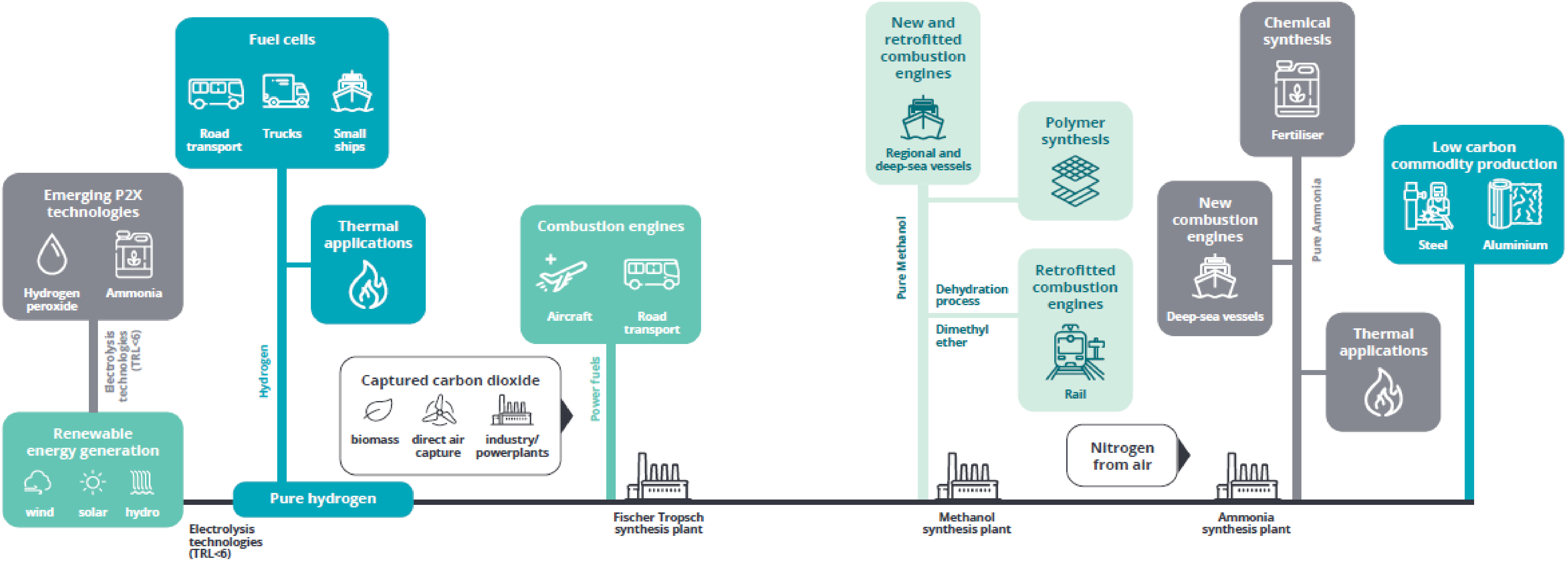
Q: What role for hydrogen?

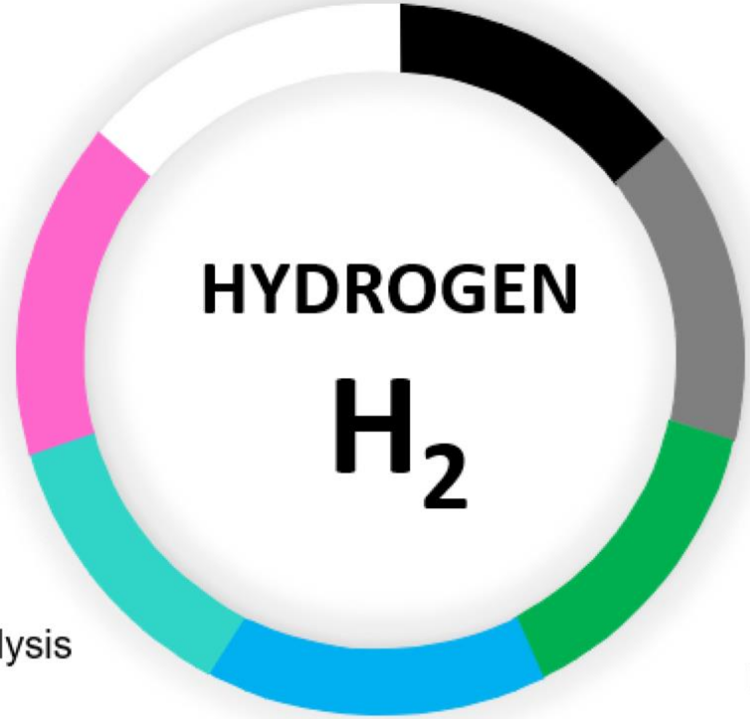
A: Assist in sectors which are otherwise hard to decarbonize

Next Q: Is it h2 or an h2 derivative that we really need?

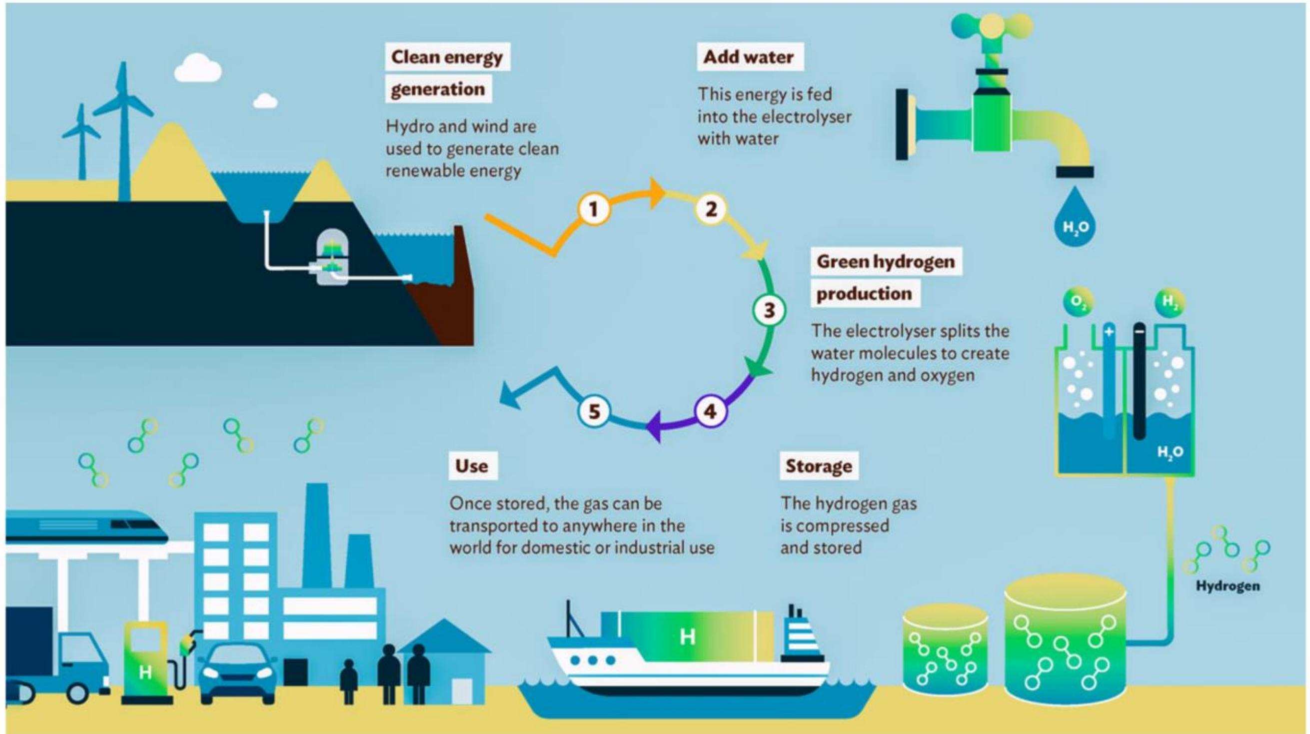
Next A: It depends (intended use, other factors)



Why the different colors – what will sellers want to sell, buyers want to buy?



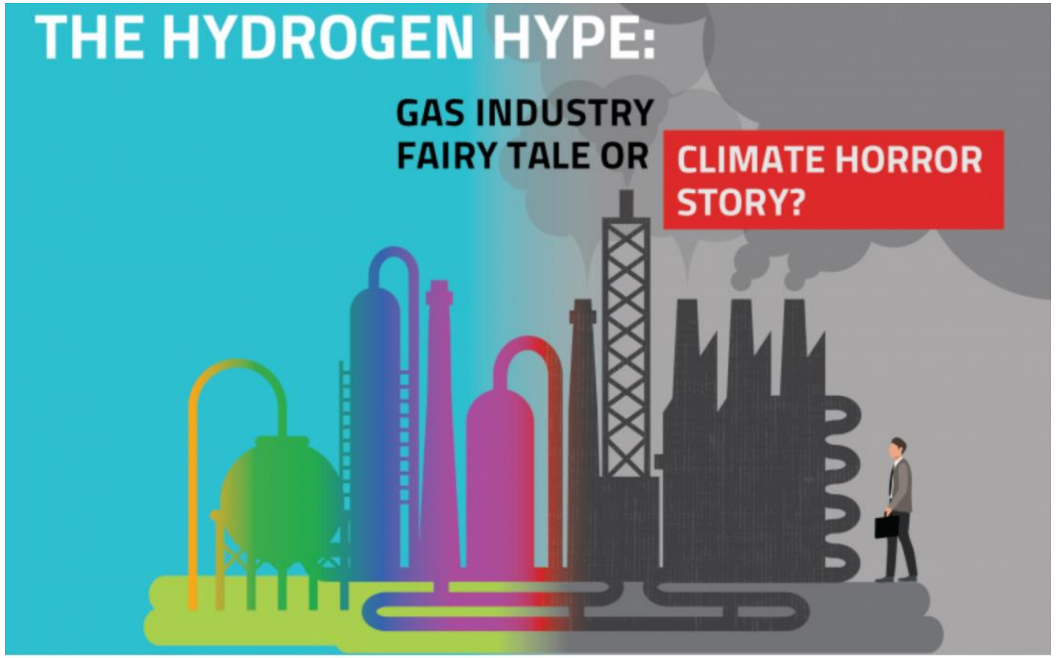
Renewable hydrogen – energy and climate hero … or villain?



Home / Renewables / Renewable Hydrogen: Driver of Green Revolution in Europe?

Renewable Hydrogen: Driver of Green Revolution in Europe?

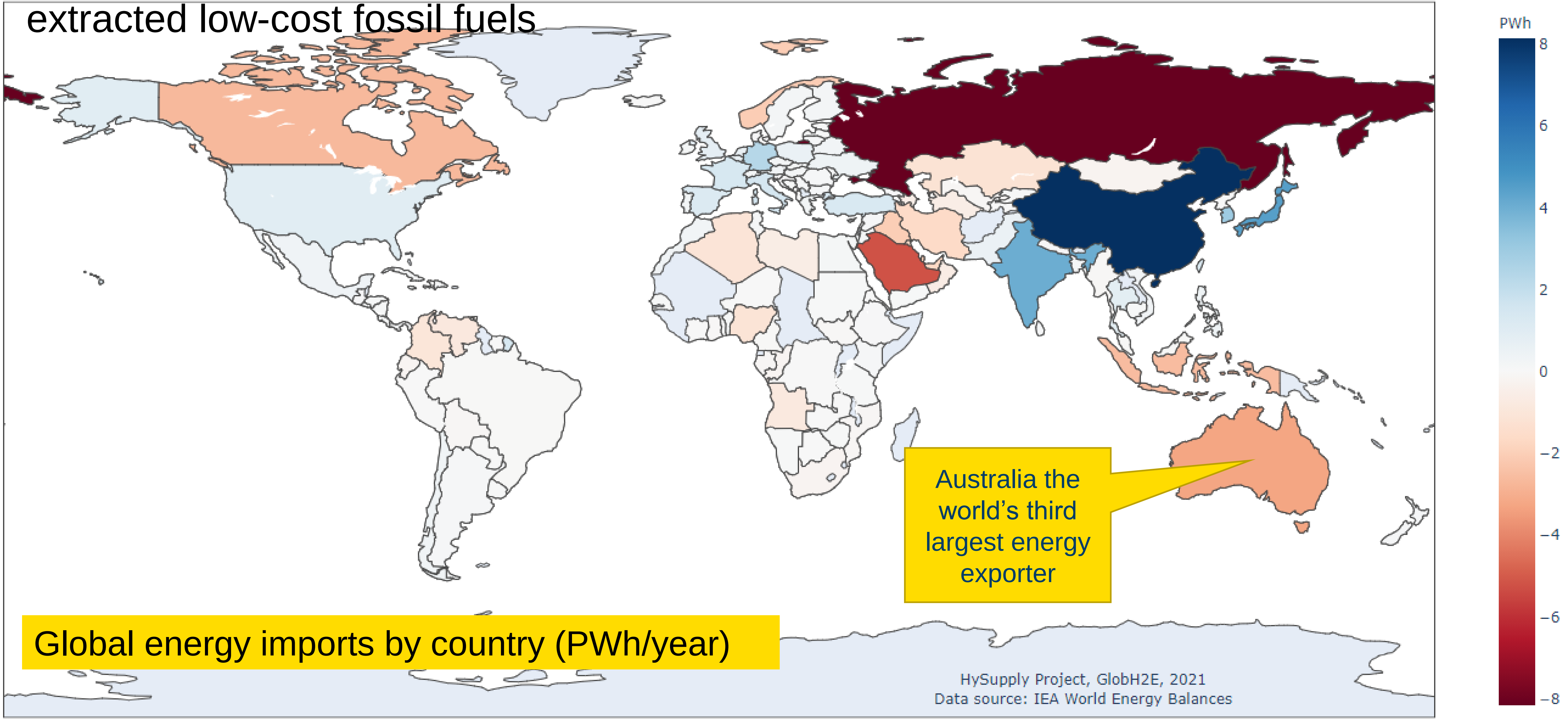
Rona Rita David · August 11, 2021 · Last Updated: August 11, 2021 · 4,338 · 12 minutes read



The hydrogen hype: Gas industry fairy tale or climate horror story?

Will we import it or make our own?

Current global energy trade largely an outcome of the availability of easily extracted low-cost fossil fuels



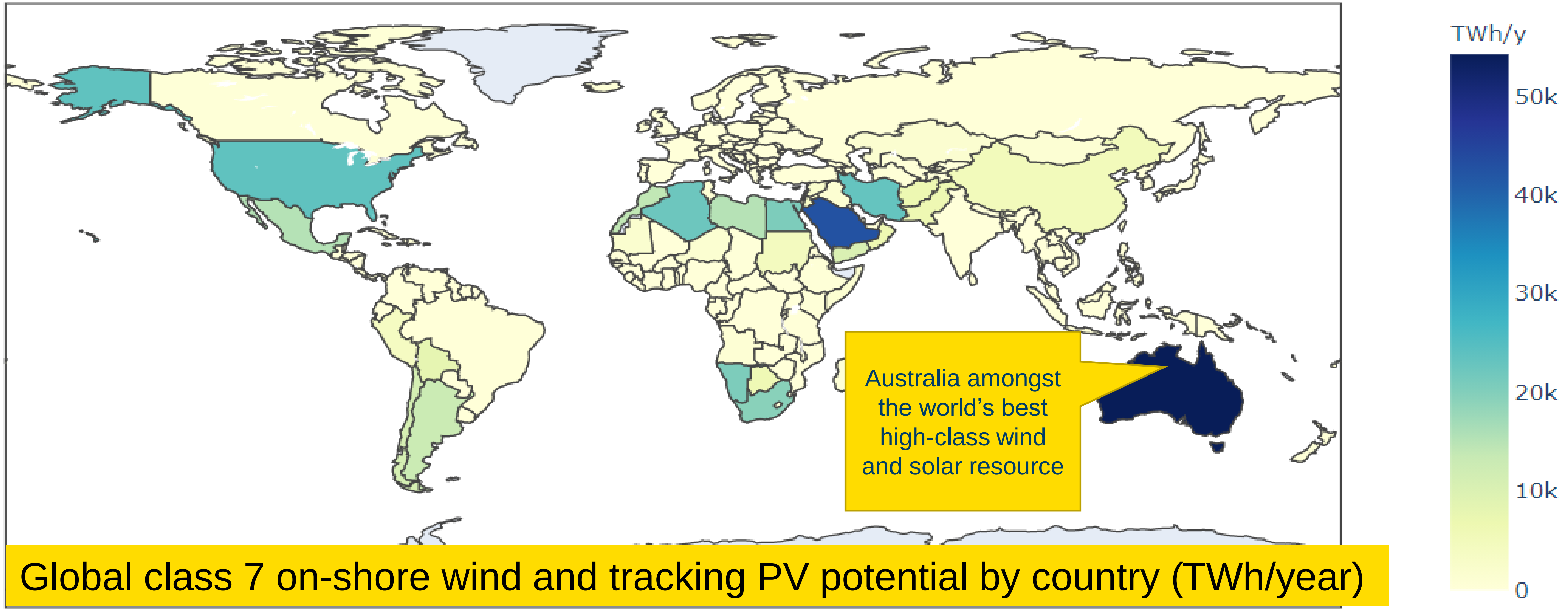
Global energy imports by country (PWh/year)

A mostly renewable world more self reliant

… however, some countries/regions still likely to require energy imports including Germany and some others in Europe, Japan, Korea

Potentially new renewables ‘electrostate’ exporters, likely some old ones

What of the pacific? A buyer, self reliant, self reliant and a seller



Global class 7 on-shore wind and tracking PV potential by country (TWh/year)

Many challenging questions for the pacific region, and its numerous jurisdictions

Masterclass on Hydrogen and Derivatives

Dr. Rahman Daiyan
Scientia Senior Lecturer and ARC DECRA Fellow,
School of Minerals and Energy Resources,
Deputy-lead NSW Powerfuels including Hydrogen Network, NSW Decarbonisation Innovation Hub
r.daiyan@unsw.edu.au

7th of September 2023| Hydrogen for the Pacific Islands

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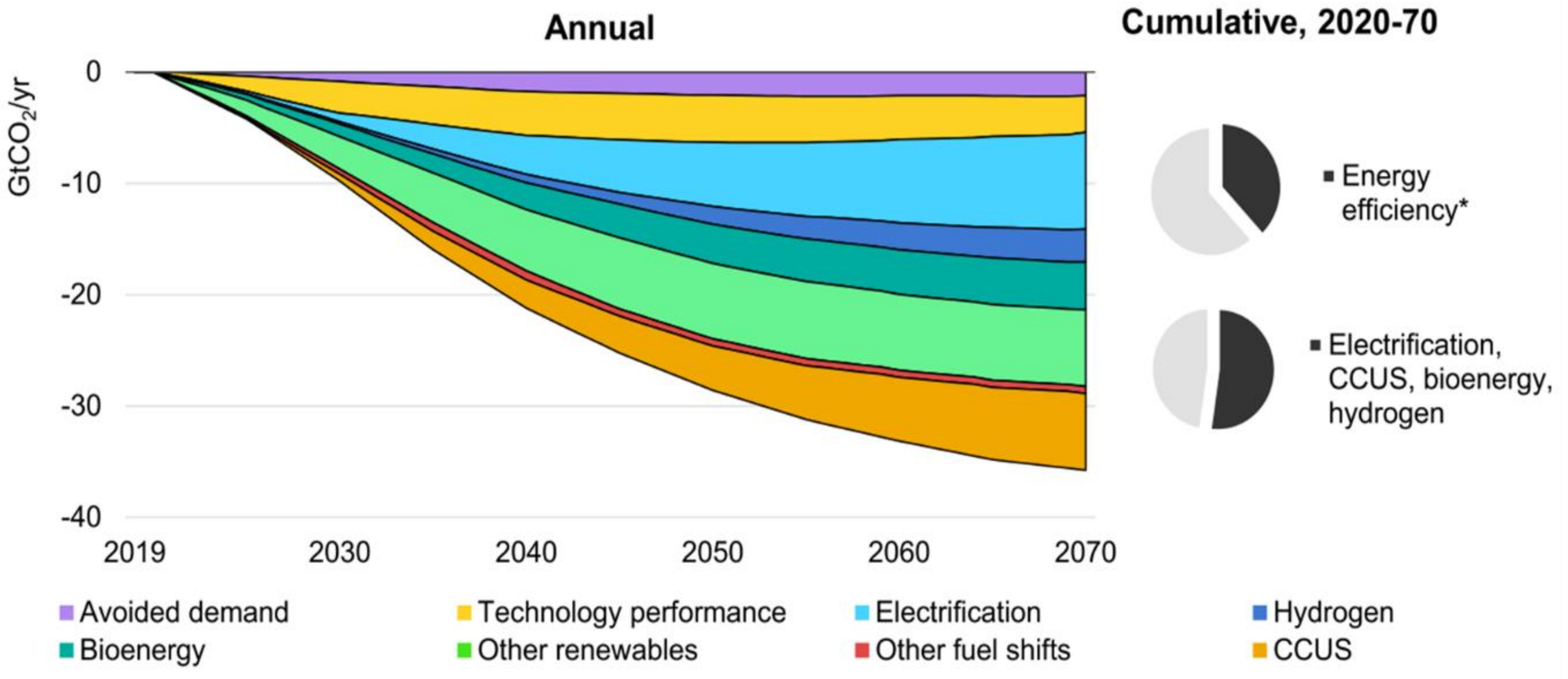
GlobH2E
ARC Industrial Transformation Training Centre for the Global Hydrogen Economy

Agenda

- Module 1: Introduction to Hydrogen
- Module 2: Green Hydrogen Production Pathways
- Module 3: Opportunities Challenges of Storage, Transportation and Uses of Pure Hydrogen
- Module 4: Hydrogen Derivatives: Power to X
- Q&A

Module 1: Introducing Hydrogen

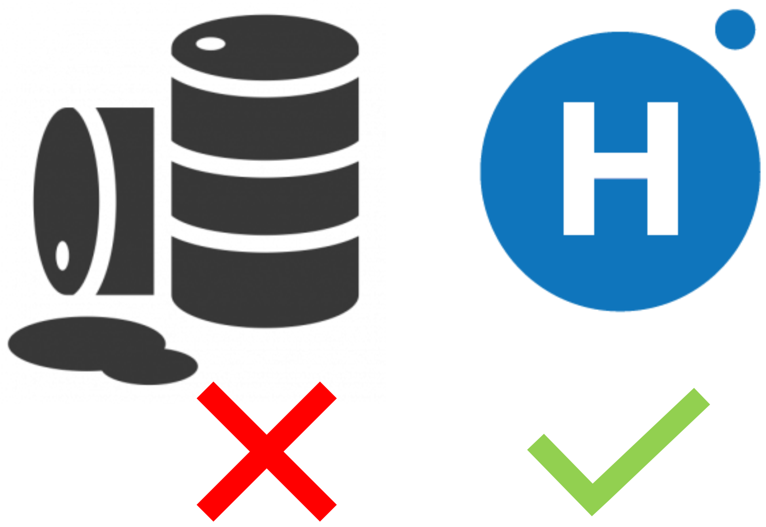
Pathways towards Net-Zero



Electrification, bioenergy and hydrogen (and derivative) will play a key role in attaining Net-Zero (source IEA)

Hydrogen and Climate Change

- Hydrogen can therefore tackle climate change if:
  - It is used in place of fossil fuels as an energy source (for example, as an energy carrier of renewable electricity)
  - It is produced through methods that do not release CO_2
- Using hydrogen produced from fossil fuels does not assist in mitigating CO_2 emissions
- How do we know that it is produced cleanly?



Hydrogen and Climate Change

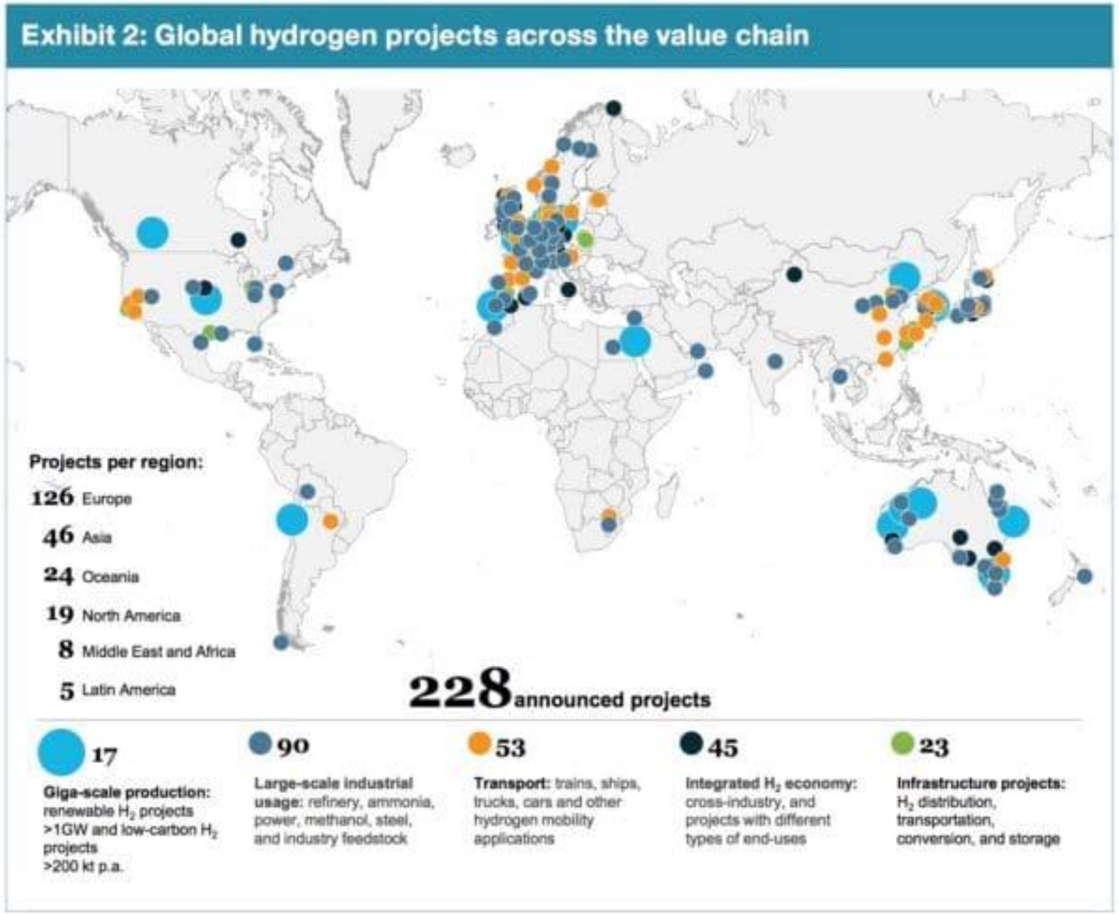
- If green hydrogen replaces the use of fossil fuels as an energy source, less CO_2 is emitted, assisting in tackling climate change
- In order to tackle climate change on a global scale, several key changes must occur:
  - Large-scale and economically-viable green hydrogen production
  - Coordination of supply and value chains
  - Introduction of safety standards and societal acceptance
- These changes are heavily influenced through government policy

Global hydrogen project pipeline expected to exceed $300 billion by 2030

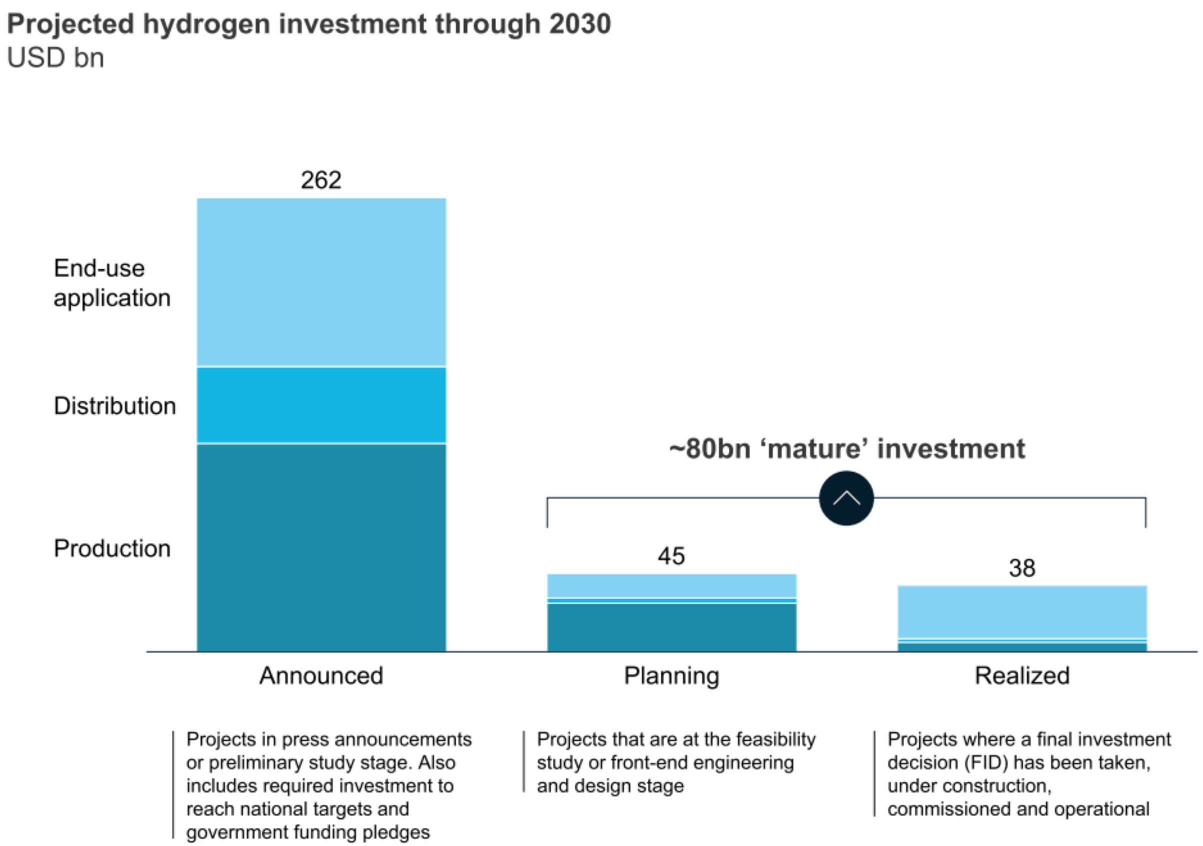
A new report from the Hydrogen Council has estimated that the current hydrogen project pipeline, if realized, would exceed investments of $300 billion by 2030. The report comes amid an acceleration in hydrogen project announcements worldwide and great expectation of hydrogen's potential in the energy transition.

FEBRUARY 18, 2021 BLAKE MATICH

GEOPOLITICS HIGHLIGHTS HYDROGEN MARKETS MARKETS & POLICY WORLD



Global Support for Hydrogen



Source: McKinsey & Company and Hydrogen Council, "Hydrogen Insights", 2021

Interest Translating to Market Activation

- **228** Projects Announced
- **U$300 Billion** Combined Investment until 2030 (= 1.4% of global energy funding)
- **U$80 Billion** mature investments
- **U$70 Billion** In Long Term Government Funding Committed

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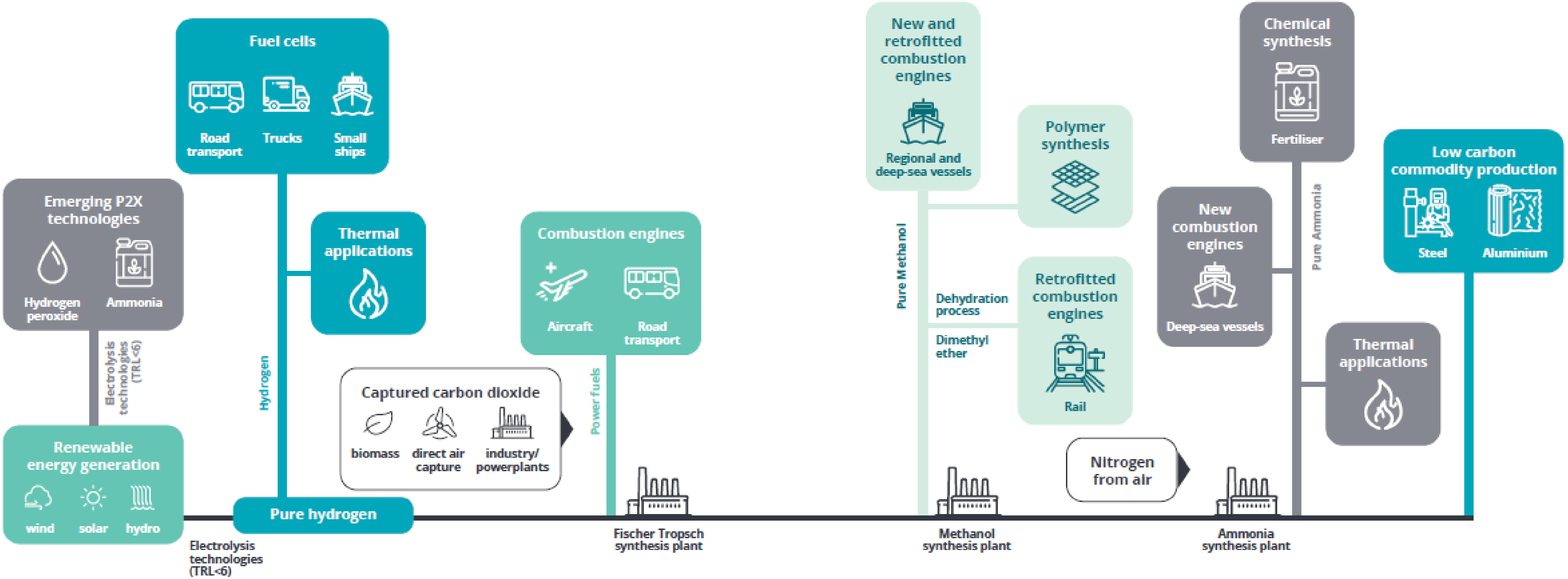
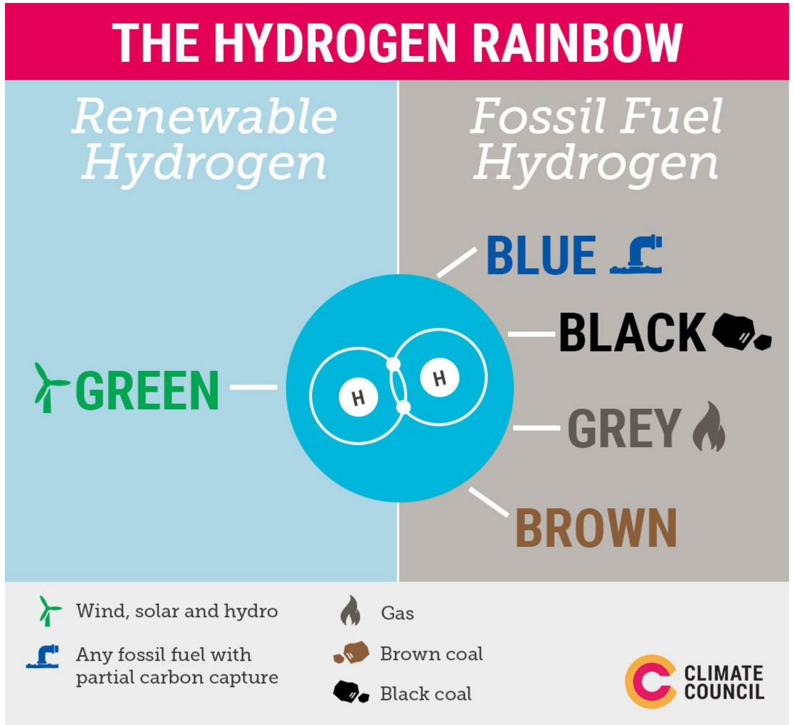
Where Hydrogen Comes to the Picture?

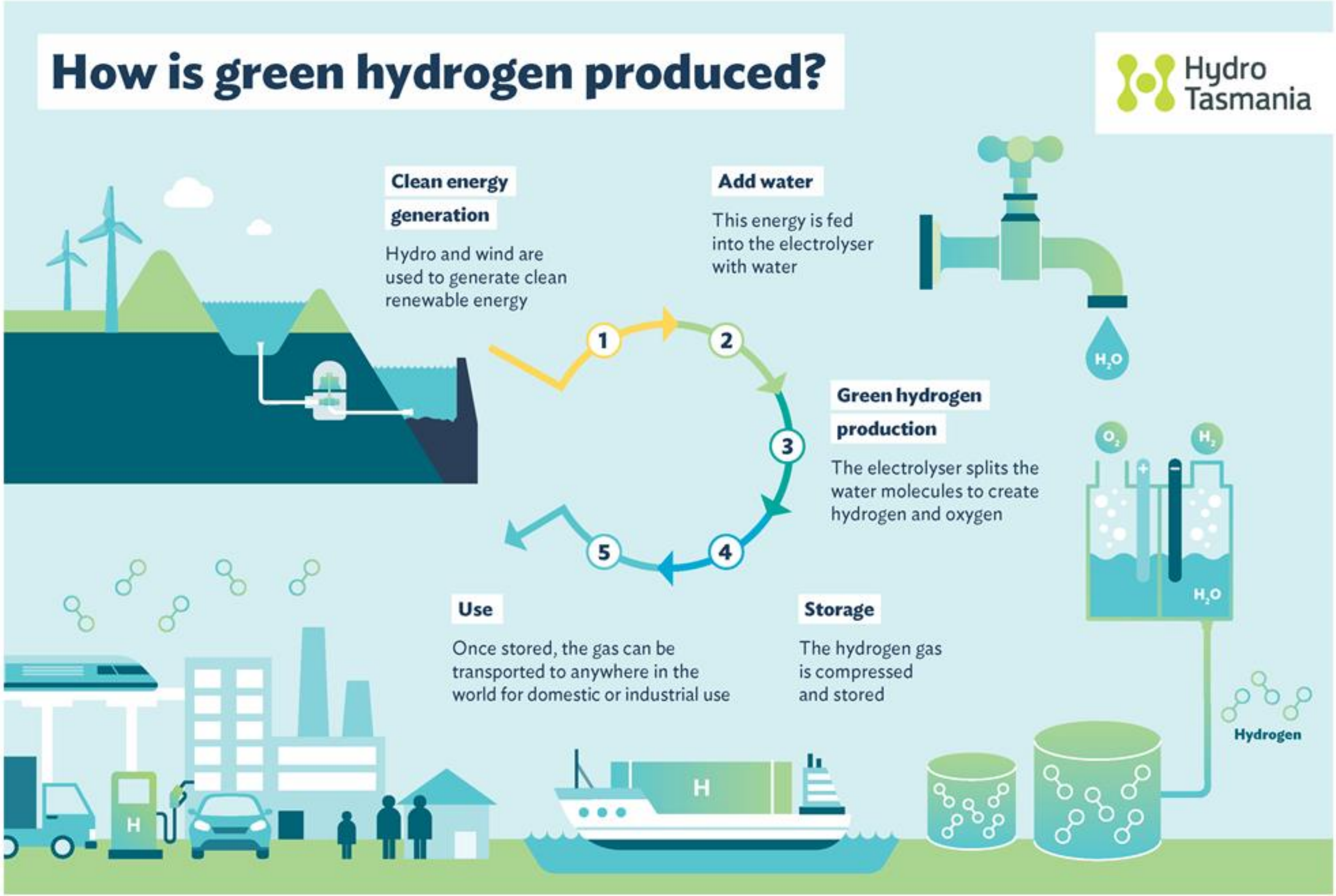


Module 2: Hydrogen Production Pathways

Hydrogen Production Classification

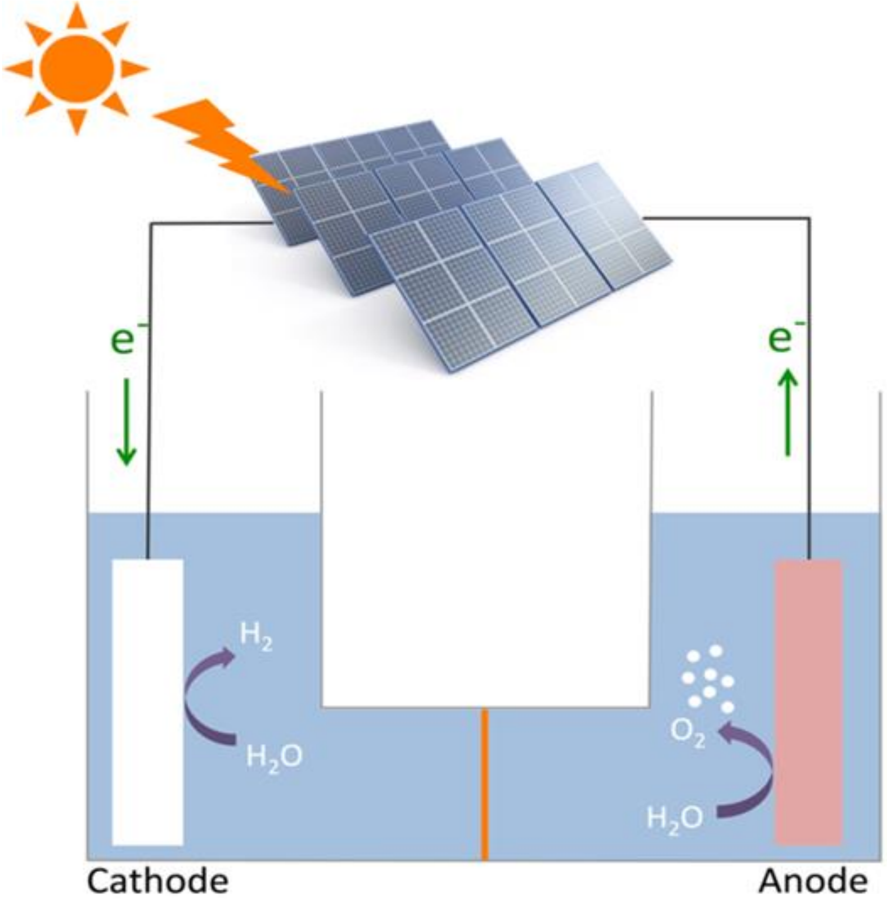
- In brief, hydrogen is classified based on its method of production:
  - Green H_2 is generated through electrolysis powered by renewable electricity
  - Blue H_2 is generated via fossil fuels but with CO_2 emissions captured
  - Grey H_2 is generated via fossil fuels with no emissions captured
  - Black H_2 is made using coal
  - Brown H_2 is made using brown coal (or lignite)
  - Turquoise H_2 and solid carbon is generated by methane pyrolysis
  - Pink H_2 is produced through nuclear energy
- Other methods also exist

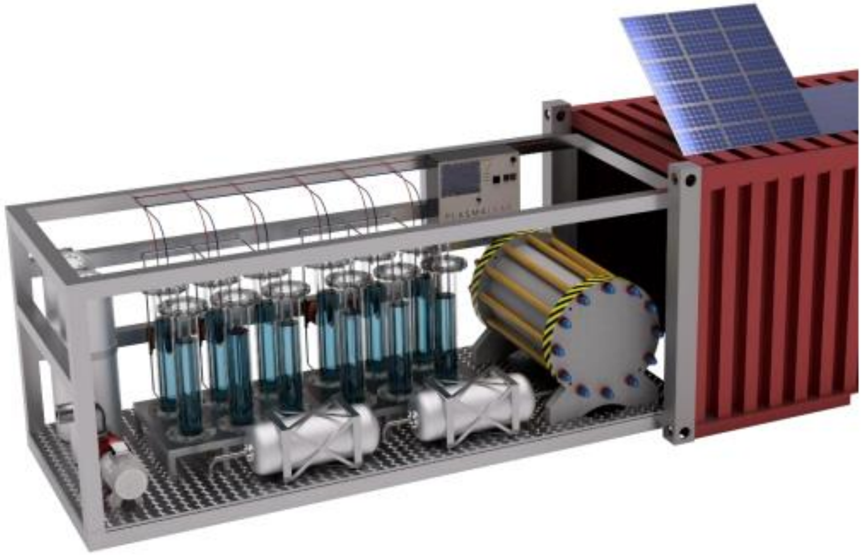


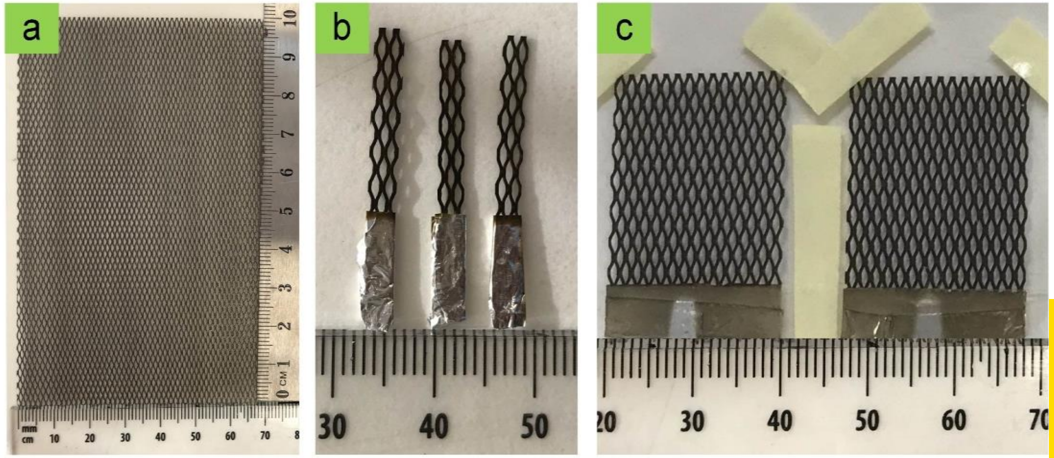

How is green hydrogen produced?
Hydro Tasmania
Clean energy generation
Hydro and wind are used to generate clean renewable energy
Add water
This energy is fed into the electrolyser with water
Green hydrogen production
The electrolyser splits the water molecules to create hydrogen and oxygen
Storage
The hydrogen gas is compressed and stored
Use
Once stored, the gas can be transported to anywhere in the world for domestic or industrial use
1
2
3
4
5
H_2O
O_2
H_2
Hydrogen
H

Electrolysis

- Electrolysis is a technique that uses electricity to drive an otherwise non-spontaneous chemical reaction (i.e. it will not occur without an external input)
- It is undertaken in a cell known as an electrolyser
- An electrolyser cell consists of an anode (positively charged) and cathode (negatively charged) chamber separated by a membrane and immersed in an electrolyte solution







Electrolyser Overview

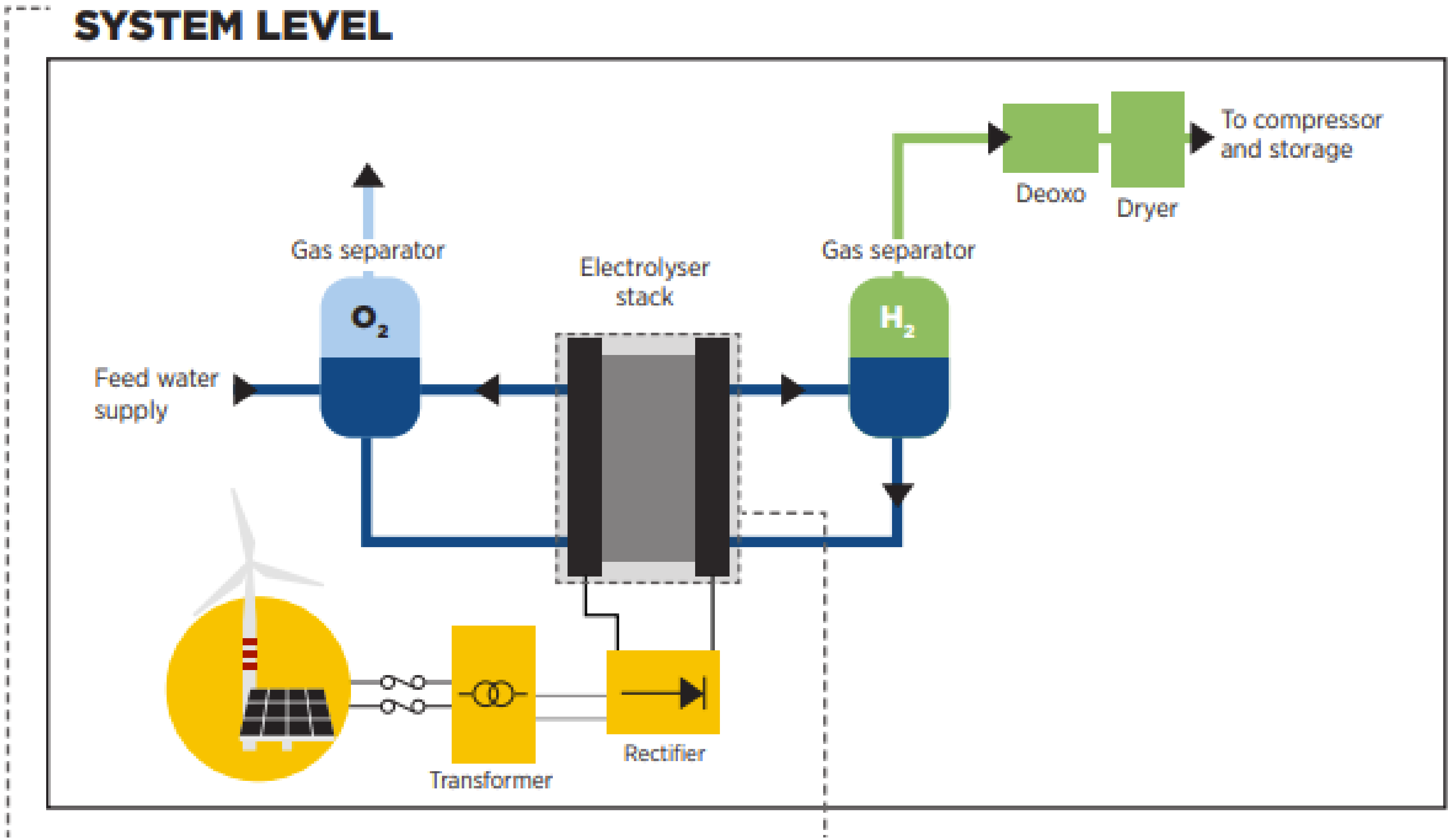
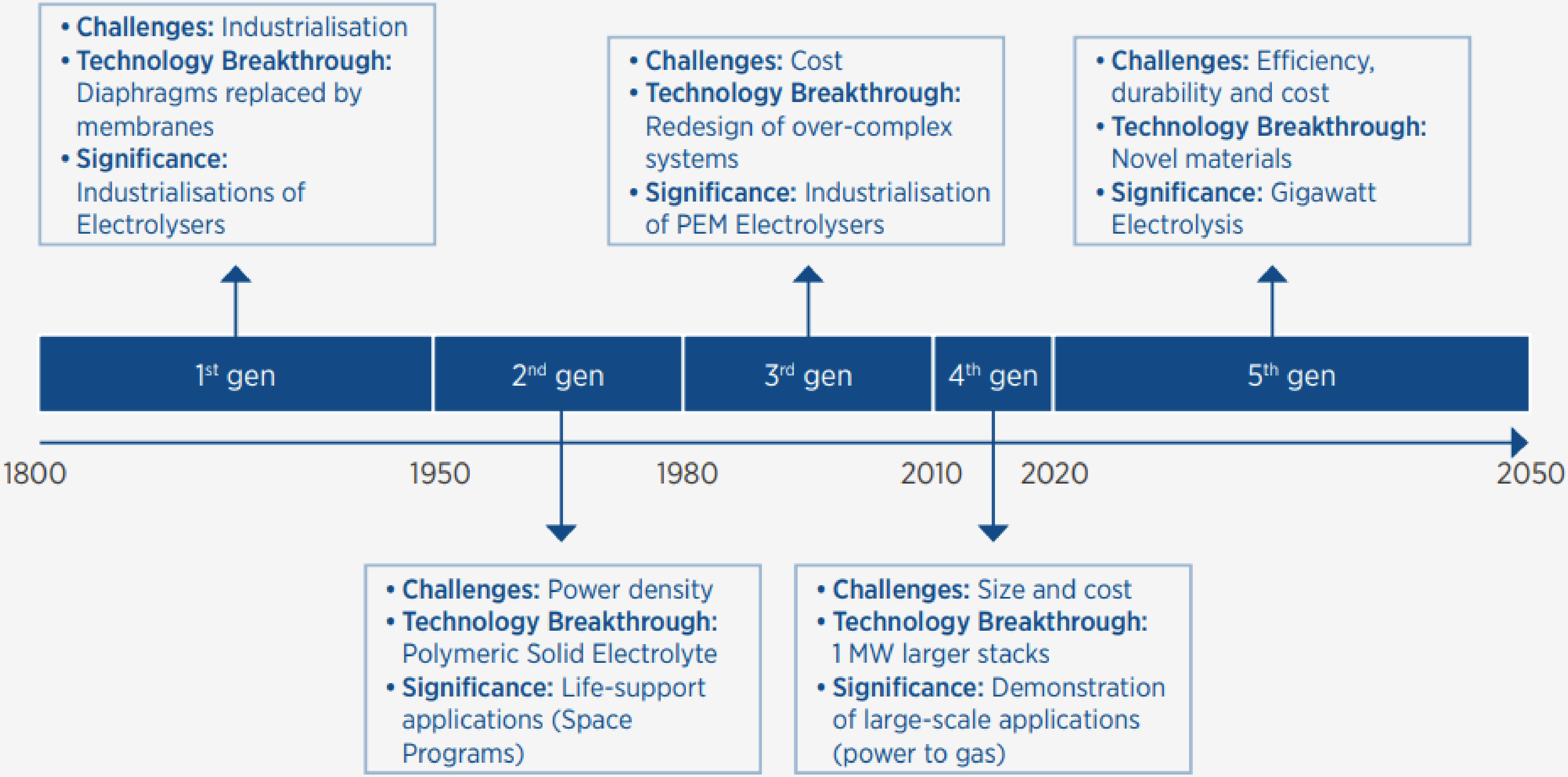


Figure 5. Challenges and technological breakthroughs for each of the generation of electrolysers.



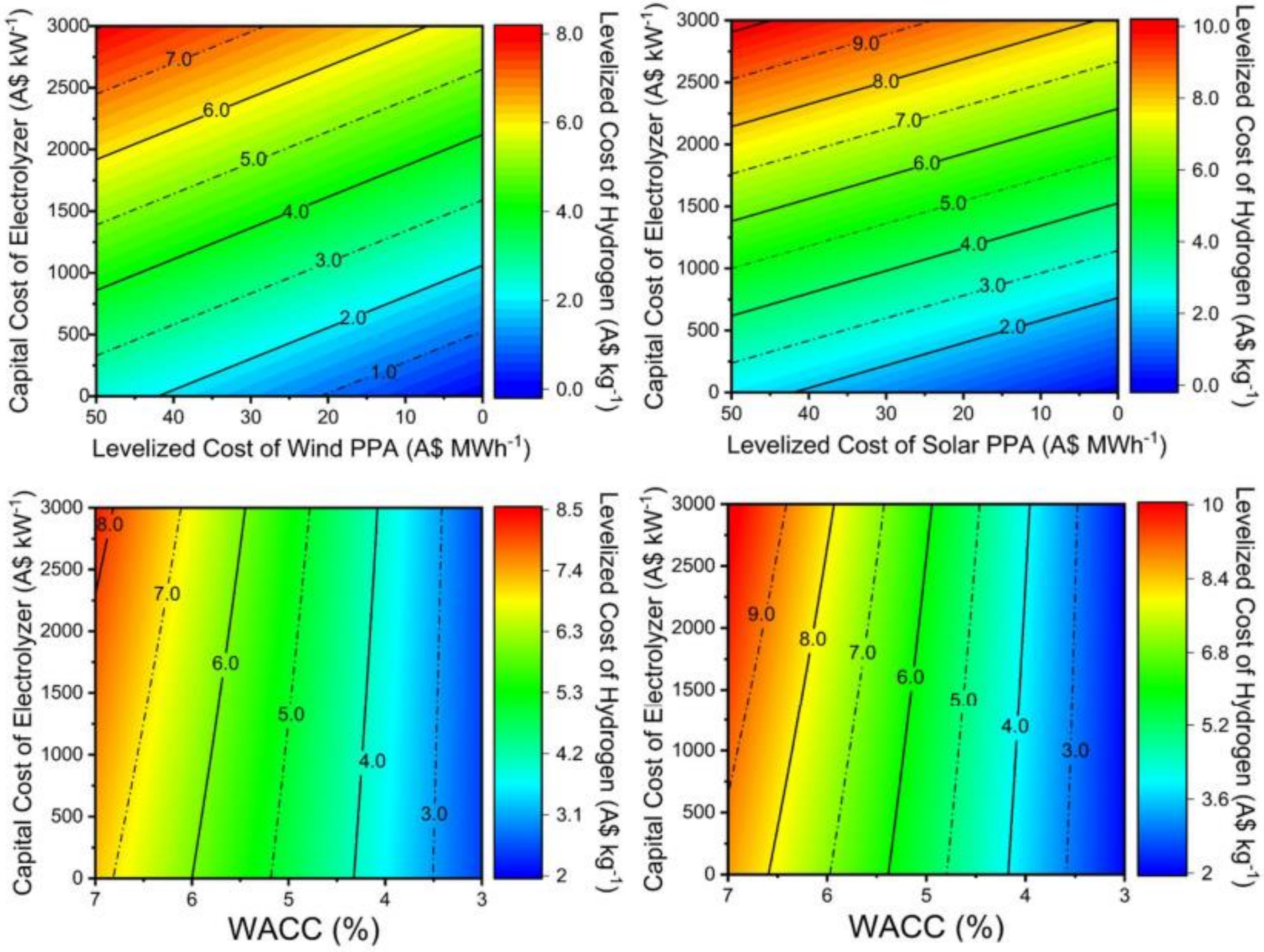
Based on IRENA analysis.

Green H2 production costs

Location matters
Cost reductions needed

- Renewables costs down, CF up
- Electrolysers costs down, efficiency up
- Improved integration (CF optimisation)
- Low cost (de-risked) finance

Proponent	Target/projection /Scenario	Price range/kg$_{H2}$	Adjusted to A$/kg$_{H2}$	Price year	References
Australian Government	Stretch target		A$2	Not indicated	Low Emissions Technology Roadmap,2020[87]
Hydrogen Council	Projection	US $1.40 – 2.30 (U$1.40 in optimal locations)	A$1.89 – 3.11	2030	Hydrogen insights, 2021[12]
EU	Target	Euro 1.1 – 2.4	A$1.77 – 3.87	2030	Hydrogen strategy, 2020[120]
IEA	Net Zero Emissions scenario	US $1.50 – 3.50	A$2.03 – 4.73	2030	Net Zero by 2050, 2021[19]
IRENA	Scenarios	US $1.40 – 2	A$1.89 – 2.70	2030	Low RE cost scenarios in Green Hydrogen cost reduction, 2020[22]
IEA	Renewables connected scenario	US $2 – 4	A$2.70 – 5.40	2030	Future of Hydrogen, 2019[10]
IRENA	Projection	US $1.80 – 3.30	A$2.60 – 4.78	2030	Hydrogen: A Renewable Energy Perspective, 2019[116]
Bloomberg	Projections	US $1.20 – 2.7	A$1.62 – 3.65	2030	BNEF: Hydrogen Economy Outlook, 2020[13]



Module 3: Pure Hydrogen-Storage, Transport and Possible End-Uses

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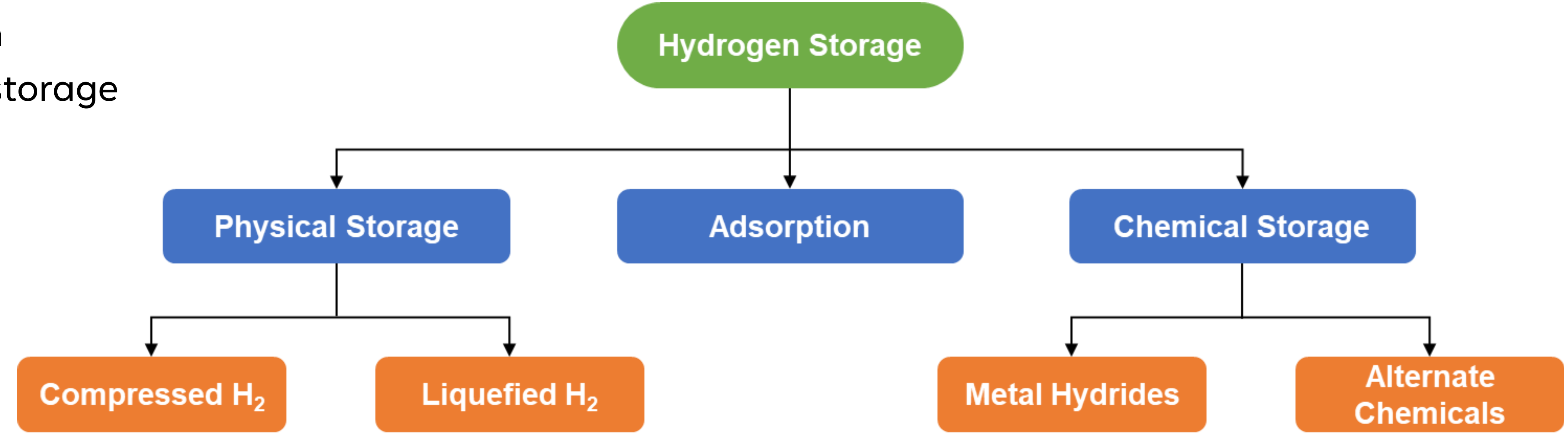
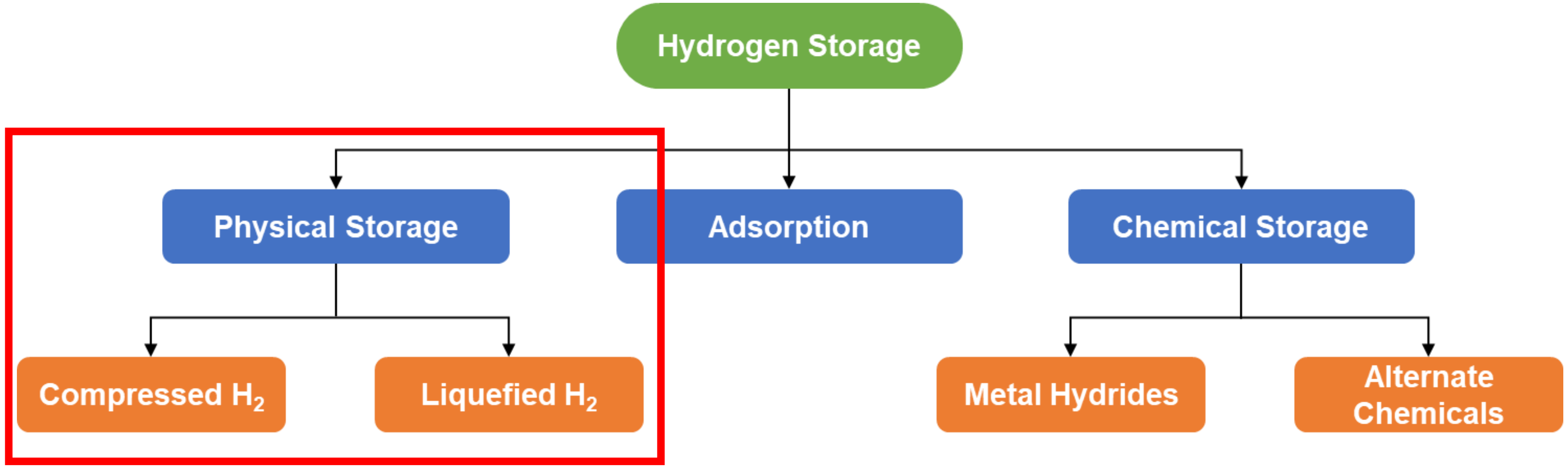
Storage of Hydrogen

- Once produced, hydrogen must be safely stored
- Hydrogen can be stored in many forms:
  - Physical storage
  - Adsorption
  - Chemical storage



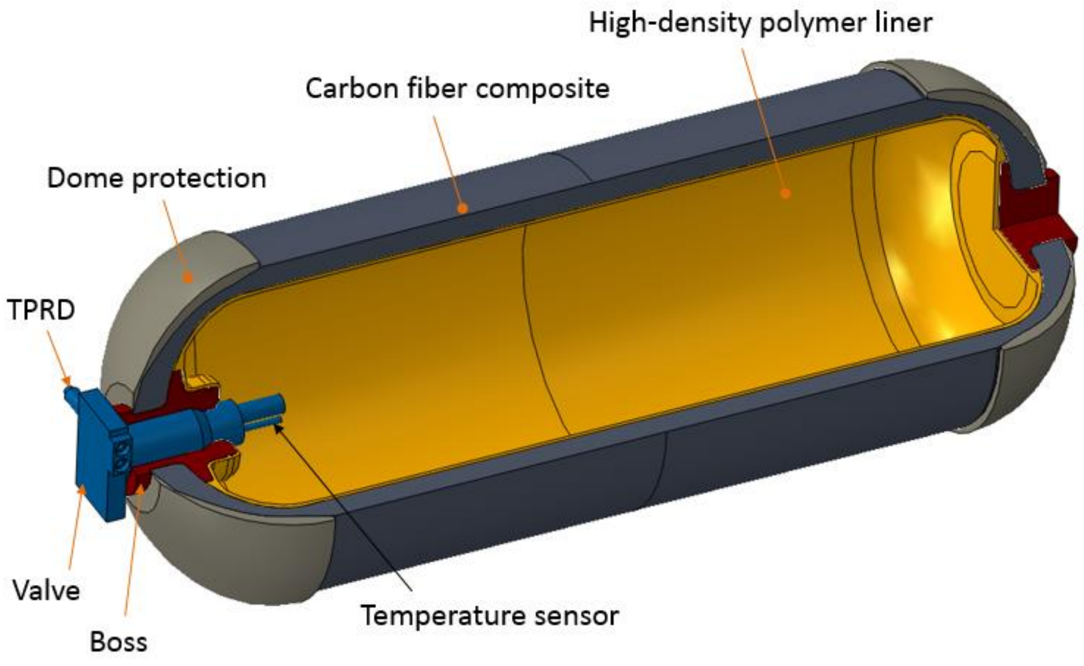
Physical Storage of Hydrogen

- The storage of pure hydrogen
  - In compressed (gas) form
  - In liquefied form



Storage of Compressed Hydrogen

- Under ambient conditions, 1 kg of hydrogen gas occupies a volume of 11 m^3
- It must therefore be compressed for effective storage and transport
- Compressed hydrogen is generally stored in cylindrical pressure vessels
- Pressures are between 3 to 35 MPa



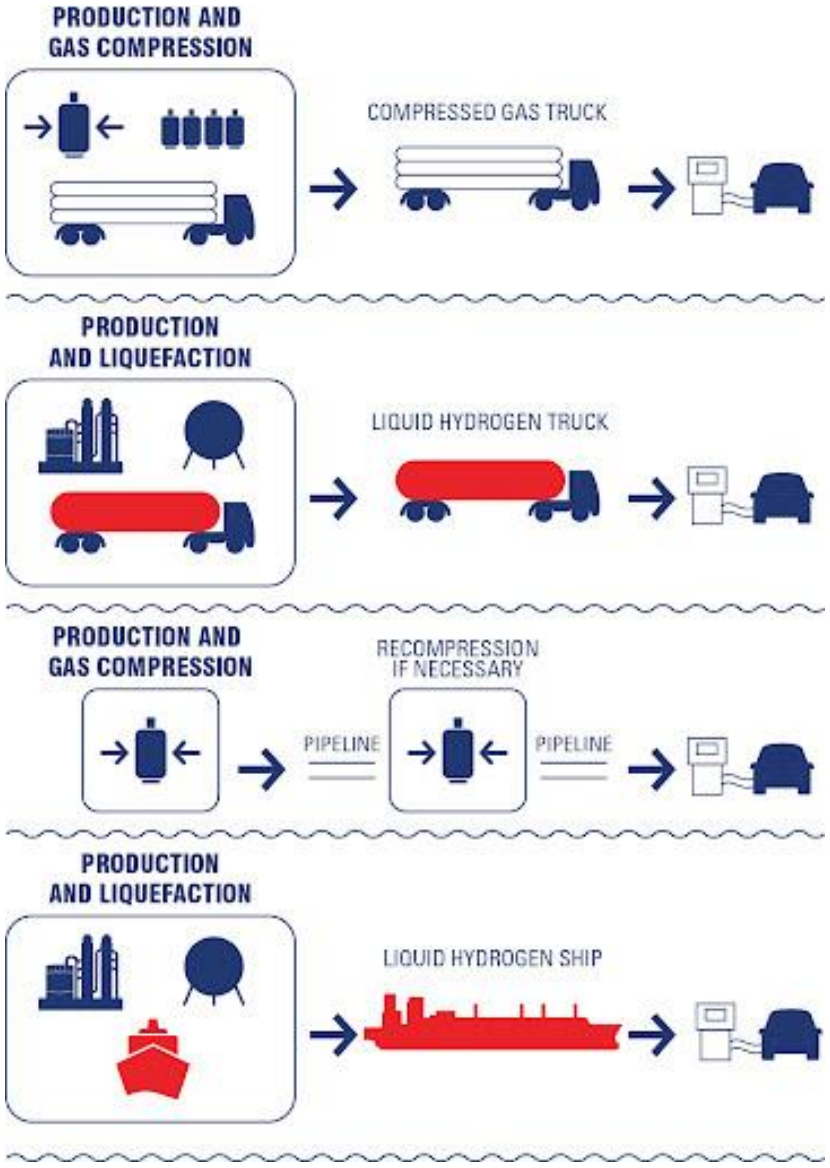
TPRD = Thermally Activated Pressure Relief Device
Credit: Process Modeling Group, Nuclear Engineering Division. Argonne National Laboratory (ANL)

Storage of Liquefied Hydrogen

- The density of hydrogen can be further increased through liquefaction
  - Liquid nitrogen pre-cooling achieves a temperature of -193°C
  - Claude or Brayton cycle further cools to -253°C
- Liquid hydrogen storage vessels are most commonly double-walled with a high vacuum applied between the wall
- The vacuum minimizes heat transfer via conduction and convection

Transportation of Hydrogen

- Once produced, hydrogen must be transported for use, including export
- Common methods for the transportation of pure hydrogen include:
  - Road
  - Rail
  - Ship
  - Pipeline



Road

- Transport of compressed and liquefied hydrogen in pressure vessels can be undertaken on roads by trucks using tube trailers
- A single truck is capable of transporting up to 1000 kg of compressed hydrogen or up to 5000 kg of liquefied hydrogen a distance of up to 1000 km
- The cost of transport is approximately 2.5 $ tH_2km^{-1} for compressed hydrogen and 1.0 $ tH_2km^{-1} for liquefied hydrogen

$ tH_2km^{-1} is the cost of transporting one tonne of hydrogen over one kilometer

Rail

- Transport of compressed and liquefied hydrogen in pressure vessels may also be undertaken by rail
- Rail transport would allow for a greater quantity of compressed hydrogen transport over longer distances, reducing operational expense
- The cost of transport is approximately 0.5 $ tH_2km^{-1} for compressed hydrogen and 0.3 $ tH_2km^{-1} for liquefied hydrogen

Pipeline

- Hydrogen may be transported over short and medium distances using steel pipelines
- Pure hydrogen can cause embrittlement in steel pipes over long distances, however other piping materials such as fiber reinforced plastic (FBR) and HDPE have been proposed
- Costs of piping compressed hydrogen are expected to be around 0.2 to 0.4 \$ tH_2km^{-1}
- Pipelines may also be used for hydrogen carriers such as methane

Ship

- Road, rail, and pipelines may be used to transport hydrogen to export hubs, where it can be shipped overseas
- Kawasaki Heavy Industry has developed a ship that will carry up to 1,250 cubic meters of liquid hydrogen
- Liquefied hydrogen may only be suitable for short to medium length voyages due to energy losses associated with boil-off
- Cost estimates range between 0.02 to 0.6 $ tH_2km^{-1}, with the inclusion of loading and unloading facilities adding significant cost

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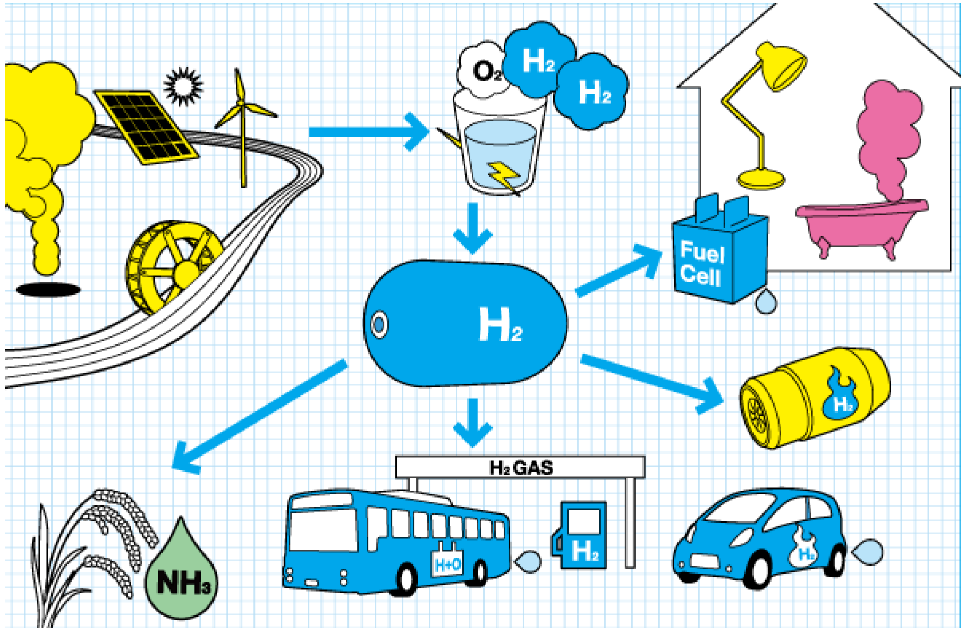
Use of Pure Hydrogen

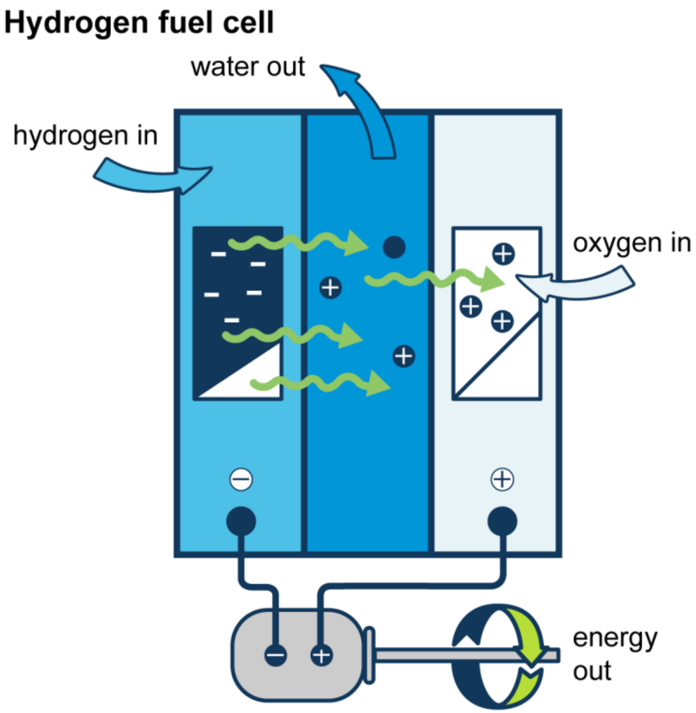
Hydrogen as an Energy Source

- The primary use of pure hydrogen is as an energy source
- Advantages of hydrogen as an energy source:
  - Potentially unlimited supply
  - High energy density
  - Clean-burning
  - Storage of intermittent renewable electricity
- How can pure hydrogen be used for energy?
  - Burned in gas form
  - Converted to electricity in fuel cells



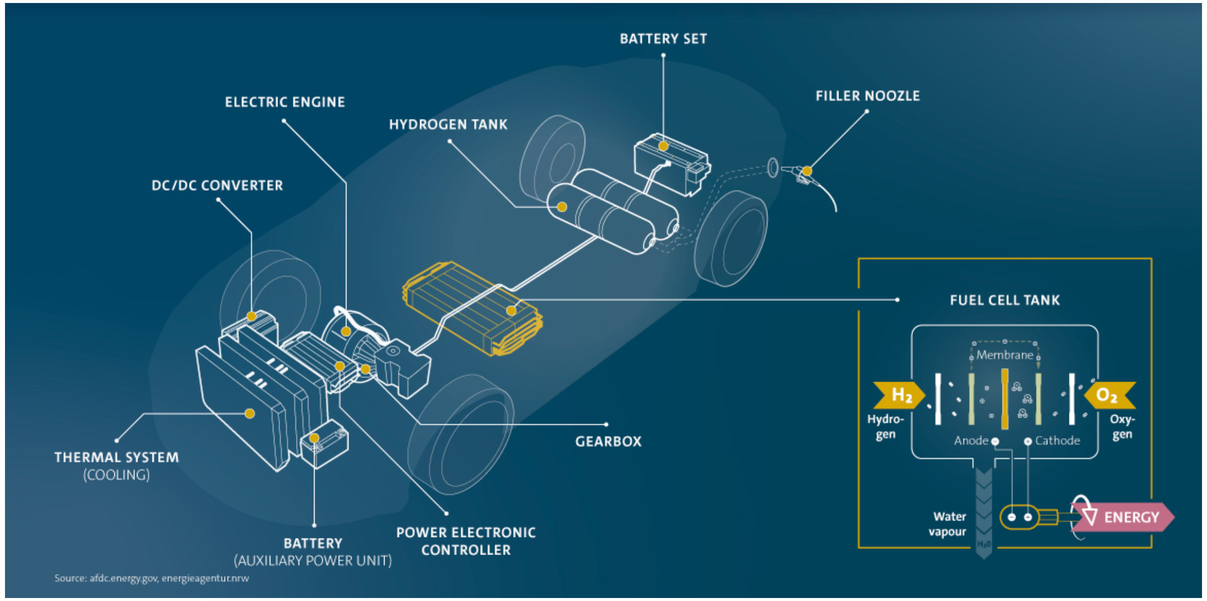
Fuel Cells

- Fuel cells were first used commercially by NASA as part of Project Gemini in the 1960s
- Fuel cells work like a battery
  - Chemical energy is converted into electrical energy
  - Charged hydrogen ions travel across a membrane to generate current, recombining with oxygen to produce water
- Efficiencies:
  - Fuel cells: Up to 60%
  - Batteries: Up to 95%
  - Internal combustion engines: Around 25%



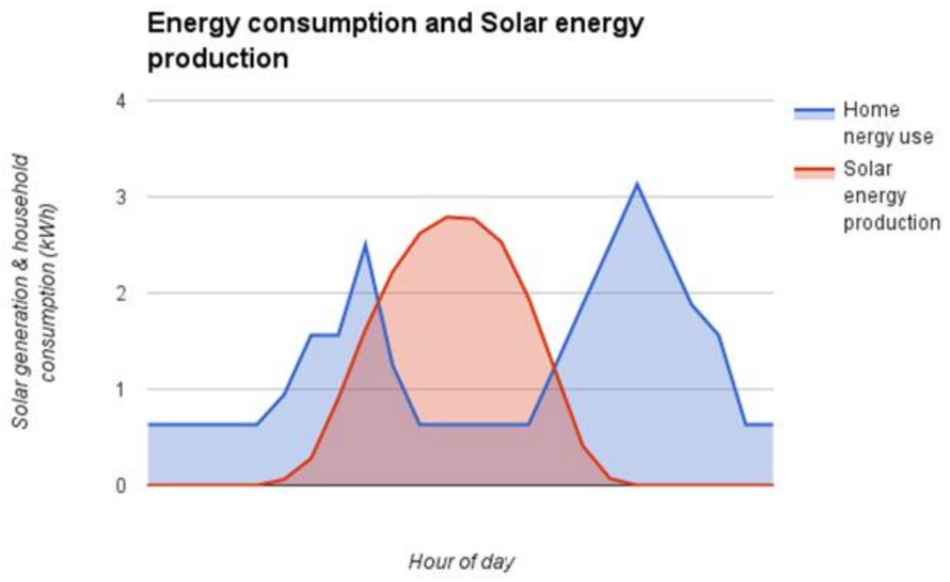
Powering Vehicles

- Fuel cells are seeing application for powering vehicles such as cars, buses, and forklifts
- Advantages include the high energy density of compressed hydrogen, low refueling times and zero-carbon emissions
- If metal hydrides were used as hydrogen storage in vehicles, they could be instantly replaced when empty



Smoothing of Intermittent Renewable Electricity

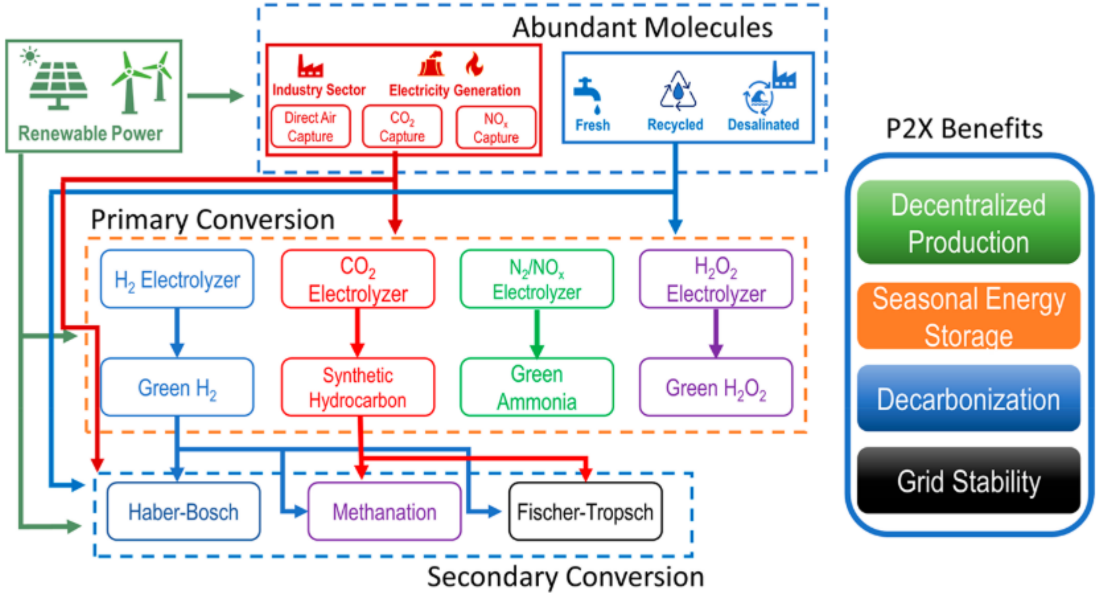
- Renewable electricity (e.g. wind and solar) is not consistently delivered
- If the electricity grid was powered by renewable electricity, peak demand would occur when supply is the lowest (at night time)
- Renewable energy can be "stored" in a chemical form (by using the energy to produce hydrogen) and can then be used to generate electricity when required
- This is known as "smoothing"



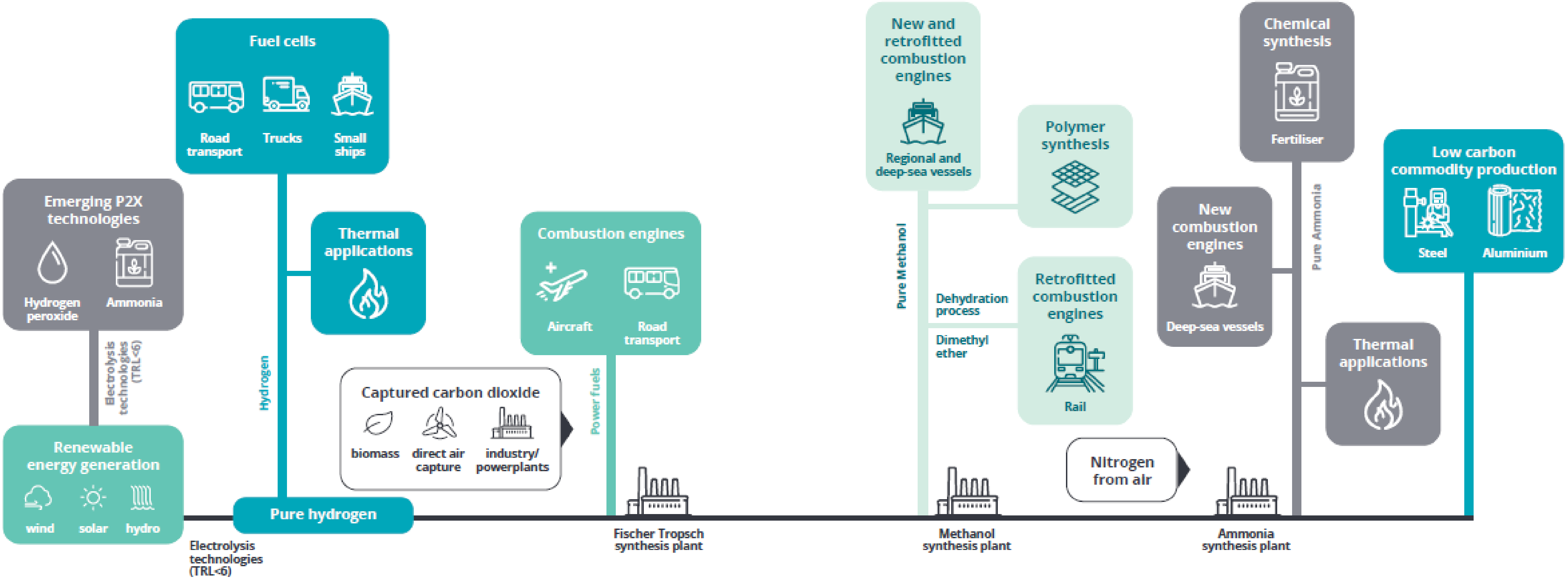
Module 4: Hydrogen Derivatives

Renewable Power-to-X

- This concept of "storing" excess renewable energy as chemicals is referred to as "renewable power-to-X"
- X can be a wide range of chemicals:
  - Hydrogen
  - Synthesis gas
  - Methane
  - Ammonia
- Electrolysis is powered by renewable energy to produce these chemicals from feedstock such as water or CO_2
- The use of these chemicals is discussed later this lecture



Hydrogen: The Decarbonisation Catalyst



PtL Pathways

PowerFuel Comparison

Each of the powerfuels evaluated offer pathways for decarbonising existing and emerging applications. However, there are parameters that must be considered when developing the value chain for these powerfuels, including decarbonisation benefits, safety and storage conditions, which are summarised in the table below:

	NH_3 Ammonia	CH_3OH Methanol	SNG Synthetic Natural Gas	SAF Sustainable Aviation Fuel
Production, Storage & Transport Technology Readiness Level	TRL 9	TRL 8	TRL 9	Production via PtL[c,d]: TRL 7 – 8 Storage & Transport: TRL 9
Powerfuel Storage Conditions	Pressurised: Ambient temperature and 16-18 bar Low-Temperature Liquid: minus 33°C and 1.1-1.2. bar	Ambient conditions as liquid	Pressurised:200-250 bar at ambient temperature Liquified: -162°C	Ambient conditions as liquid. Can use conventional jet fuel storage infrastructure
Volumetric Energy Density (MJ/L)[a,b]	12.7	16.0	20.6	33.2
Gravimetric Energy Density (MJ/kg)[a,b]	18.6	20.0	53.6	44.2
Decarbonisation Benefit (kg CO_2-e/kg fuel)[e,f]	0	0.25	0.18	0.33-0.52 for bio-based production. Lower values for PtL production
Safety	Flammable with toxic fumes and dangerous for the environment if released	Flammable, toxic and dangerous for the environment if released	Highly flammable and will explode at gas-to-air ratio between 5% and 15%	Aviation
End-Use Sectors	Agriculture, Mining, Power Generation, Maritime, Chemical Feedstock	Power Generation, Mining, Maritime, Chemical Feedstock	Power Generation, Residential Appliances	Aviation

References:
a.- H2 Tools.Link
b.- IATA. Link
c.- Johnson Matthey. Link
d.- Collis, J., Duch, K. & Schomäcker, R. Techno-economic assessment of jet fuel production using the Fischer-Tropsch process from steel mill gas. Front. Energy Res. 10, (2022). DOI: 10.3389/fenrg.2022.1049229
e - ICAO. Link
f.- Sean M. Jarvis, Sheila Samsatli, Renewable and Sustainable Energy Reviews Link

Shipping PtL

Global shipping of PtL can take advantage of current infrastructure

Figure 23: LNG Shipping Density Map for 2019[172]

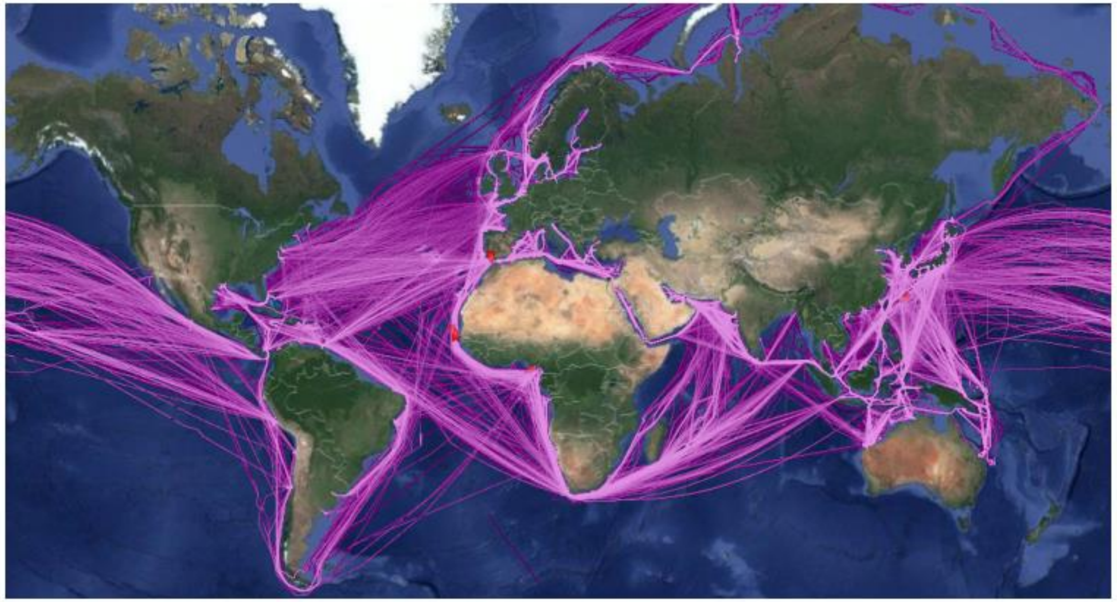
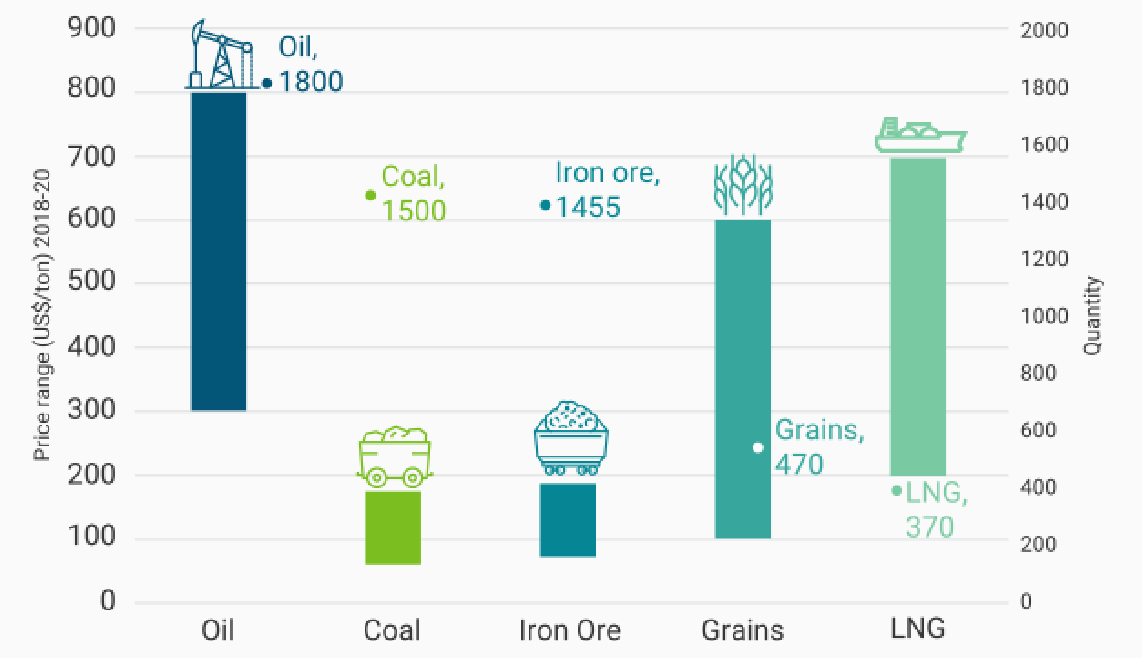


Figure 5: Shipped tonnage and average price ranges for some key traded commodities.
Note that the price indications are spot price ranges over 2018-2020 and shipped tonnages from 2019. For hydrogen trade, prices of around US$1.50 – 2.50/kg would translate to ~US$1,500-2,500/ton, representing a relatively high value commodity while traded volumes in various 2050 scenarios would likely be well below the shipped tonnage of some existing commodities.



Power to Ammonia (1/5)

The Concept

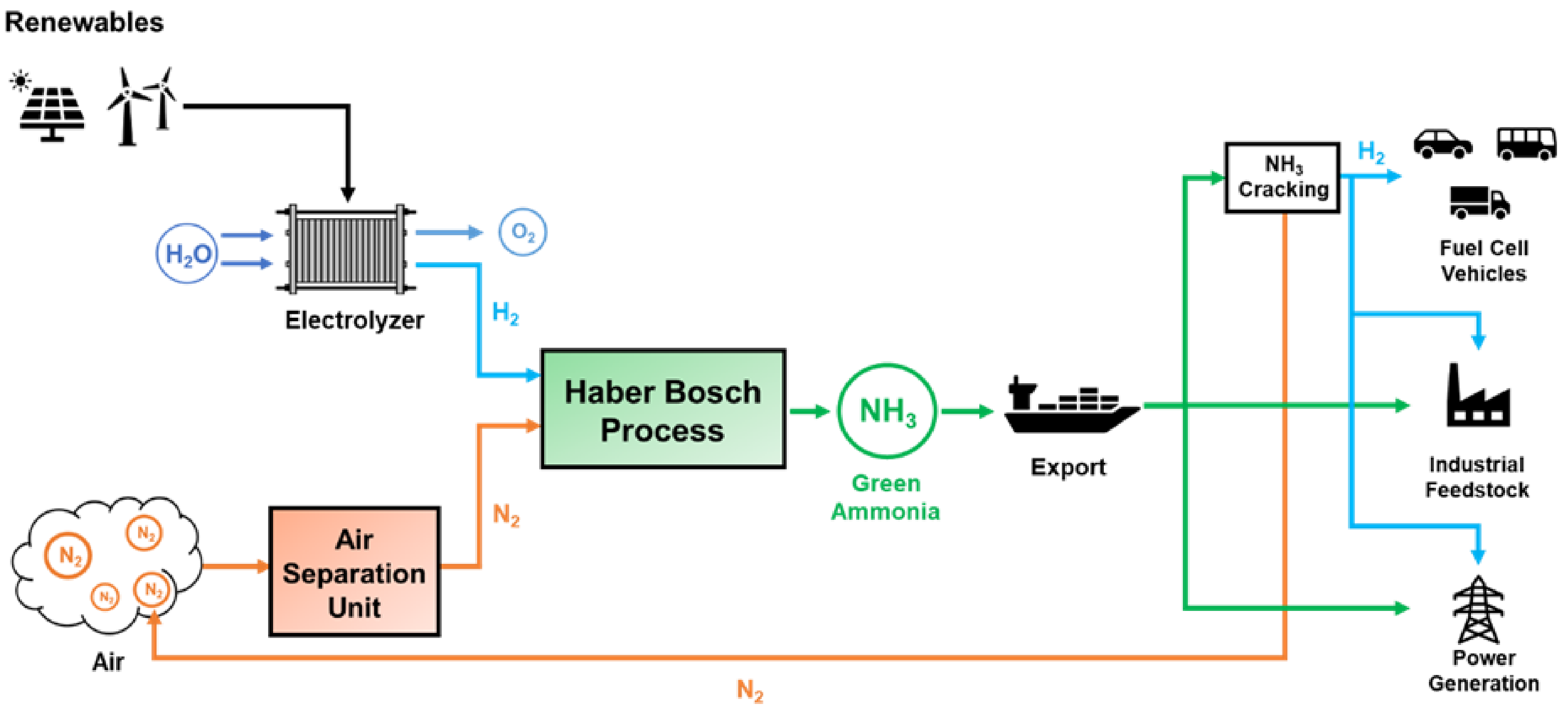


Figure: A Green Ammonia Export Chain

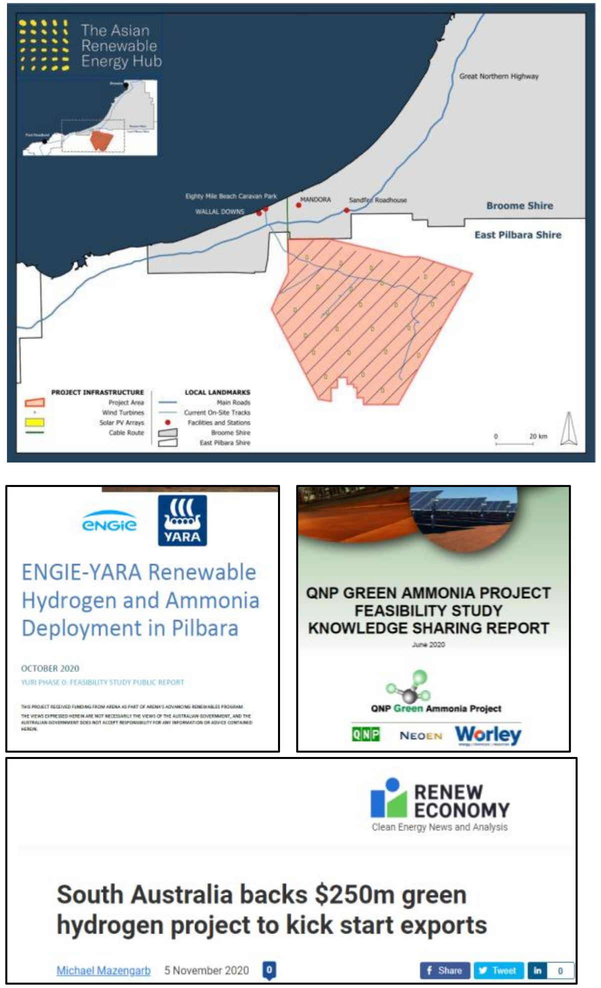


Figure: Several high profile Green Ammonia Generation Projects are already being proposed across Australia.

Power to Ammonia (2/5)

Ammonia Economy

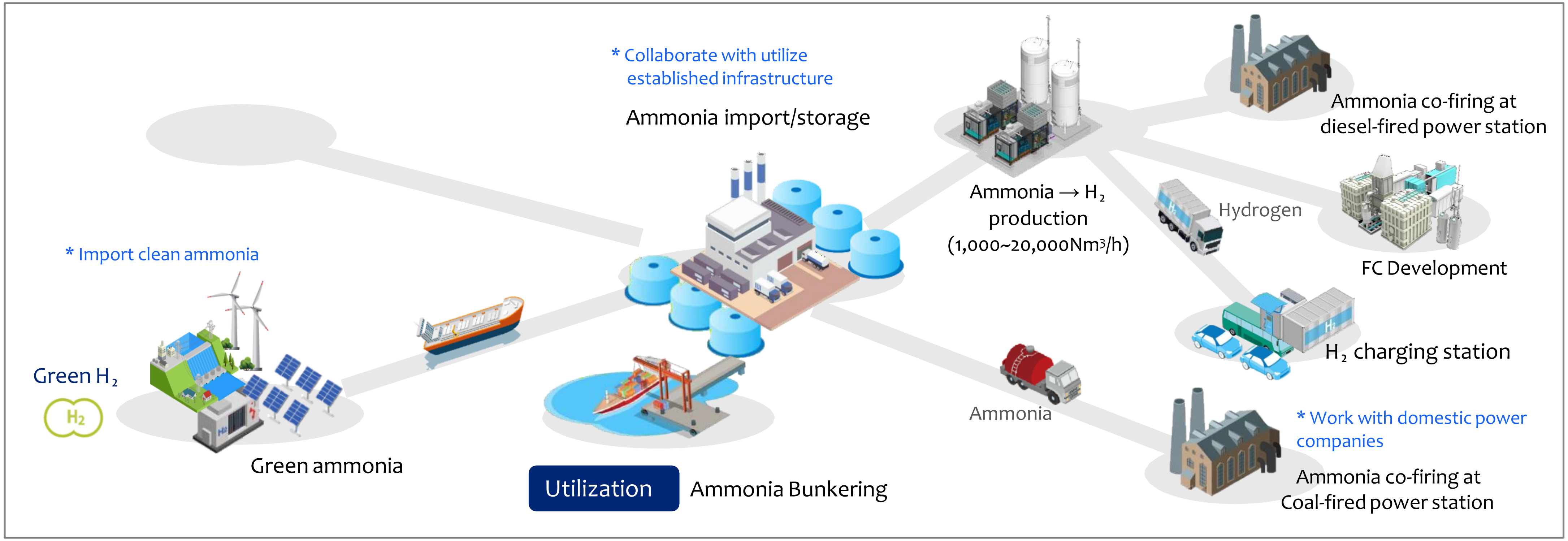
Production — Clean H_2 production abroad

Transport — Conversion to ammonia and transfer

Storage — Import/store ammonia

Conversion — Ammonia → H_2 (re)conversion

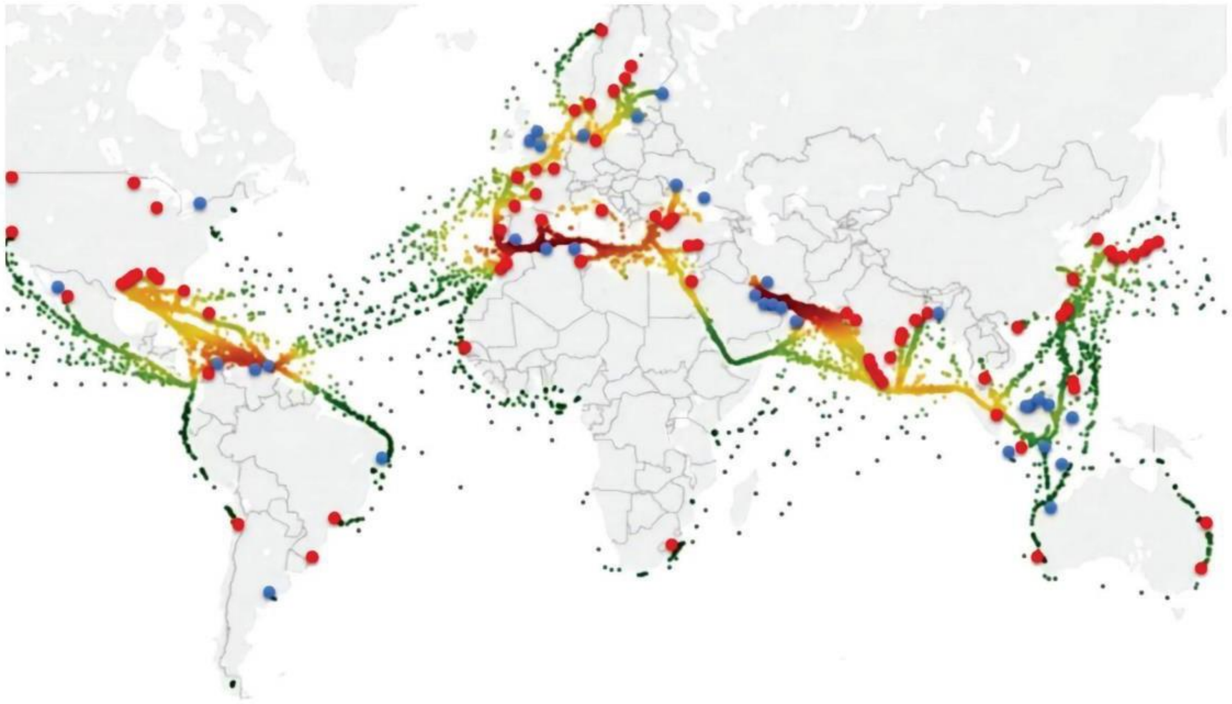
Utilization



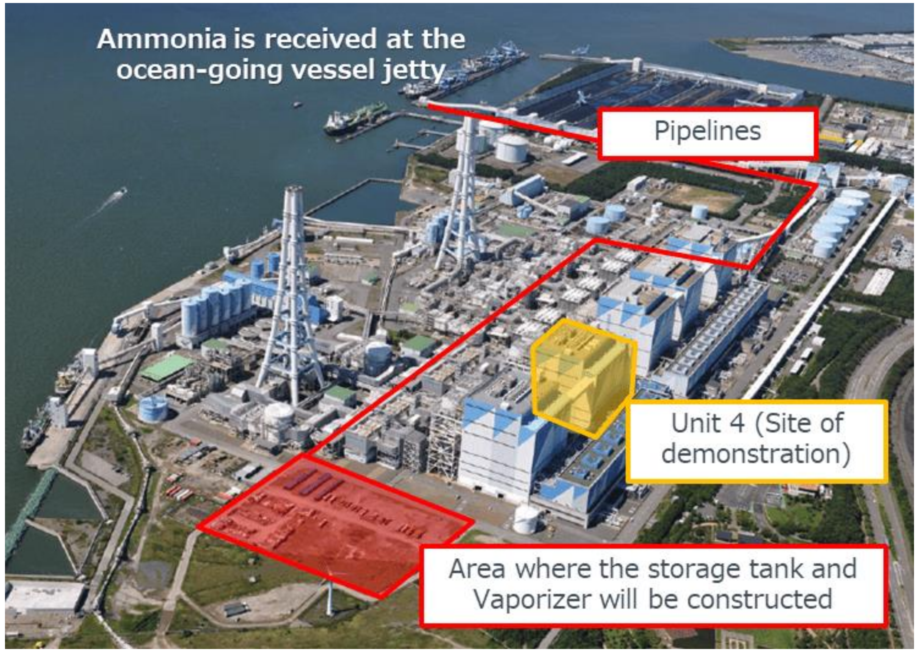
Power to Ammonia (3/5)

Ammonia Infrastructure and Projects

● Ammonia loading facilities ● Ammonia unloading port facilities

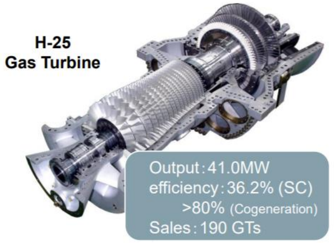


Source: The Royal Society, 2020; IEA, 2020

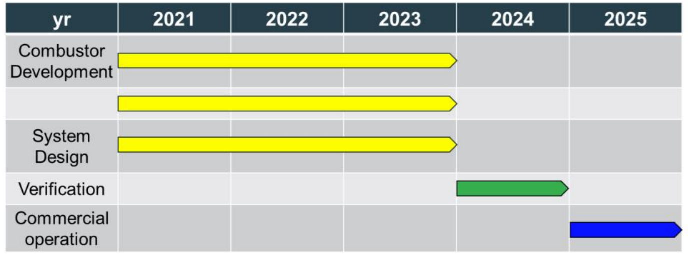


Mitsubishi Power is now expanding the line-up of carbon free combustion system, not only hydrogen combustion but also ammonia direct combustion.

- ☞ start development of ammonia direct combustor
- ☞ plan to verify the system in 2024
- ☞ start commercial operation from 2025



Development Schedule



Power to Ammonia (4/5)

Economic Considerations

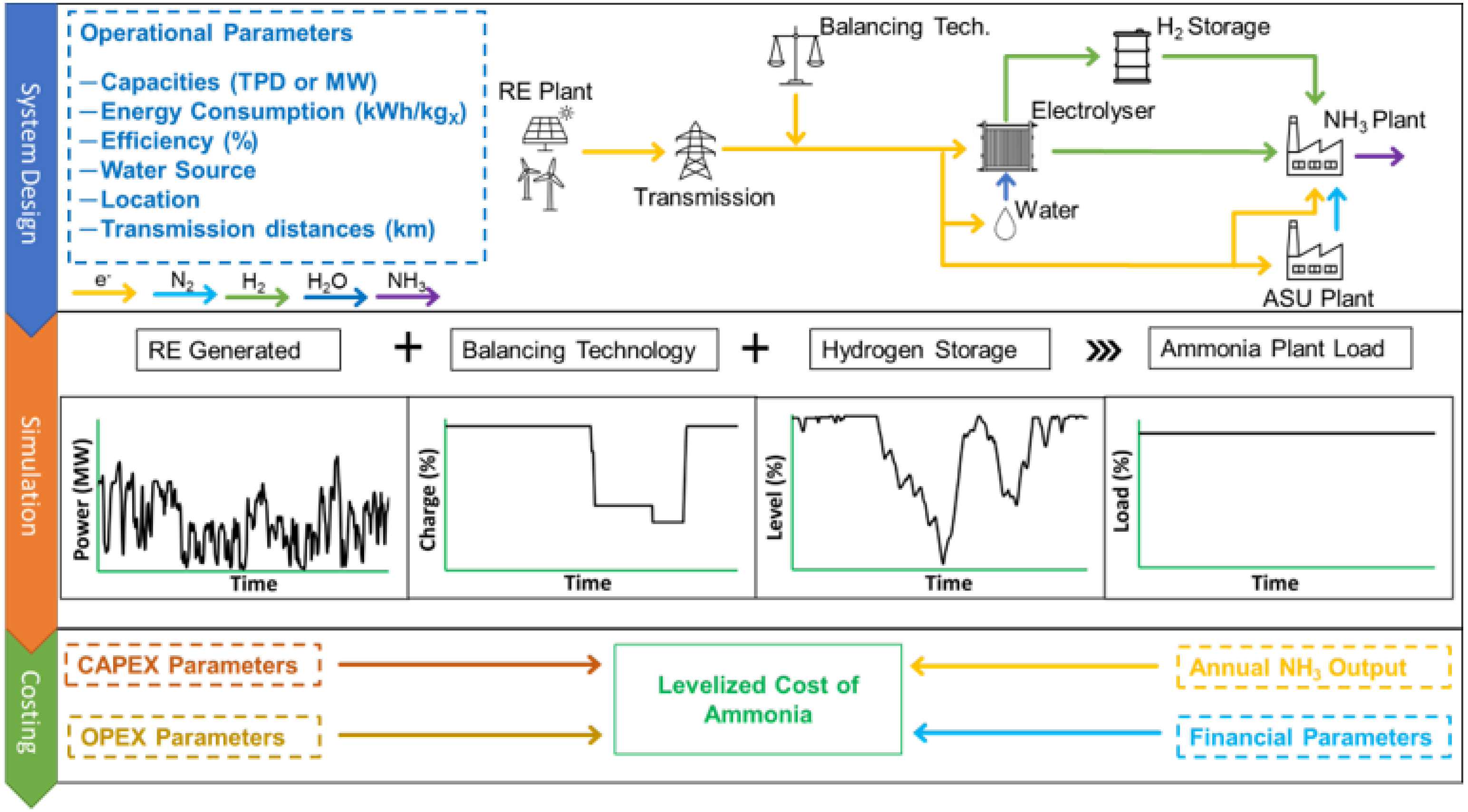


Figure: Summary of the framework used to assess the feasibility of green ammonia projects. The first level involves system design to define the operational parameters. The second level simulates the chosen design with outputs displayed graphically to determine the viability of the project. The third level uses the production output and pre-defined cost parameters to generate a Levelized Cost of Ammonia (LCOA).

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Power to Ammonia (5/5)

Cost Challenges

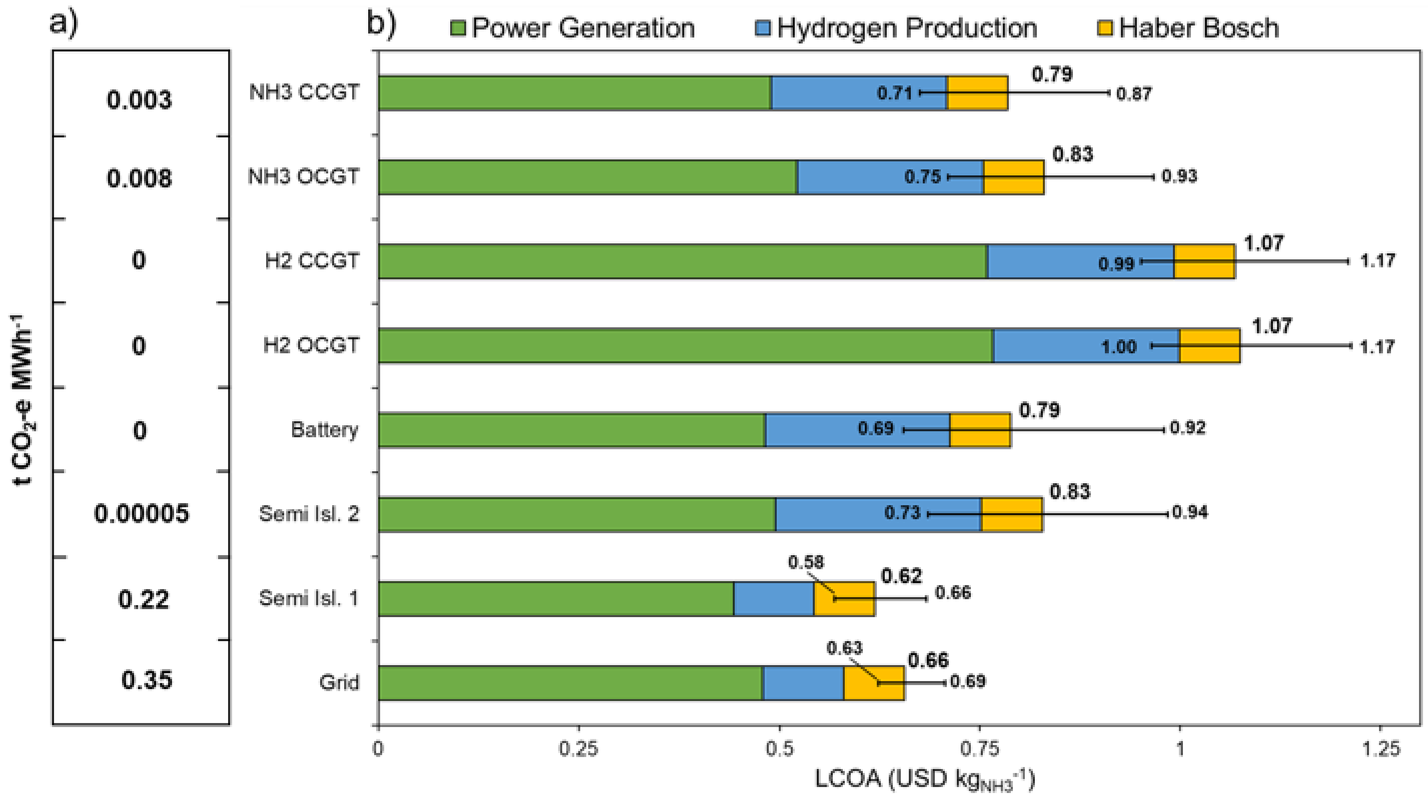
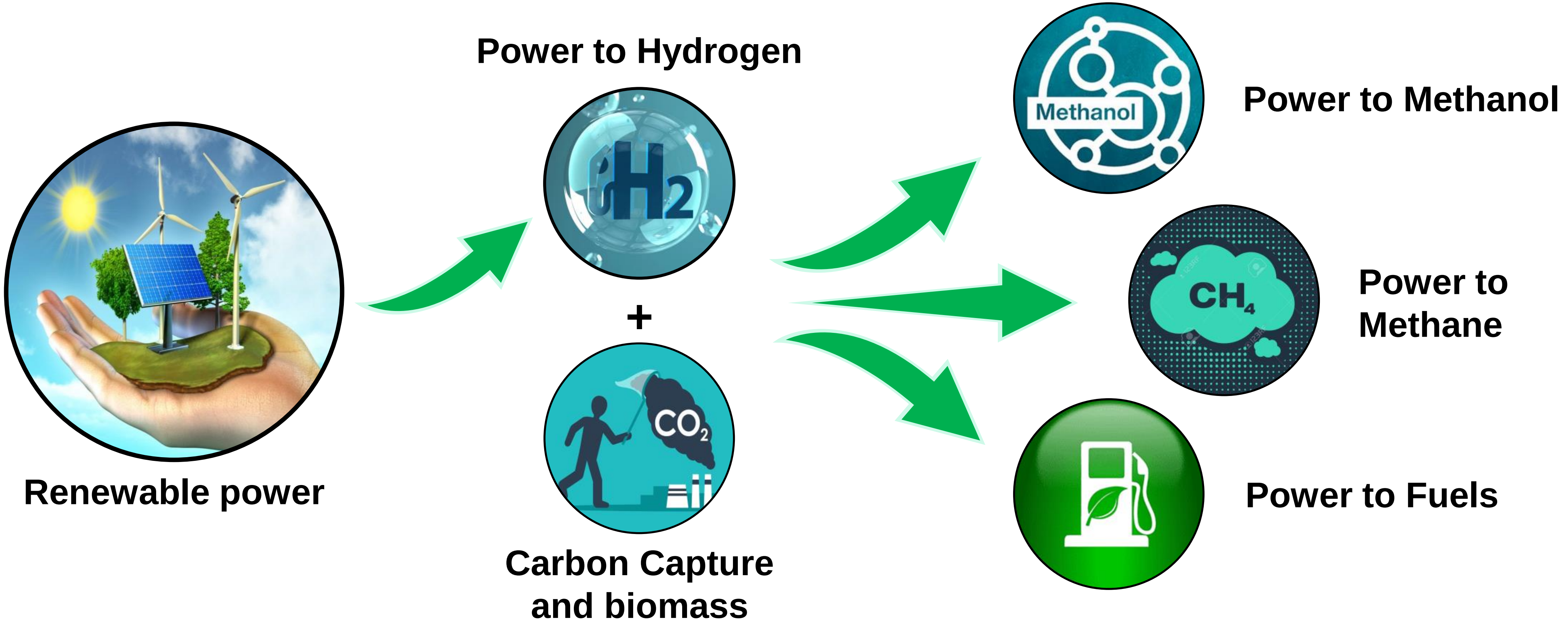


Figure: Power source and balancing technology comparison for 1 MMTPA ammonia plant in 2030. (a) Estimated carbon intensity for scope 1 and 2 emissions for different power sources and balancing technologies assessed. (b) Breakdown of costs covering power generation, hydrogen production and Haber Bosch for each of the power sources and balancing technologies assessed.

Power to Synthetic Fuel



Clean energy carriers
Green fuels
Green chemicals and products

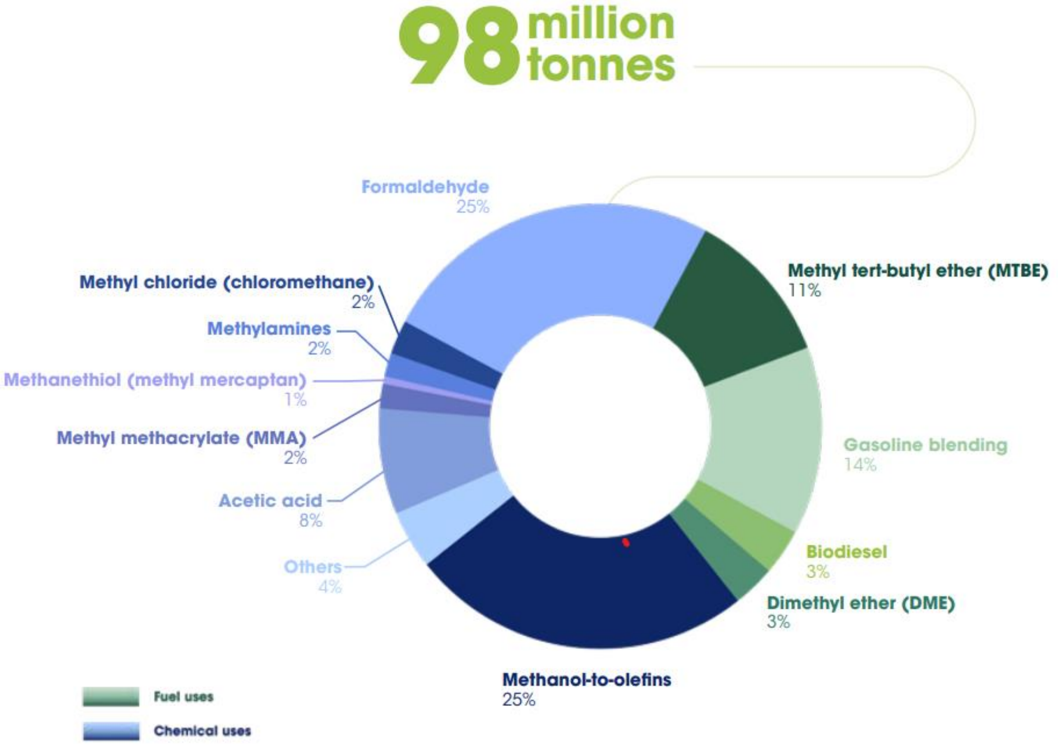
Closing the carbon loop

Clean energy storage
Decarbonising the value chain
Trade and export

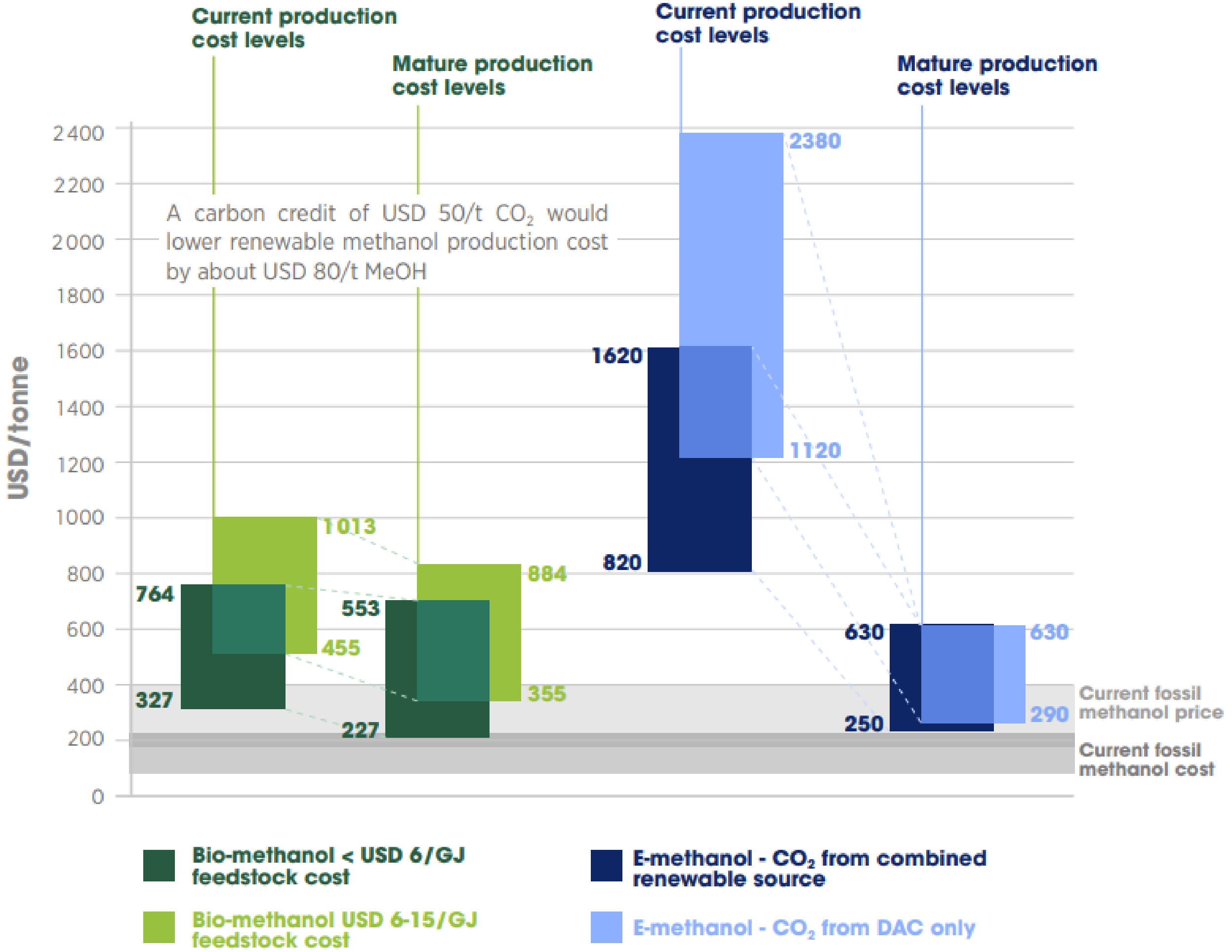
UNSW. Sydney, "NSW Power to X (P2X) Industry Pre- Feasibility Study A Roadmap for a P2X economy in NSW."

Power to Methanol (1/5)

Established Trade in Methanol



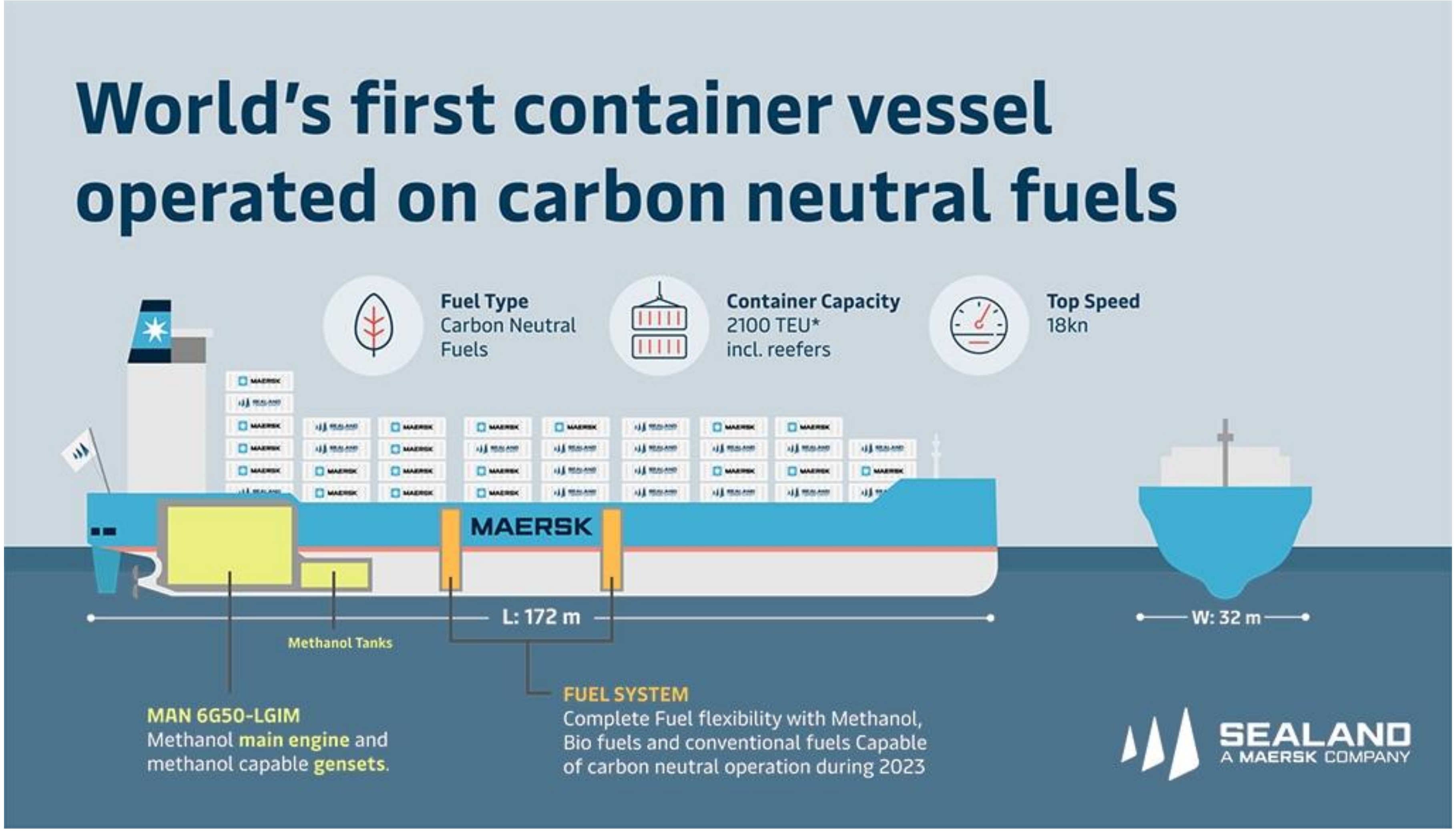
Source: *Based on data from MMSA (2020)*



Notes: *MeOH = methanol. Costs do not incorporate any carbon credit that might be available. Current fossil methanol cost and price are from coal and natural gas feedstock in 2020. Exchange rate used in this figure is USD 1 = EUR 0.9.*

Power to Methanol (2/5)

Emerging Uses as Bunker Fuels



Renewable Methanol – (250 Mt/y – 2050)

- Marine transport fuel
- Chemical Feedstock (MTO, DME, etc.)
- Renewable energy trade and export
- Fuel cell backup power

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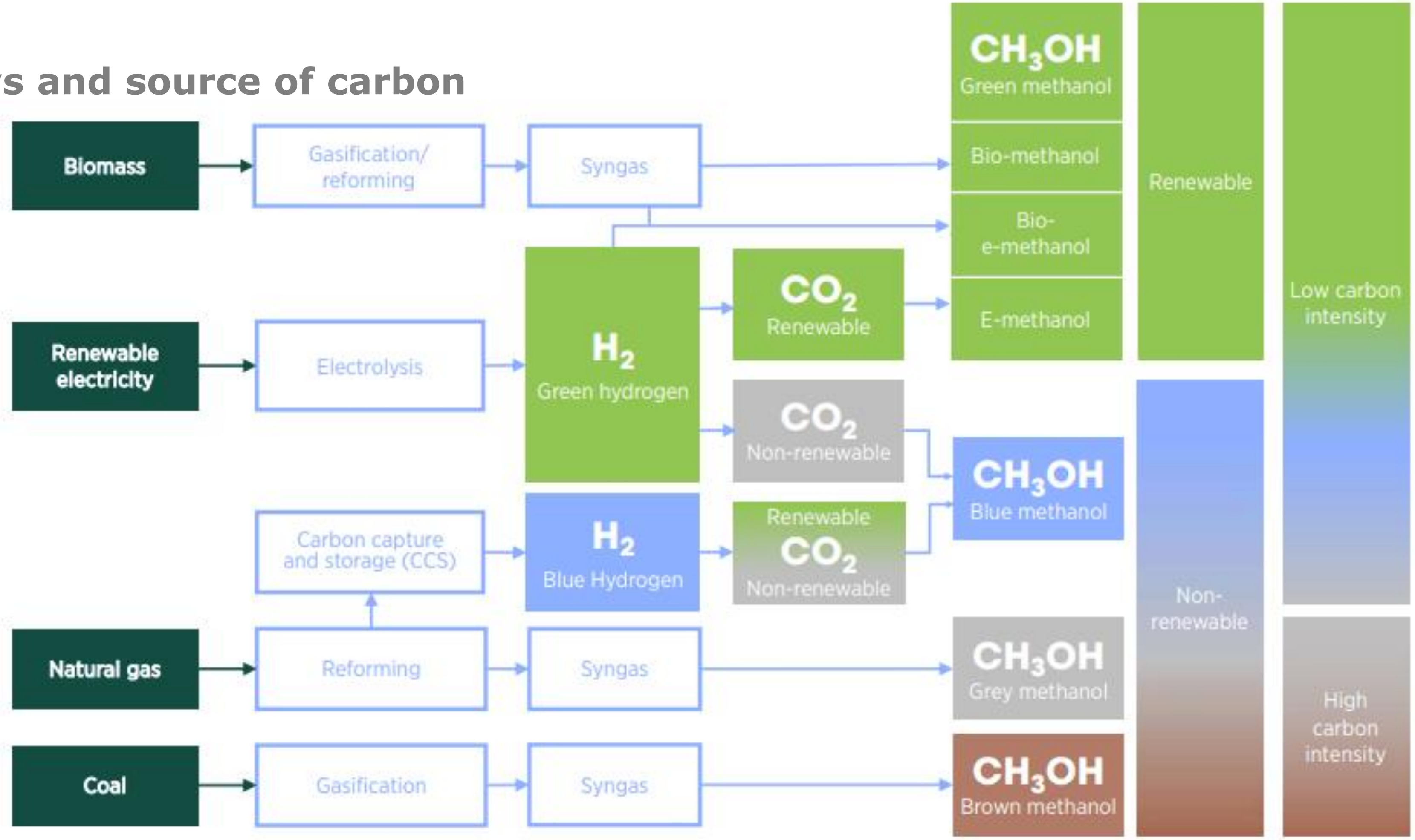
Power to Methanol (3/5)

Production pathways and source of carbon



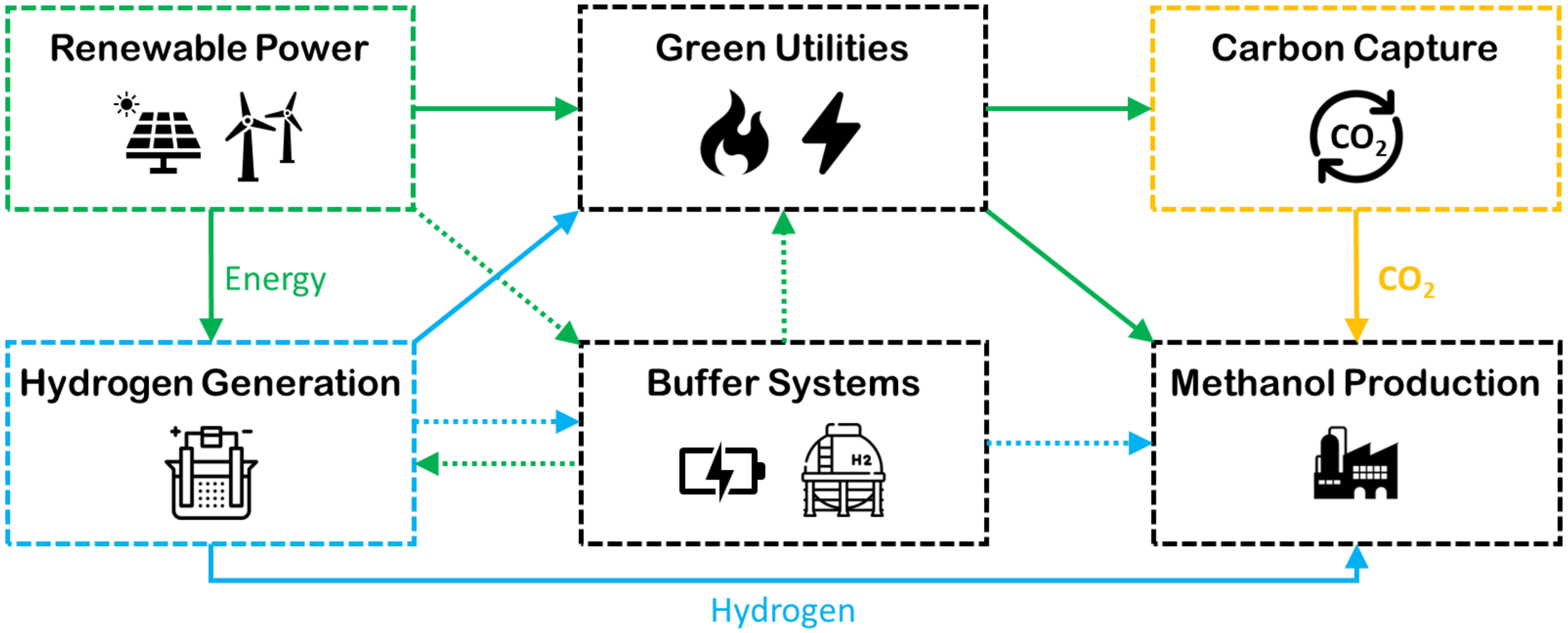
Renewable CO_2: *from bio-origin and through direct air capture (DAC)*

Non-renewable CO_2: *from fossil origin, industry*

While there is not a standard colour code for the different types of methanol production processes; this illustration of various types of methanol according to feedstock and energy sources is an initial proposition that is meant to be a basis for further discussion with stakeholders

Power to Methanol (4/5)

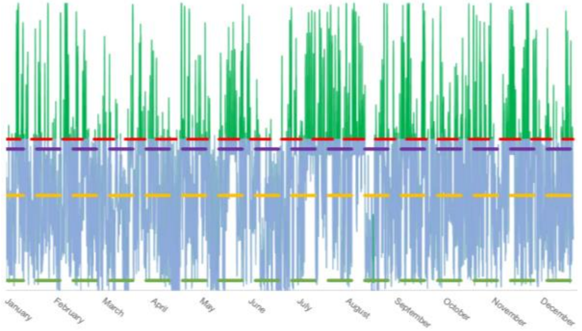
Cost Framework



Dynamic modelling

Configuration analysis

Buffer systems



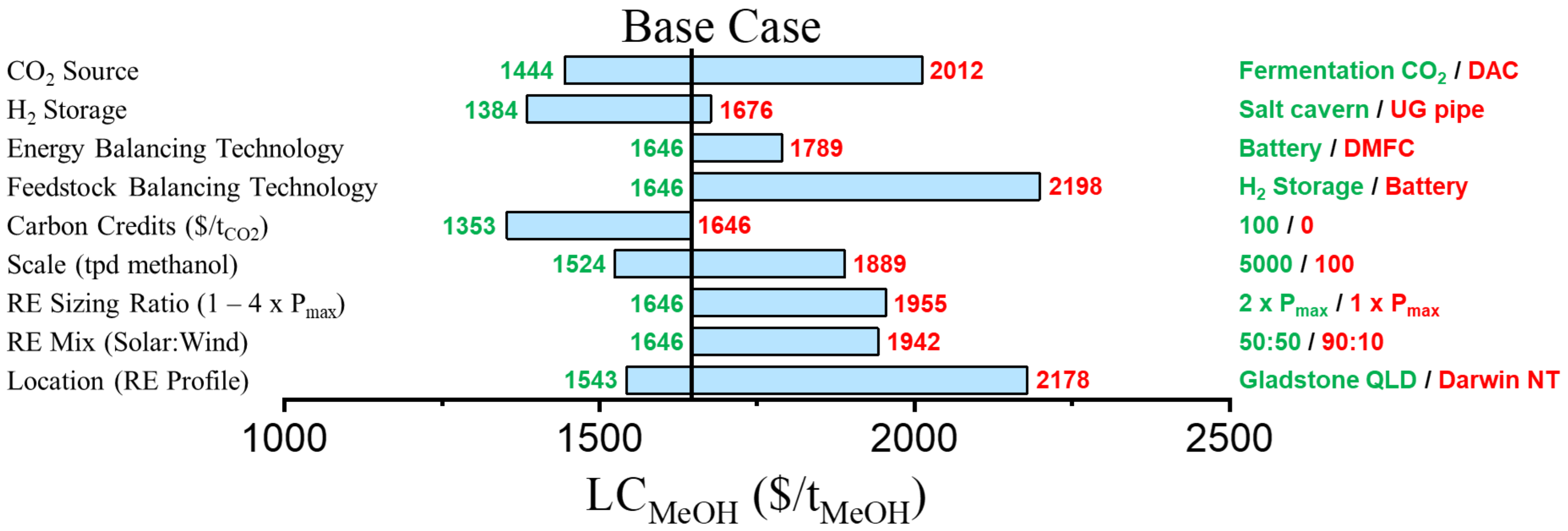
Open-source tool

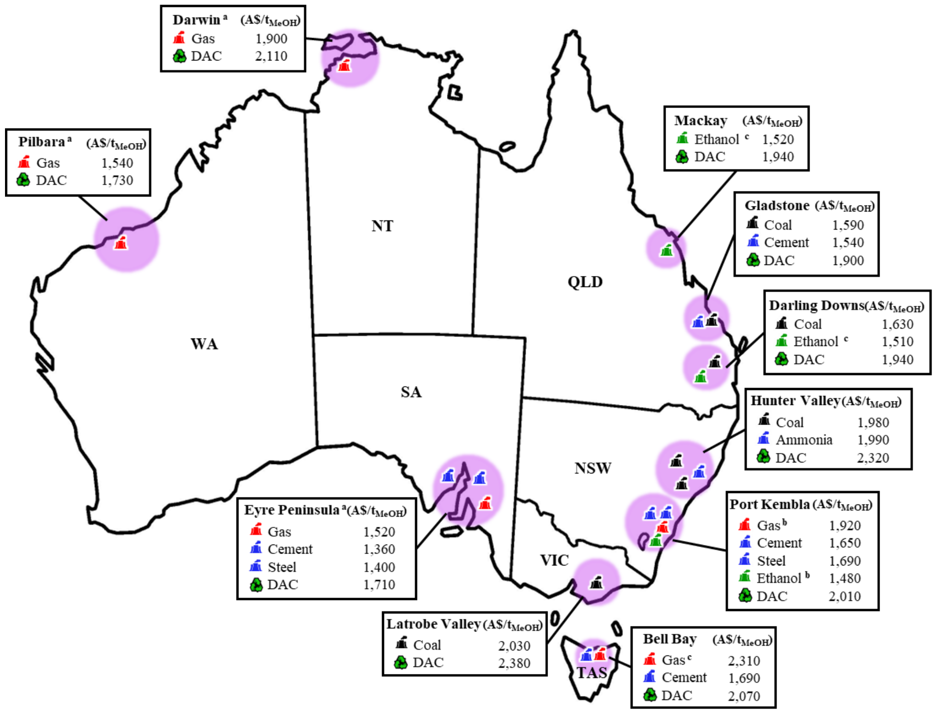
Location specific results

CO_2 point source types

Power to Methanol (5/5)

Cost Framework





Power to Sustainable Aviation Fuel (1/3)

Sustainable aviation fuel (SAF) is the main term used by the aviation industry to describe a sustainable, non-conventional, alternative to fossil-based jet fuel.

Current SAF focused on so-called 'drop-in fuels'

- Physical and chemical characteristics are almost identical to conventional fossil based jet fuel and can therefore be safely mixed (at various blend ratios).
- Uses the same fuel supply infrastructure and doesn't require adaptation of current global fleet.

- Over **450,000 flights** have taken to the skies using SAF
- **7 technical pathways** exist
- Over **300 million litres** of SAF were produced in 2022
- SAF can **reduce emissions by up to 80%** during its full lifecycle
- Around **17 billion US dollars** of SAF are in forward purchase agreements in 2022
- More than **50 airlines** now have experience with SAF

Decarbonisation Technology Pathways	Sustainable aviation fuel	Battery-electricity	Hydrogen (fuel cell and turbine)
Emissions reduction potential	Medium to High, depends on blending ratio	Low to Medium, if powered by renewable electricity but restricted for short-haul flights	Medium to High, restricted for short-haul flights and depending on hydrogen production pathways
Aircraft design impact	Minor design changes	Medium to High, new design for battery and control system	Medium impacts on design
Range and type	Applications to full range and both cargo and commuter flights	Restricted applications between 500 km and 1000 km, commuter flights only	Restricted applications between 500 km and 10,000 km, both cargo and commuter flights
Aircraft refuelling infrastructure impact	Low Impact, existing infrastructure can be used	High Impact, energy storage, transmission and fast-charging infrastructure required	High Impact, liquid hydrogen storage and distribution infrastructure required
Technology Readiness Level and deployment timeframe	6-9, deploying with commercial projects	3-4, R&D and early piloting, to be deployed post-2040	3-4, R&D and early piloting, to be deployed post-2040

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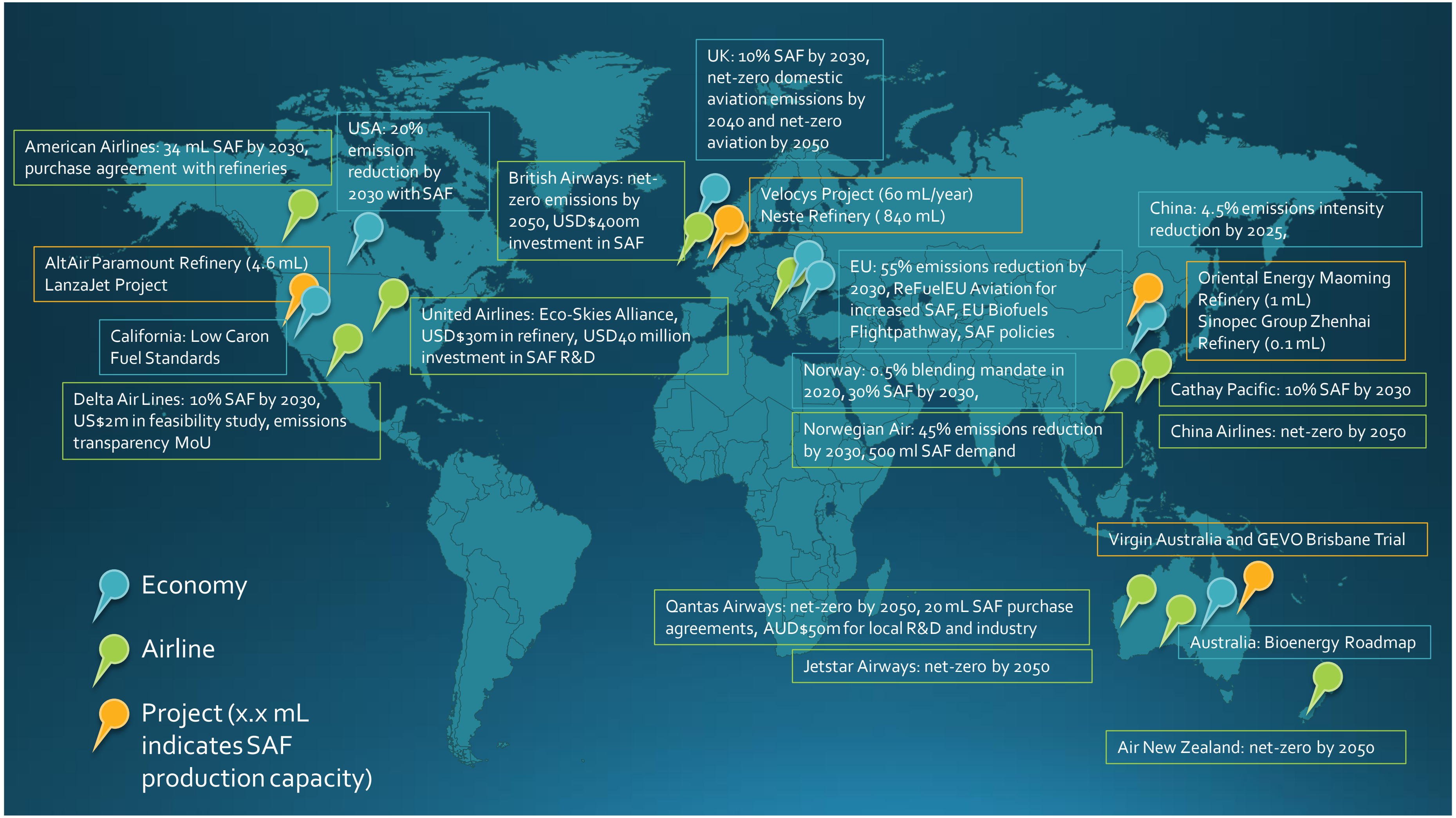
Power to SAF (2/3)

Global Commitments and Projects



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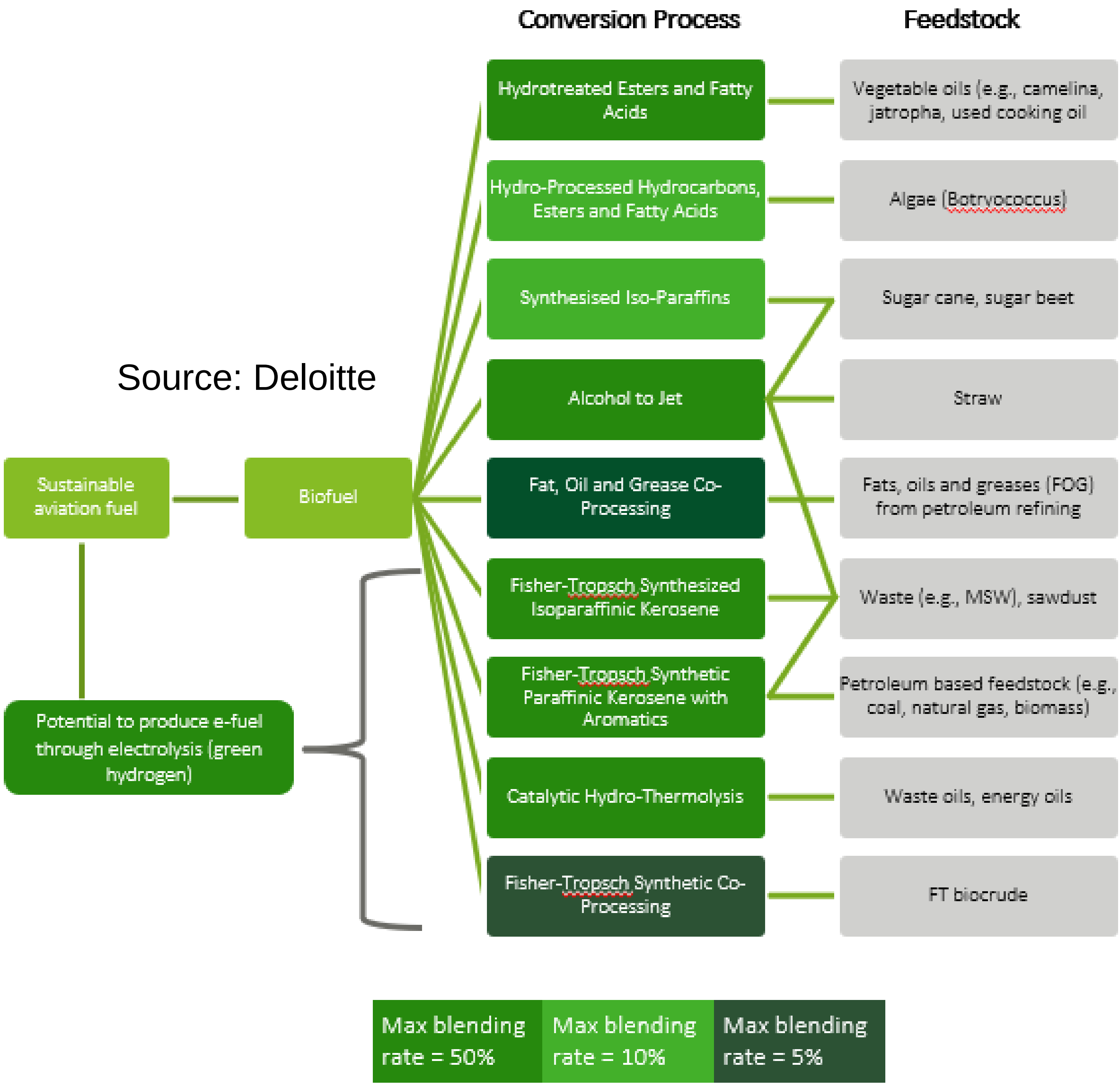
Power to SAF (3/3)

How is it made?



“Much to be optimistic about… but much much more to be done…….”

Q&A

Session 2

		Regional perspectives	**Atul Ratui**
11:30am	11.45am	Mr Peceli Nakavulevu - International Renewable Energy Agency; IRENA work and projects in the region	
11:45am	12 midday	Ms Florence Ventura - Pacific Community (SPC) perspectives	
12 midday	12.15pm	Dr Ali Mohammadi - Engineering and Physics - University of the South Pacific; hydrogen based research at USP	
12.15pm	12.35pm	Dr Rahman Daiyan - other hydroge project proposals for the region Iain MacGill and Shayan Naderi - Renewable energy potential for hydrogen production in the region	
12.35pm	1pm	Regional challenges and opportunities - perspectives from Governments and Utilities (Vanuatu, Solomons, Fiji), other stakeholders	

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IRENA perspectives

Mr Peceli Nakavulevu

SPC perspectives

Mr Inia Saula

Some researcher perspectives

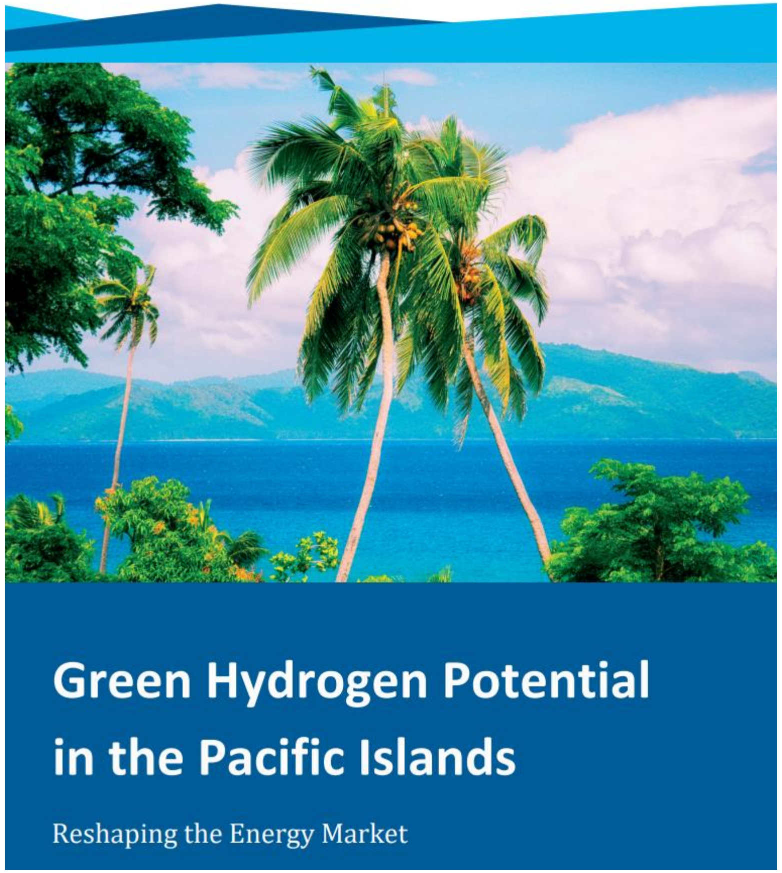
Dr Ali Mohammadi and colleagues, USP

Some other regional hydrogen initiatives, proposed projects

Dr Rahman Daiyan

Pacific Green Hydrogen Project

- The German New Zealand Chamber of Commerce's (GNZCC) regional responsibility includes seven countries in the Pacific – Fiji, Samoa, Tonga, Cook Islands, Kiribati, Niue, and Tuvalu.
- Roles of the GNZCC include:
  - Business Intelligence
  - Consulting Services for Market Entry
  - Sourcing for Business Partnerships
  - International Trade Fair Participation
- The Pacific Green Hydrogen Project aims to connect small-to-medium German enterprises that manufacture hydrogen technologies for an off-grid application in the Pacific Islands.
- Excess energy from renewable energy plants is stored in the form of hydrogen and oxygen by electrolysis. This green hydrogen can be used to generate electricity with the help of a fuel cell.



Reference: https://neuseeland.ahk.de/en/services/projects/pacific-green-hydrogen-project

Renewable H_2 to Palau

- Queensland-produced renewable hydrogen will be exported to the Republic of Palau from 2023 as part of a collaboration between Sojitz Corporation, Nippon Engineering Consultants and CS Energy.
- The project will assess the potential of renewable hydrogen for use in fuel cells and marine vessels in Palau to reduce its reliance on fossil fuels and has received subsidies from Japan's Ministry of the Environment.
- Renewable hydrogen for the project will be supplied from CS Energy's Kogan Renewable Hydrogen Demonstration Plant, which will be built on the Western Downs and produce renewable hydrogen from behind-the-meter solar energy.

Figure: Kogan renewable hydrogen plant (1 MW electrolyser, 2 MW solar PV farm).

Reference: https://www.csenergy.com.au/news/queensland-renewable-hydrogen-to-power-pacific-islands-demonstration-project

HDF Project in Fiji

- The HDF Energy Australia team is currently developing a green hydrogen project on Fiji's Viti Levu island.
- The plant could generate 6 MWe of electricity during the day and evening, and 1.5 MWe throughout the night.
- HDF develops, finances, builds and operates multimegawatt industrial power generation infrastructures.
- HDF marketed the Renewstable® power plants, which capture intermittent renewable energy and store it massively in the form of hydrogen. HDF Energy currently has around ten Renewstable® projects in the advanced development phase in several countries.

Figure: Concept images of the solar PV farm and the hydrogen generation, storage, and fuel cell facilities.

Reference: https://www.hydrogenpower-fiji.com/

H_2 Powered Boats in Fiji

- Fiji aims to begin replacing its current Government shipping fleet with hybrid and green hydrogen solutions.
- During Fiji's Presidency of COP23, it launched the 'Oceans Pathway', with the expectation to place oceans where it belongs – at the heart of climate action.
- In Fijis's Low Emissions Development Strategy 2018-2050, the potential for methanol, ammonia, and hydrogen as the most likely alternative fuels for maritime transport is discussed.

FIJI NEWS | NATION | NEWS

PM: Fiji To Replace Govt Vessels With Hybrid, Green Hydrogen Solutions

During Fiji's Presidency of COP23, it launched the 'Oceans Pathway', with the expectation to place oceans where it belongs - at the heart of climate action.

By **Rosi Doviverata**

05 Nov 2021 15:30

References:
https://fijisun.com.fj/2021/11/05/pm-fiji-to-replace-govt-vessels-with-hybrid-green-hydrogen-solutions/
https://unfccc.int/sites/default/files/resource/Fiji_Low%20Emission%20Development%20%20Strategy%202018%20-%202050.pdf

Hydrogen Production in Papua New Guinea

- Two agreements between Fortescue Future Industries and Papua New Guinea signed in 2020 and 2021 enabled feasibility studies on up to 18 hydropower and geothermal projects in the country, including a hydro project along the Purari River on the nation's southern coast.
- These projects would provide renewable hydrogen to TotalEnergies' Papua LNG project.
- However, Fortescue has not provided any updates on the projects since December 2021 when it said a pre-feasibility study was well advanced.

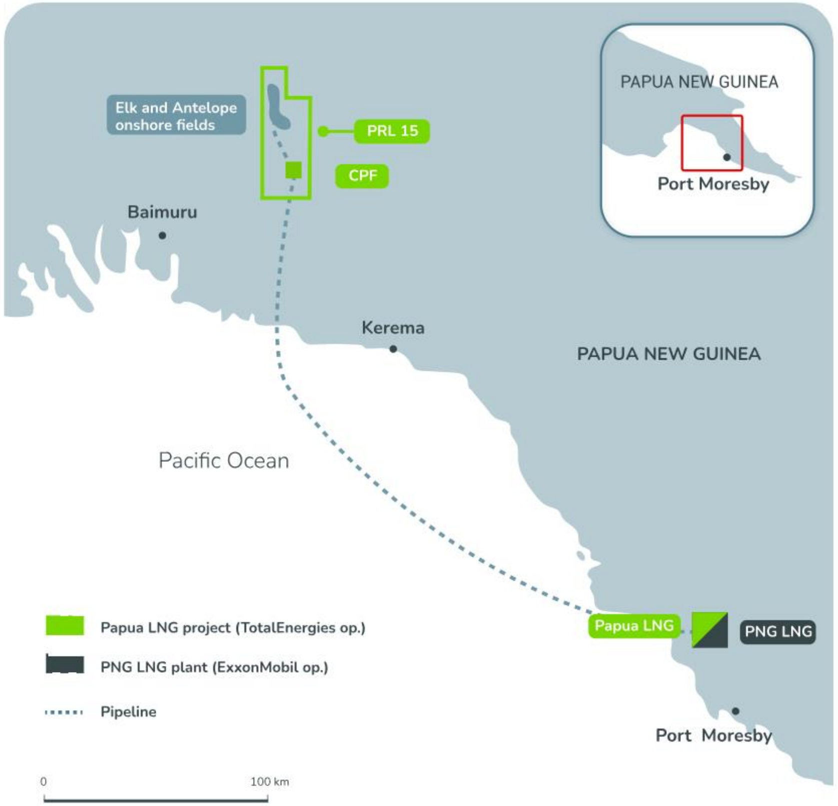


Figure: The Papua LNG project.

Reference: https://www.reuters.com/business/energy/totalenergies-may-buy-green-power-fortescue-papua-new-guinea-regulator-2022-12-08/

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Renewable energy potential for hydrogen in the Pacific

Dr Iain MacGill and Mr Shayan Naderi

ain MacGill and Shayan Naderi - Renewable energy potential for hydrogen

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GlobH2E

Collaboration on Energy and Environmental Markets

IRENA International Renewable Energy Agency

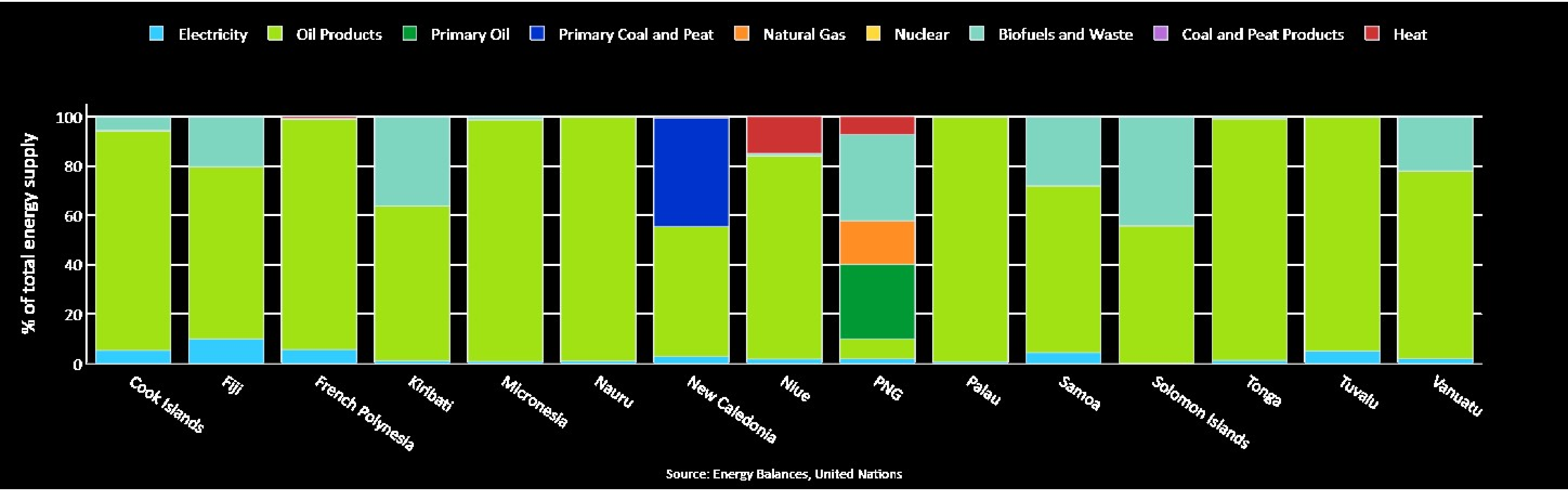
USP THE UNIVERSITY OF THE SOUTH PACIFIC

Pacific Community Communauté du Pacifique

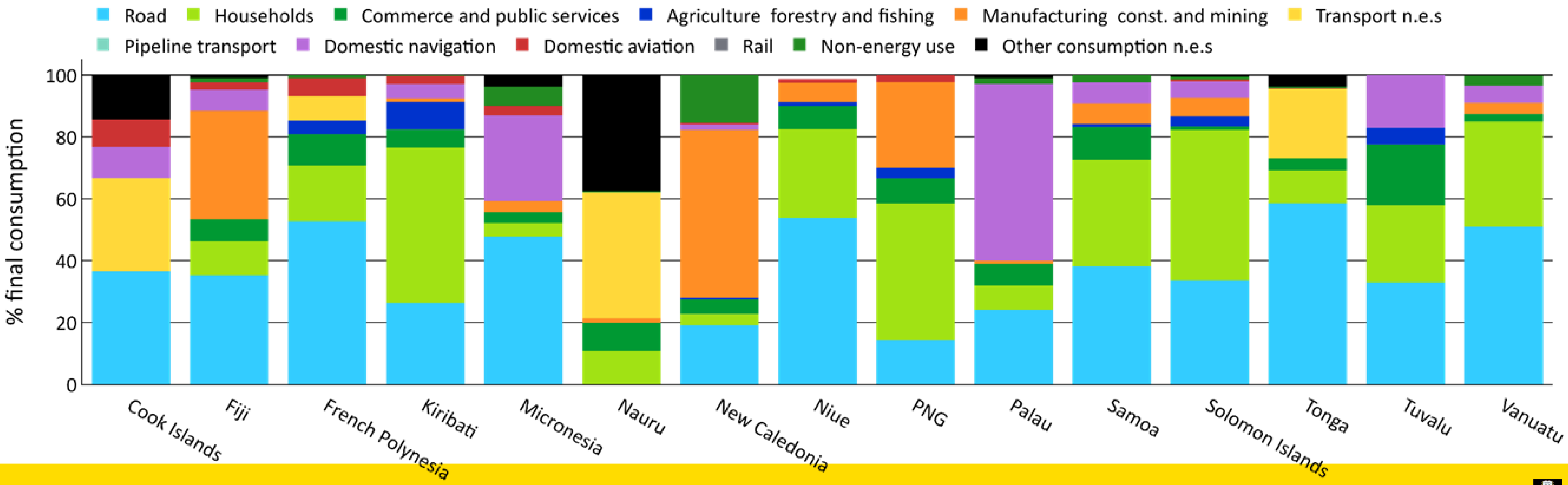
PPA PACIFIC POWER ASSOCIATION

Australian Government
Department of Climate Change, Energy, the Environment and Water

Current renewable energy contribution is low

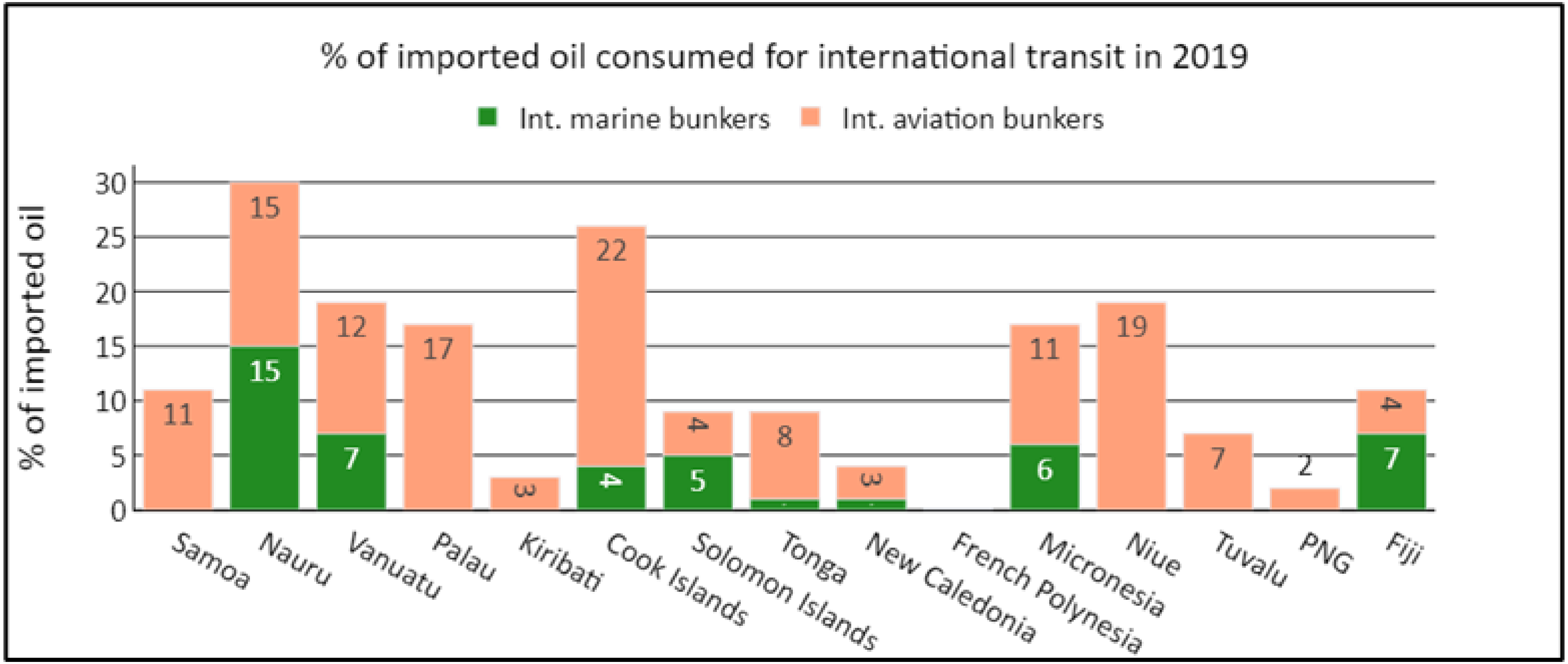


Renewable electricity generation will first go to current loads, newly electrified loads…
whatever is left perhaps to local h2 production with key use cases – domestic navigation, aviation

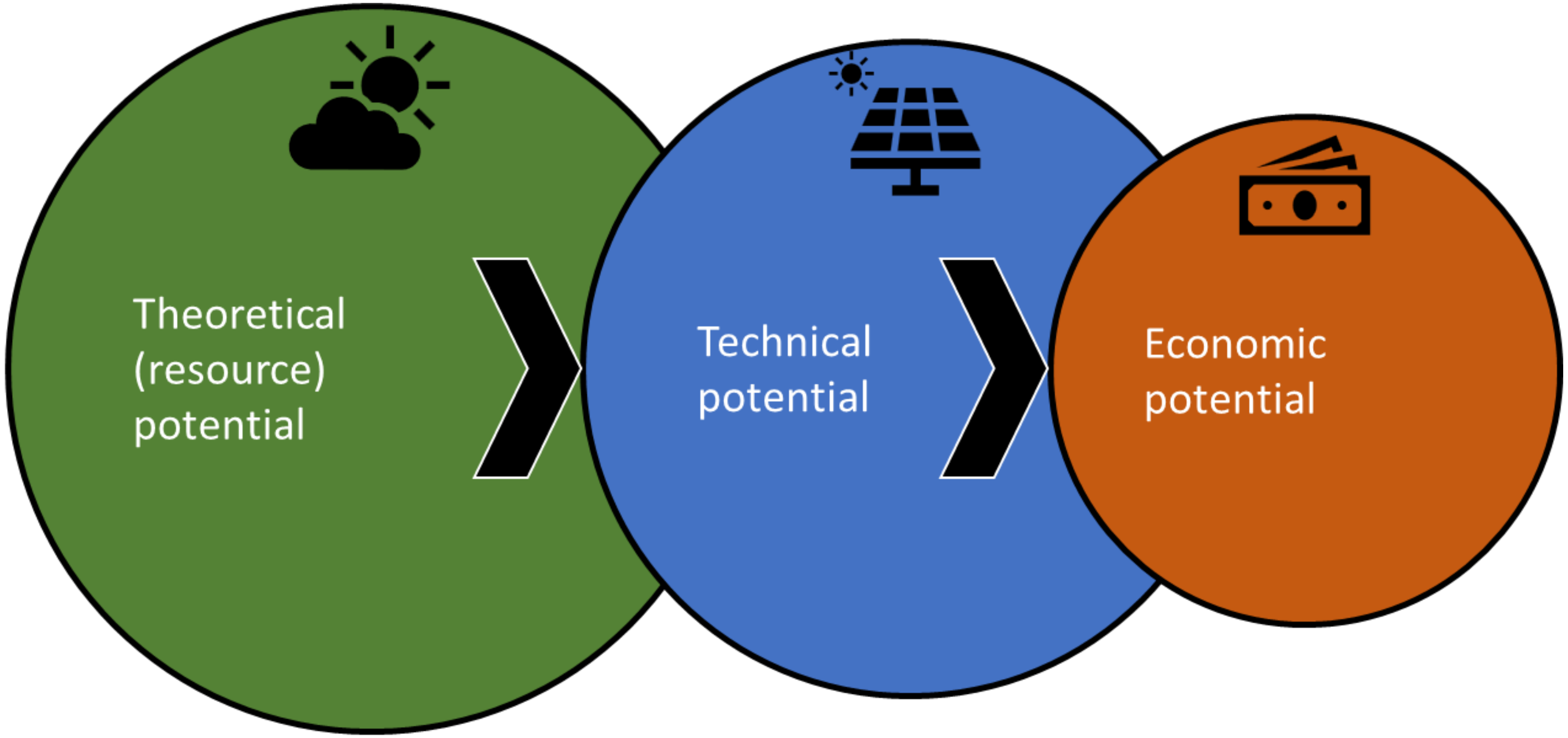


Source: Energy Balances, United Nations

International bunker fuels add further complexity



Is there sufficient renewables for all demand?



- Wind and solar resources

- Available land for PV
- Available coastline for wind turbine
- Rooftop PV potential

What might future demand be?

Decarbonization of the electricity sector

Electrification of all sectors

IEA Net zero emission scenario by 2050

Sufficient renewables? *It depends*

Country	Technical potential (GWh/year)	Demand (GWh/year)			Payback period (years)
		Decarbonizing the electricity sector	Electrification	Net zero emission	
Samoa	1,198	94	605	2,025	24
Nauru	18	36	102	107	20
Vanuatu	4,569	61	356	3,078	20
Palau	1,355	94	422	179	21
Kiribati	799	26	145	1,190	21
Cook Islands	155	29	167	175	18
Solomon Islands	2,998	95	635	6,529	22
Tonga	1,295	64	337	1,007	21
New Caledonia	7,282	2,873	7,772	2,972	28
French Polynesia	4,409	492	1,818	2,759	21
Micronesia	7,822	64	282	1,045	20
Niue	166	4	12	16	16
Tuvalu	22	7	15	116	21
PNG	15,703	2,494	11,824	89,350	26
Fiji	9,743	449	3,009	9,293	25

Some reflections on regional hydrogen initiatives

Vanuatu, Solomon Islands, Fiji

Session 3

		Early progress on roadmapping, possible ways forward	**Iain MacGill and Rahman Daiyan**
2pm	2.30pm	Dr Rahman Daiyan - Early progress on a regional hydrogen roadmap - some preliminary findings, and possible ways forward	
2.30pm	3pm	Stakeholder reflections on key issues for roadmap development including from project partners; Fiji, Vanuatu, Solomon Islands - government, utilities, regulators, industry	
3pm	3.10pm	**Thanks, workshop close**	
		Workshop ends	

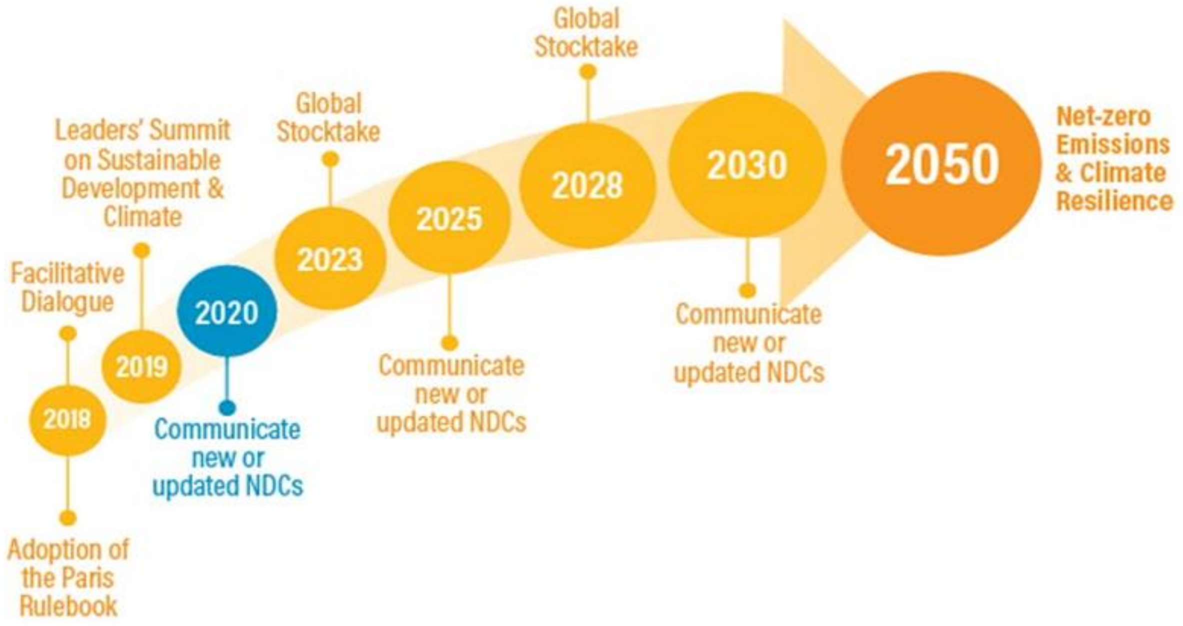
Regional Green Hydrogen Roadmapping

Workplans, Early findings and Possible Ways Forward

Dr Rahman Daiyan

Global Contributions of PICTs

- The Pacific Island Countries and Territories are a minor contributor to global emissions – the assessed PICTs contribute only **0.03%** of global energy-related CO_2 emissions.
- It is understood that the PICTs are in no meaningful way responsible for the emissions of GHGs and their effect on global climate change, however they **feel the effects of climate sooner and more disproportionately** compared to most of the rest of the world.
- As such, the PICTs have put forth ambitious energy and climate targets in their nationally determined contributions (NDCs), to **set forth an example for achieving net zero** by 2050 and limiting the effects of climate change.



Energy and Emissions Overview

Energy Breakdown

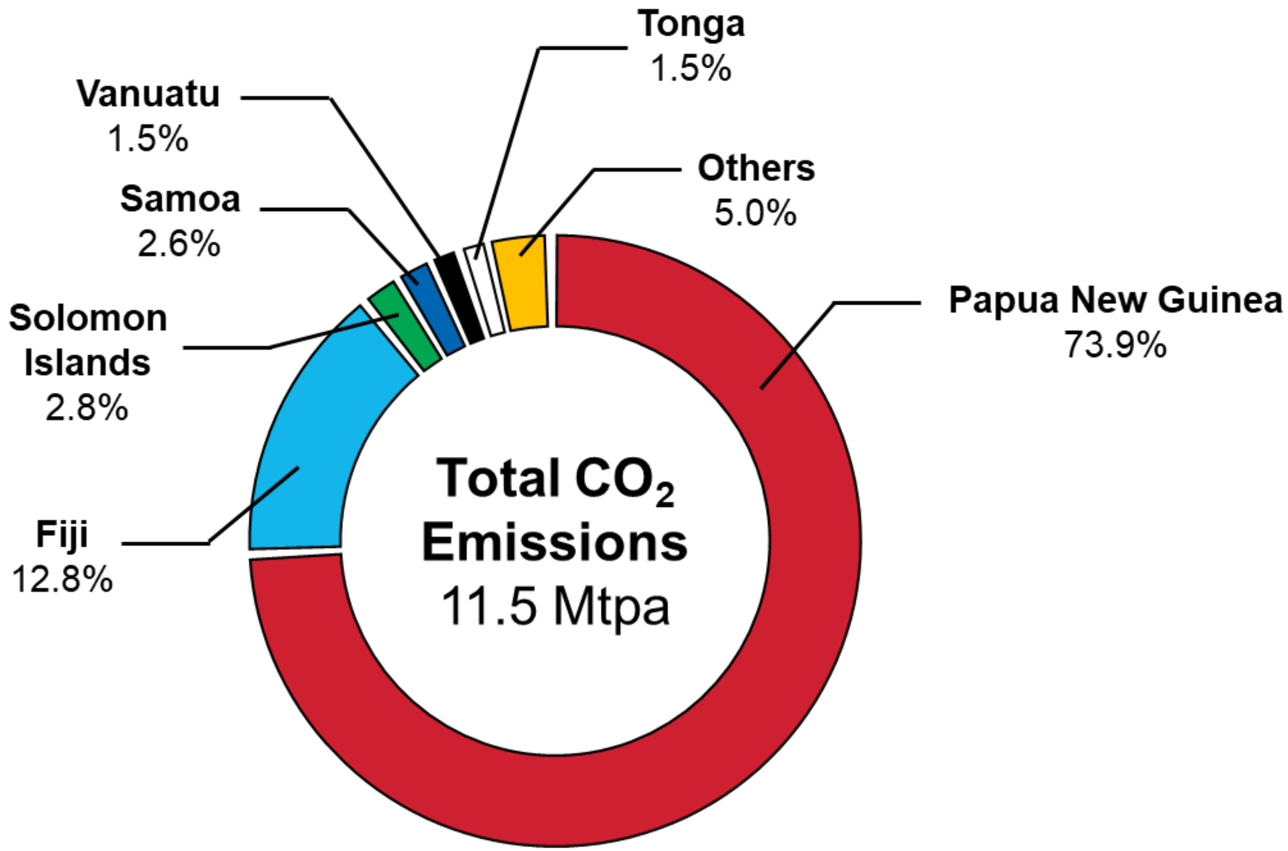
- On average, the total energy usage of each PICT is around 81% fossil fuel based, which is mostly imported, highlighting their heavy exposure to volatile oil prices.
- Whilst only around 60% of total energy use in the Solomon Islands, Papua New Guinea, and Kiribati is fossil fuel based, biomass contributes most of the remainder of their energy, which can be considered sustainable however still contributes to emissions of CO_2.
- Papua New Guinea (9.7%) and Fiji (7.9%) generate the largest proportion of their total energy supply as renewable energy.

PICT	Total Energy Use (TWh)	Fossil-Fuel Based (%)
Fiji	7.24	75
Samoa	1.58	70
Vanuatu	0.90	72
Solomon Islands	2.11	56
Papua New Guinea	54.88	56
Kiribati	0.45	63
Micronesia	0.60	94
Tonga	0.64	98
Cook Islands	0.35	91
Marshall Islands	0.35	99
Tuvalu	0.04	94
Nauru	0.20	99
	Total: 69.33 TWh	**Average:** 81%

Note: Renewable energy sources considered include solar, wind, geothermal, and hydro. Biomass is not included. See the accompanying appendices for further information.

Emissions Breakdown

- Papua New Guinea is responsible for the majority of CO_2 emissions from the assessed PICTs (8.5 Mtpa), whilst ten of the twelve PICTs combined comprise less than 15% of emissions.
- Emissions in the PICTs are mostly associated with electricity generation, use in industry, and transport (domestic land, maritime, and aviation transport).



Other nations: Kiribati, Micronesia, Cook Islands, Marshall Islands, Tuvalu, Nauru

Note: International aviation emissions (i.e., those of national air carriers) are not considered in these values. These values are mostly energy-related CO_2 emissions, and do not include GHG emissions (such as CH_4 or N_2O) from the waste or agricultural sectors. See the accompanying appendices for further information.

Role of Hydrogen in PICTs

In the Pacific Island Countries and Territories, green hydrogen and hydrogen derivatives can play the following role:

- **Penetration of renewables into power generation (for industry and grid electricity)**
- **Displacement of fossil fuels for mobility applications (land transport, maritime transport, and aviation)**

23 **million** bbl diesel equivalent of fossil fuel per year can be replaced by green hydrogen or derivatives in the Pacific Islands.

= 10 **million** tonnes of CO_2 per year abated.

& $2.2 **billion** worth of fossil fuel import savings per year.

The application of hydrogen derivatives in key sectors is expanded upon in following slides.

Disclaimer: Note these demand and saving values on the current and following slides are based on preliminary desktop research assuming 100% of the fossil fuel used in the power and mobility sector can be replaced with hydrogen to provide a baseline case for green hydrogen and its derivatives. Detailed assessments of the potential for hydrogen and the subsequent economic and environmental impact will be conducted in subsequent reports.

Role of Methanol in PICTs

In the Pacific Island Countries and Territories, methanol can play the following role:

- **Replacement of fossil fuels for domestic maritime applications**

0.5 **million** bbl diesel equivalent of fossil fuel per year can be replaced by methanol in the Pacific Islands. = 0.2 **million** tonnes of CO_2 per year abated. & $47 **million** worth of fossil fuel import savings per year.

- **Direct replacement of fossil fuels for small to medium scale power generation in remote and isolated locations with limited or unstable power networks**

8.1 **million** bbl diesel equivalent of fossil fuel per year can be replaced by methanol in the Pacific Islands. = 3.5 **million** tonnes of CO_2 per year abated. & $740 **million** worth of fossil fuel import savings per year.

- **Displacement of fossil fuels for land mobility applications**

6.1 **million** bbl diesel equivalent of fossil fuel per year can be replaced by methanol in the Pacific Islands. = 2.6 **million** tonnes of CO_2 per year abated. & $560 **million** worth of fossil fuel import savings per year.

Other potential applications for methanol in PICTs:

- **Strategic positioning of methanol refuelling for large maritime vessels along international trade routes.**
- **Direct replacement of fossil fuels for commercial and domestic heating applications**
- **Displacement of fossil raw materials in manufacturing and chemical synthesis.**

Role of Ammonia in PICTs

In the Pacific Island Countries and Territories, ammonia can play the following role:

- **Replacement of fossil fuels for domestic maritime applications**

0.5 **million** bbl diesel equivalent of fossil fuel per year can be replaced by ammonia in the Pacific Islands. = 0.2 **million** tonnes of CO_2 per year abated. & $47 **million** worth of fossil fuel import savings per year.

- **Direct replacement of fossil fuels for small to medium scale power generation in remote and isolated locations with limited or unstable power networks**

8.1 **million** bbl diesel equivalent of fossil fuel per year can be replaced by ammonia in the Pacific Islands. = 3.5 **million** tonnes of CO_2 per year abated. & $740 **million** worth of fossil fuel import savings per year.

Other potential applications for ammonia in PICTs:

- **In the production of synthetic fertilisers for the agricultural sector.**
- **In the production of explosives for construction and mining.**

Role of SAF in PICTs

In the Pacific Island Countries and Territories, SAF can play the following role:

- **Displacement of fossil fuels for aviation off-takers:** Airlines in the region are yet to announce any SAF procurement targets. Air Niugini has purchased 4 Trent 1000 engines to power two new Boeing 787-8 Dreamliner aircrafts, which can technically operate at up to 50% SAF blend[7].
- **Displacement of fossil fuels for mining off-takers:** There are also numerous potential mining off takers that may seek to procure renewable diesel: Societe Minere du Sud Pacifique (New Caledonia), Dome Gold Mines (Fiji, PNG), Vatukoulia Gold Mines (Fiji), Lion One Metals Limited (Fiji), Ok Tedi Copper and Gold Mine (PNG), Porgera Gold Mine (PNG), and Lihir Gold Mine (PNG)[7].

- **Displacement of fossil fuels for domestic aviation:**

0.8 **million** bbl diesel equivalent of fossil fuel per year can be replaced by methanol in the Pacific Islands. = 0.3 **million** tonnes of CO_2 per year abated. & $73 **million** worth of fossil fuel import savings per year.

- **Displacement of fossil fuels for national carriers:**

7.9 **million** bbl diesel equivalent of fossil fuel per year can be replaced by methanol in the Pacific Islands. = 3.4 **million** tonnes of CO_2 per year abated. & $730 **million** worth of fossil fuel import savings per year.

Note: The values for estimated fuel use for national carriers is subject to variation pending updated data.

References:
Deloitte, 2023, Sustainable Aviation Fuels in the Pacific.

Power to X: Key Challenges and Opportunities

Challenges:

- Geography, natural disasters, and low diversification of economies heavily impact the effect of global climate change on the PICTs, many of which rank highly on the World Risk Index.
- Decarbonisation of electricity generation is impacted by large distances and remote communities
- Further challenges to decarbonisation shared amongst many PICTs include:
  - A lack of adequate data.
  - Insurance and financing.
  - Technical assistance.
  - Enabling policies.

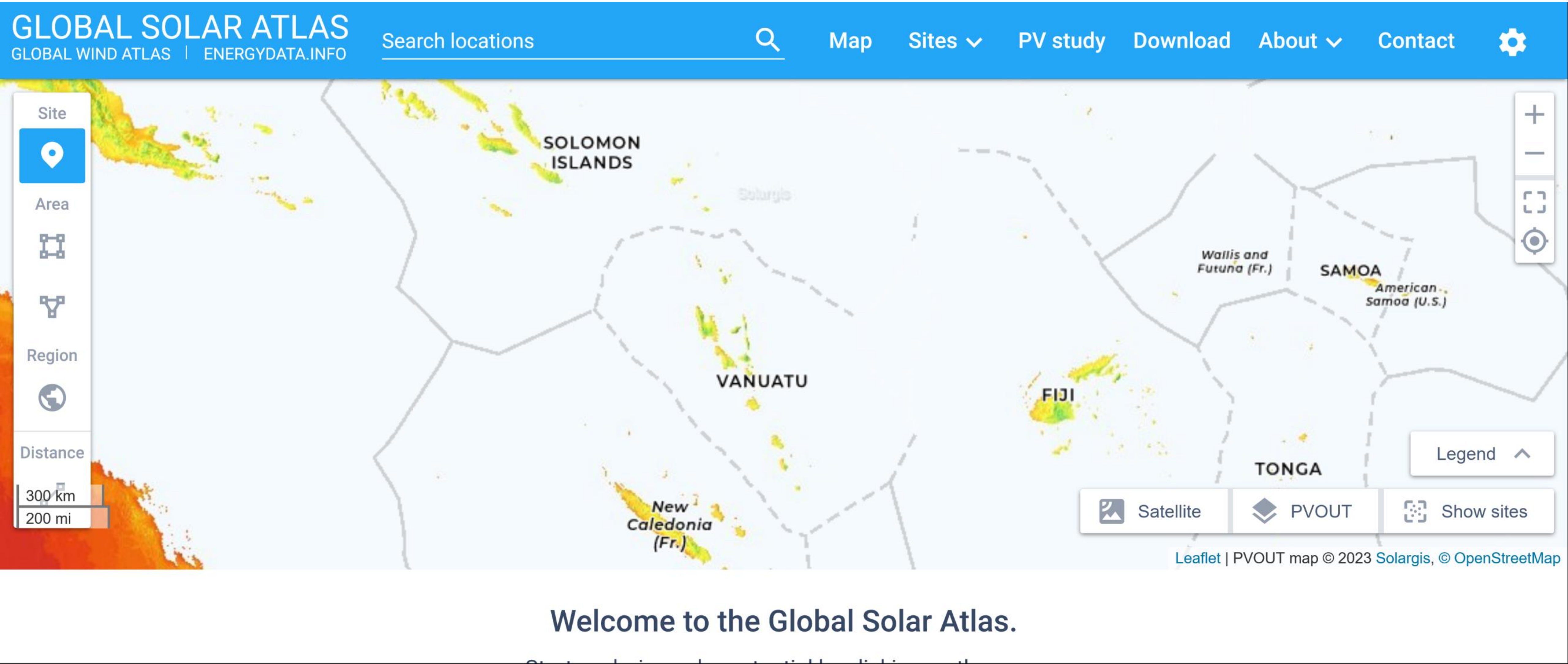
Opportunities:

- Power-to-X can assist in decarbonisation of transport – including land, maritime, and aviation, which are otherwise difficult to decarbonise.
- Green hydrogen and derivatives can be used for energy storage of intermittent renewable energy.
- Green hydrogen derivatives can be used for electricity generation, suitable for replacement of diesel, for use in isolated communities, or during natural disasters.
- Collaboration between the PICTs, Hub and spoke model

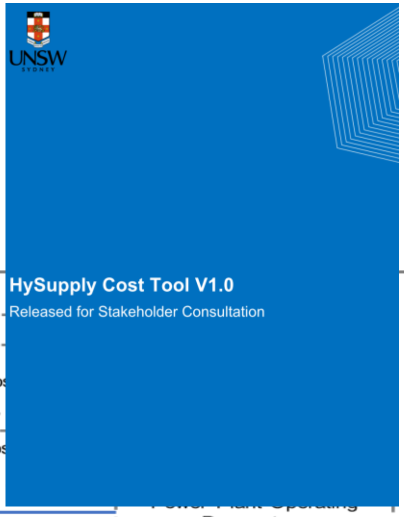
Note: See the accompanying appendices for further information.

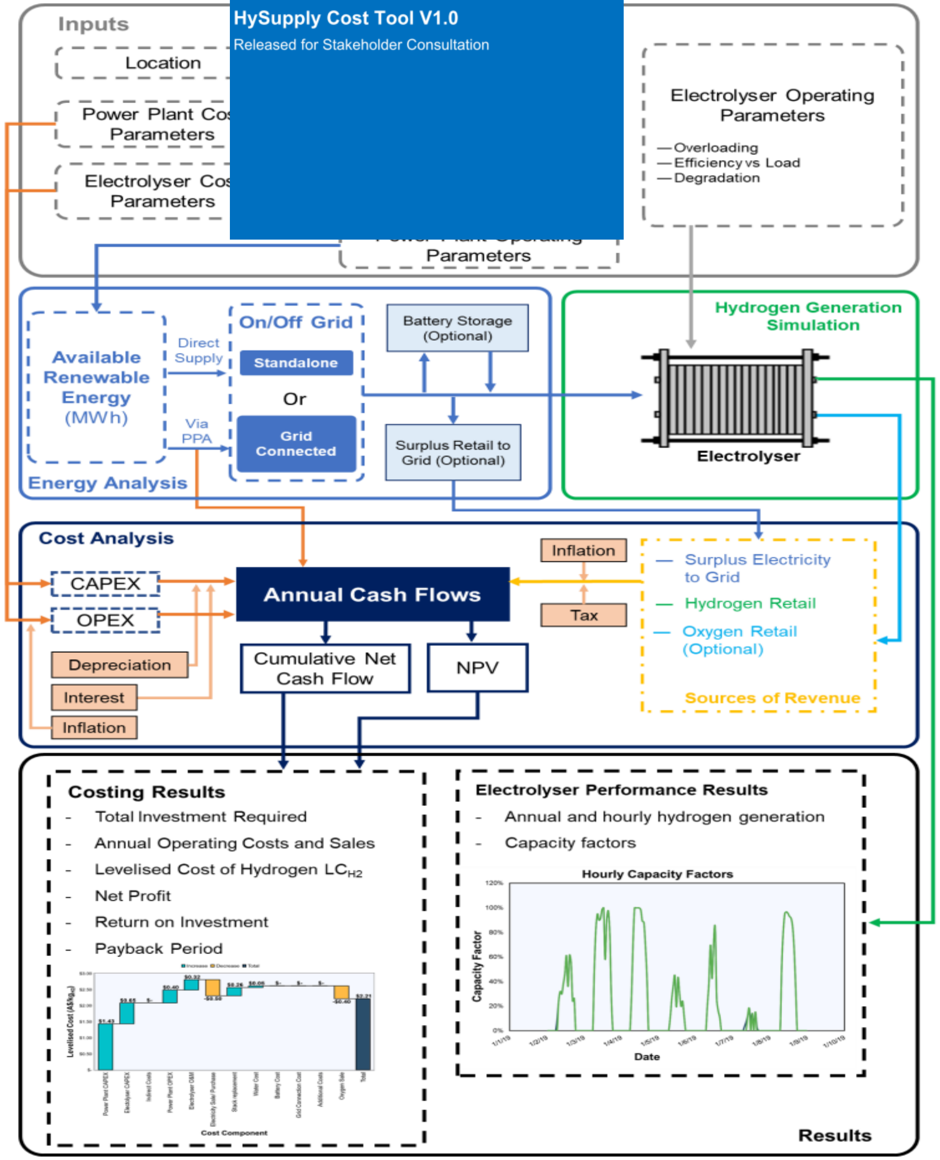
Open-Source Modelling Tools

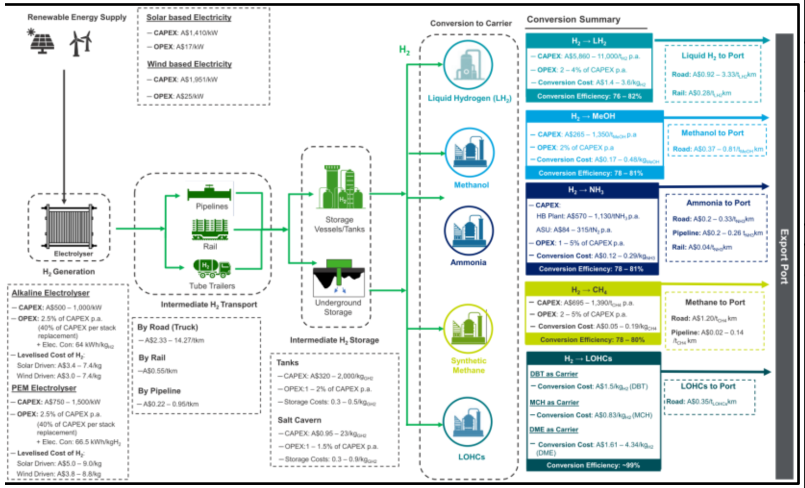
Valuable existing tools from various stakeholders

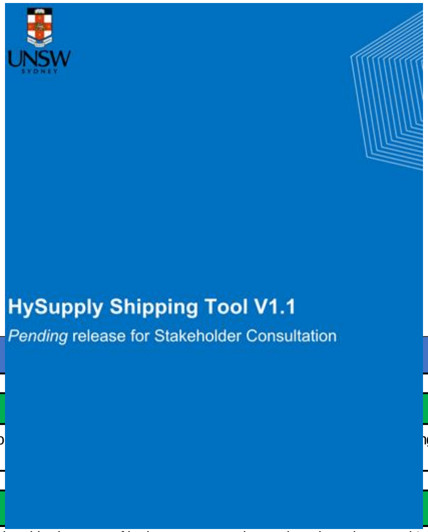


Modelling renewable hydrogen supply and value chains – open-source tools to assist a potentially wide range of stakeholders to better understand and evaluate a range of possible supply chains, including key uncertainties – e.g. scale effects, technology progress









Project Description

Project Statement

The HySupply Shipping Analysis To ... g hydrogen (and hydrogen carriers) via shipping.

Project Scope

The tool allows the user to analyse the shipping cost of hydrogen, ammonia, methanol, methane and LOHC (DME) on shipping routes of their choice, with the individual system performance parameters adopted from literature and advice from

Tool Competencies

The tool includes a comprehensive range of costs designed to emulate a close to reality analysis for shipping transportation of hydrogen and hydrogen carriers. The tool does not consider costs for intermediate storage before and/or after shipping, analysing only the cost up to and including the loading and unloading process. The tool is a living tool with additional features being and expected to be added after consultation with various stakeholders. We also encourage feedback from the user to help us improve the tool. Feedback can be provided to Associate Professor Iain MacGill (i.macgill@unsw.edu.au) and Dr. Rahman Daiyan (r.daiyan@unsw.edu.au) and further updates on the tool will be provided at https://www.globh2e.org.au/.

Analysis Methodology

The model calculates the levelised cost of transport via shipping for LNG, ammonia, methanol, LOHCs (with DME the LOHC costed) and liquefied hydrogen. The levelised cost is calculated by adding the total annual costs and dividing by the annual total energy delivered.

Total energy delivered is dependent on the ship speed, shipping route length, time at port and days per year the ship is available for operation. Total annual costs are a summation of capital and operating costs. Annual capital costs were calculated using a capital recovery factor for the ship capital costs. Annual operating costs were given through the addition of fuel, labour, canal, port, maintenance, miscellaneous, insurance and boil-off gas (BOG) costs. Users are also given the option to incorporate additional capital and operating costs into the model.

Open-Source Pacific Modelling Tools Demo

Discussion and Reflections Session

1. Key roles that renewable hydrogen and its derivatives can play in the Pacific to help achieve it’s clean energy goals?
2. Which derivatives are likely most appropriate for the region?
3. Key priorities in developing hydrogen pathways for the region?
4. Opportunities for regional collaboration on developing hydrogen pathways in the region
5. Key capacity building needs?

6. What’s missing?