Carbon Footprint Evaluation of Various Hydrogen Production Technologies

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Grey Hydrogen
Source: Natural Gas

Black/Brown Hydrogen
Source: Coal

Blue Hydrogen
Source: Natural gas/coal with CCS

Turquoise Hydrogen
Source: Natural gas

Pink hydrogen
Source: Nuclear Energy

Green hydrogen
Source: Biomass and water with RE

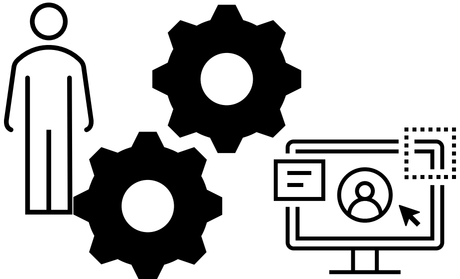
White Hydrogen
Source: Geological

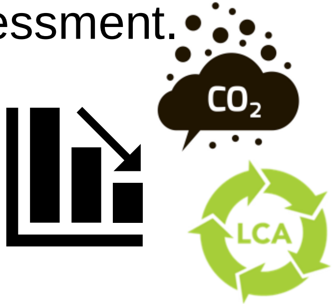
Yellow Hydrogen
Source: Electrolysis using grid solar power

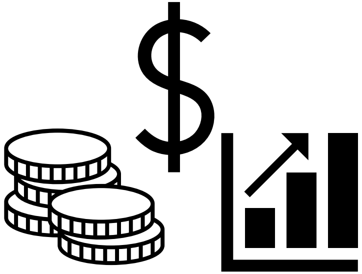
Our Team at CSIRO

- CSIRO’s Techno-economics for decarbonisation team, has a know-how and long history of process design and development of techno-economic and LCA models:
  - Hydrogen production technologies
  - Chemical production
  - Low-emission energy production technologies
  - integration of clean energies with high-temperature processes

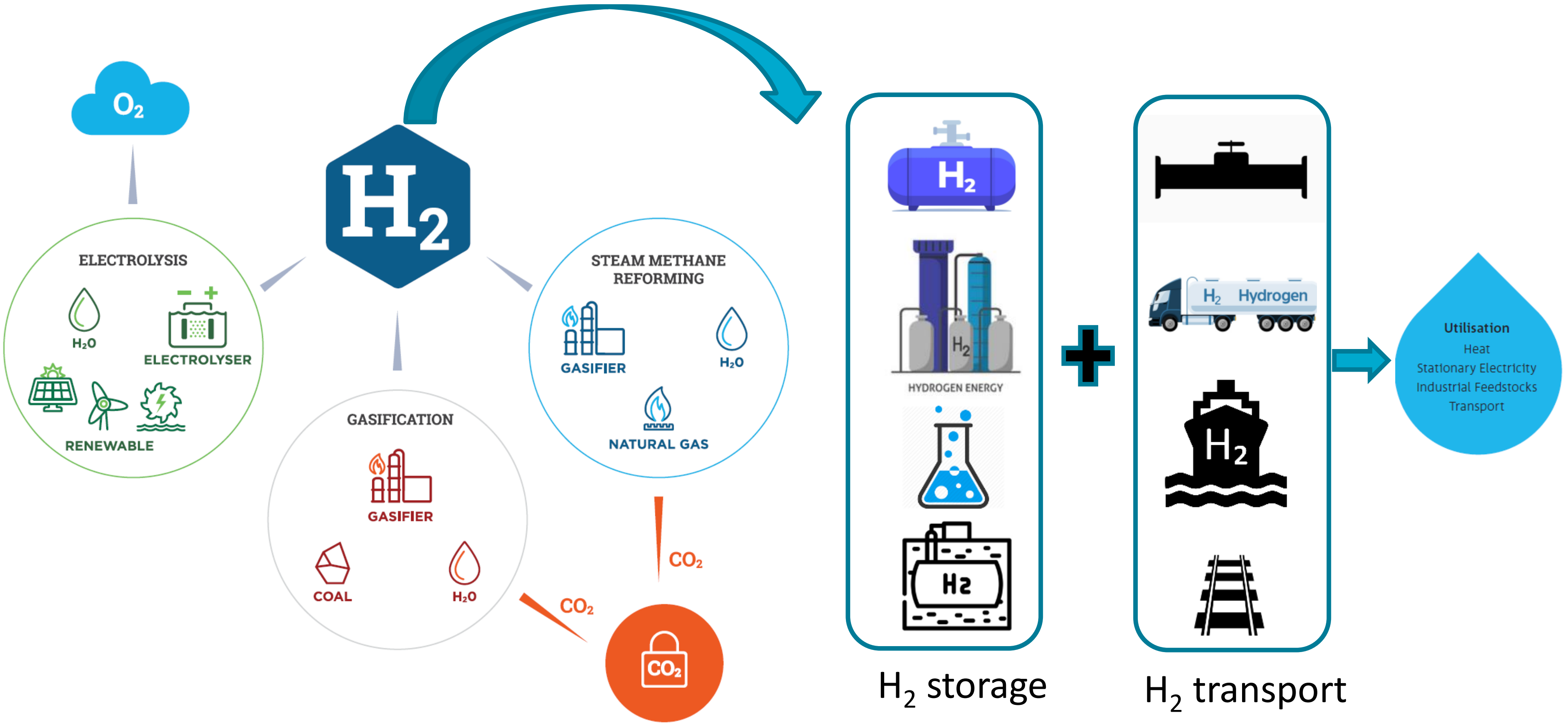
This team has experienced resources and capabilities and has access to different commercial software for process simulation, Techno-economic assessment and life cycle assessment.



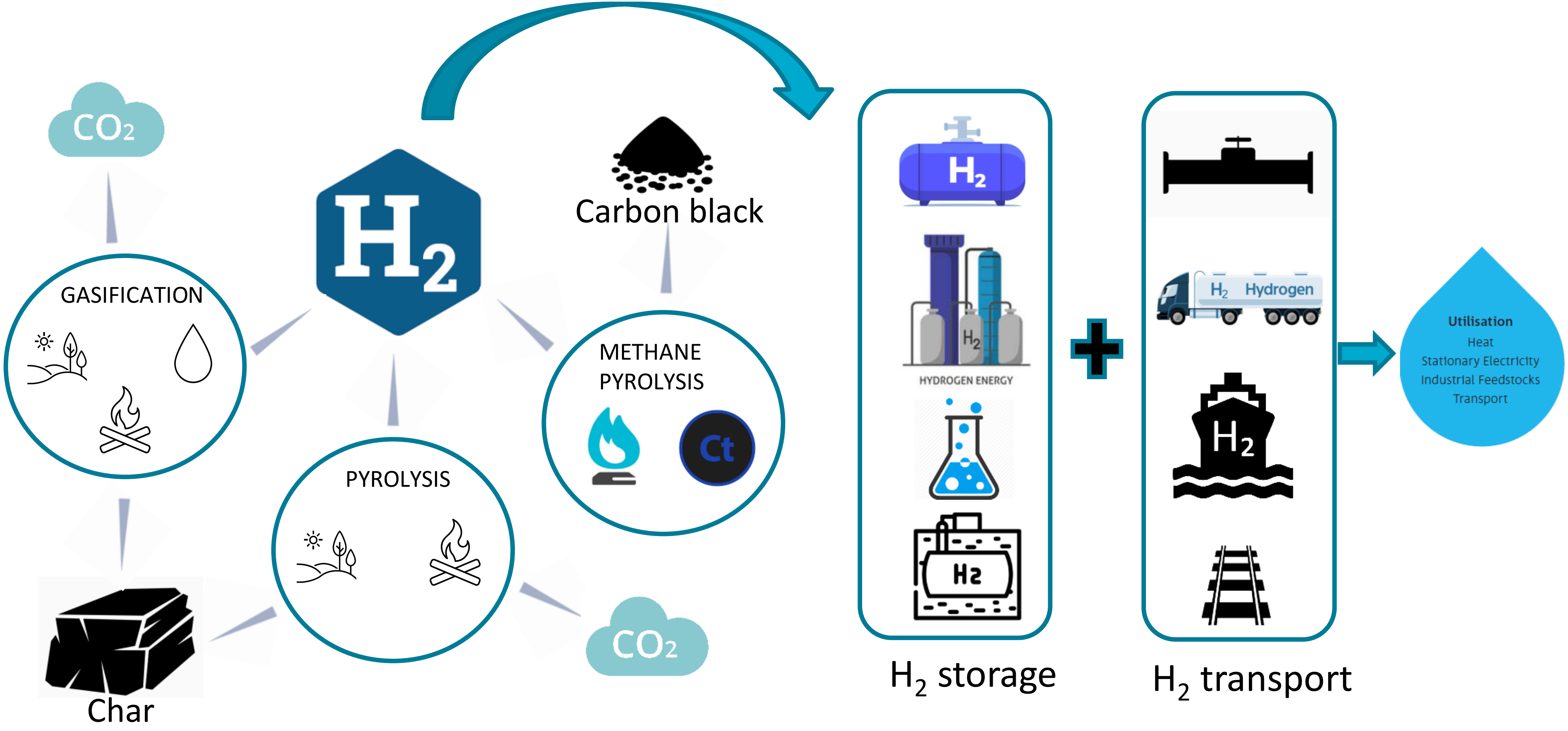




Hydrogen supply chain –Conventional technologies



Hydrogen supply chain –Emerging technologies



Scenarios for LCA

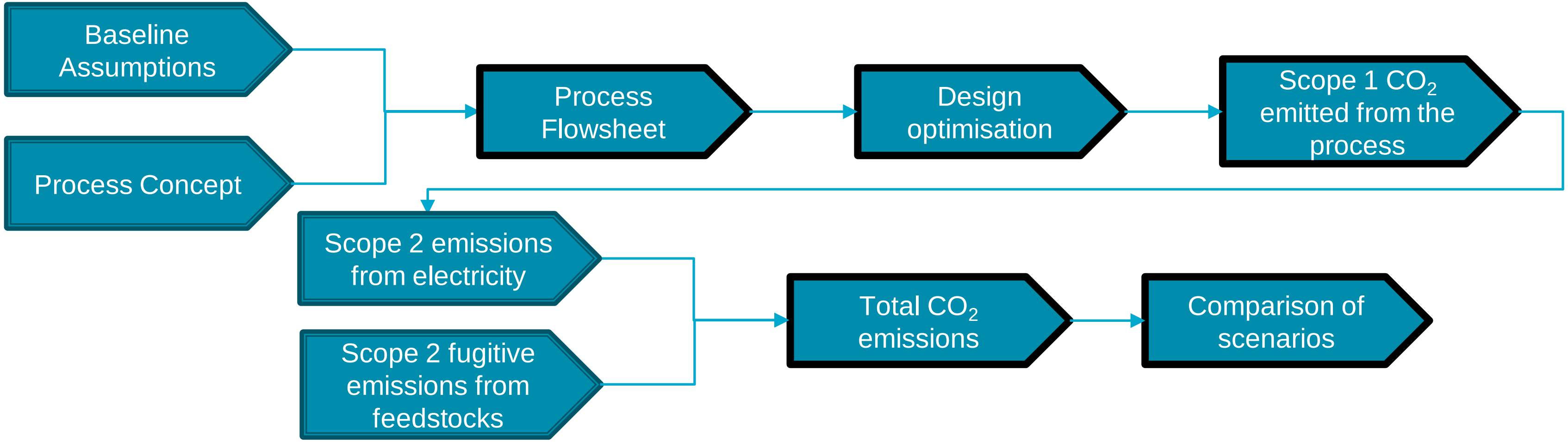
Feedstock	Process	Source of electricity	Carbon Capture	Hydrogen production (kt/a)
Natural Gas	SMR	National Grid	Y	100
Natural Gas	SMR	National Grid	N	100
Natural Gas	ATR	National Grid	Y	100
Natural Gas	ATR	National Grid	N	100
Black Coal	Gasification	National Grid	Y	100
Black Coal	Gasification	National Grid	N	100
Brown Coal	Gasification	National Grid	Y	100
Brown Coal	Gasification	National Grid	N	100
Biomass	Pyrolysis	National Grid	Y-Partial	25
Biomass	Pyrolysis	National Grid	Y	25
Biomass	Gasification	National Grid	Y-Partial	25
Water	AWE	National Grid	NA	25
Water	PEM	National Grid	NA	25
Water	AWE	Solar PV	NA	25
Water	PEM	Solar PV	NA	25
Water	AWE	Wind	NA	25
Water	PEM	Wind	NA	25

SMR: Steam methane reforming
ATR: Autothermal reformer
AWE: Alkaline electrolyser
PEM: Proton-Exchange membrane Electrolyser

- Hydrogen can be produced from low- or high-carbon pathways.
- There is a need to define “green” hydrogen standards to certify low-carbon hydrogen for consumers
- The cleanness of hydrogen production technologies are now being colour labelled to give another perspective on the production routes

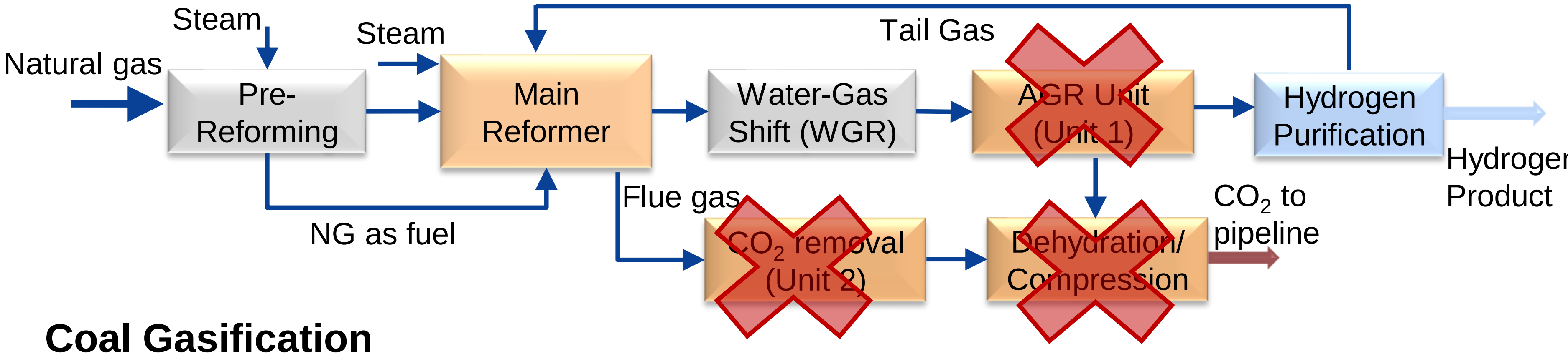
Carbon footprint analysis approach

- For all of the processes, the energy required for the process (including steam or high-temperature heat) was provided on-site.
- The CO_2 emission from the process, includes the CO_2 emission from the process itself, together with the CO_2 emitted from provision of energy to the process.
- The electricity required for the plant, includes electricity required for ASU (if needed) and auxiliary equipment and is provided from grid.
- The electricity required for the electrolysers with renewable energy is provided from respective renewable energy plant.

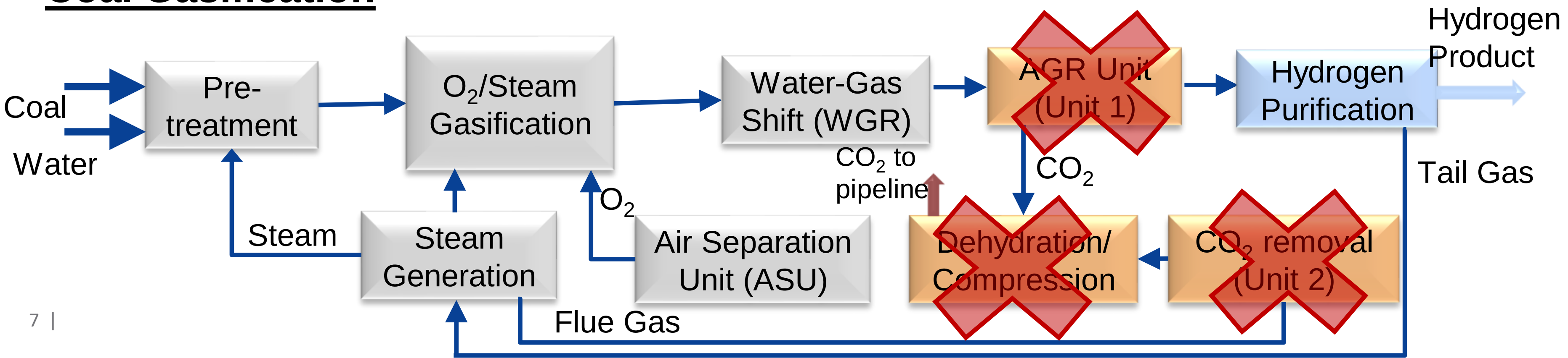


Fossil fuel routes

Natural Gas SMR

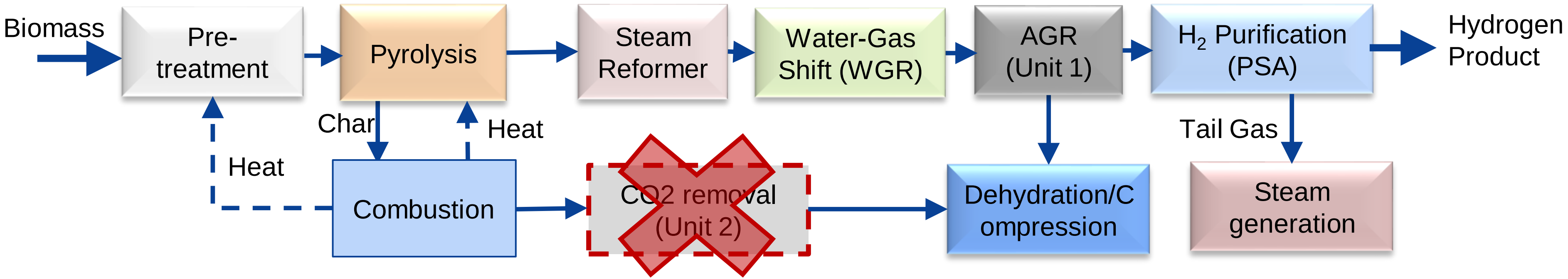


Coal Gasification

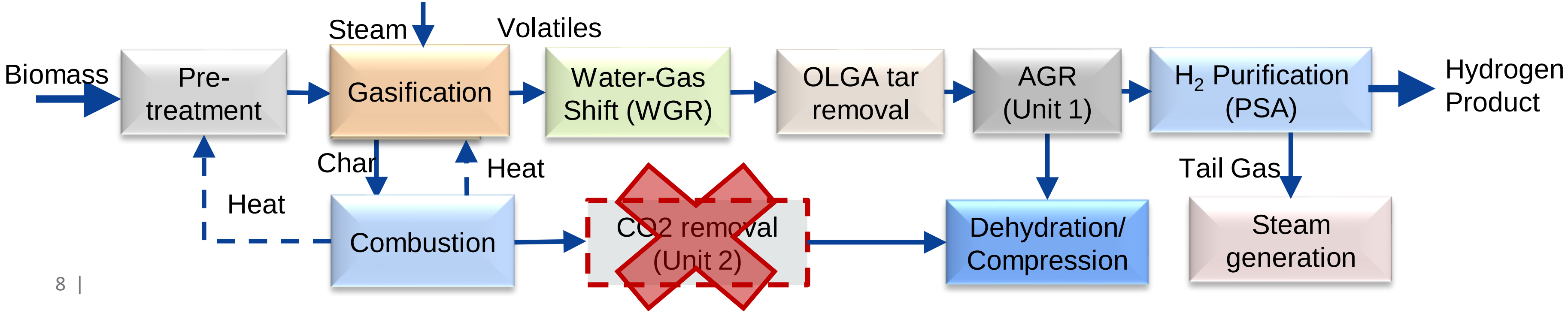


Biomass routes

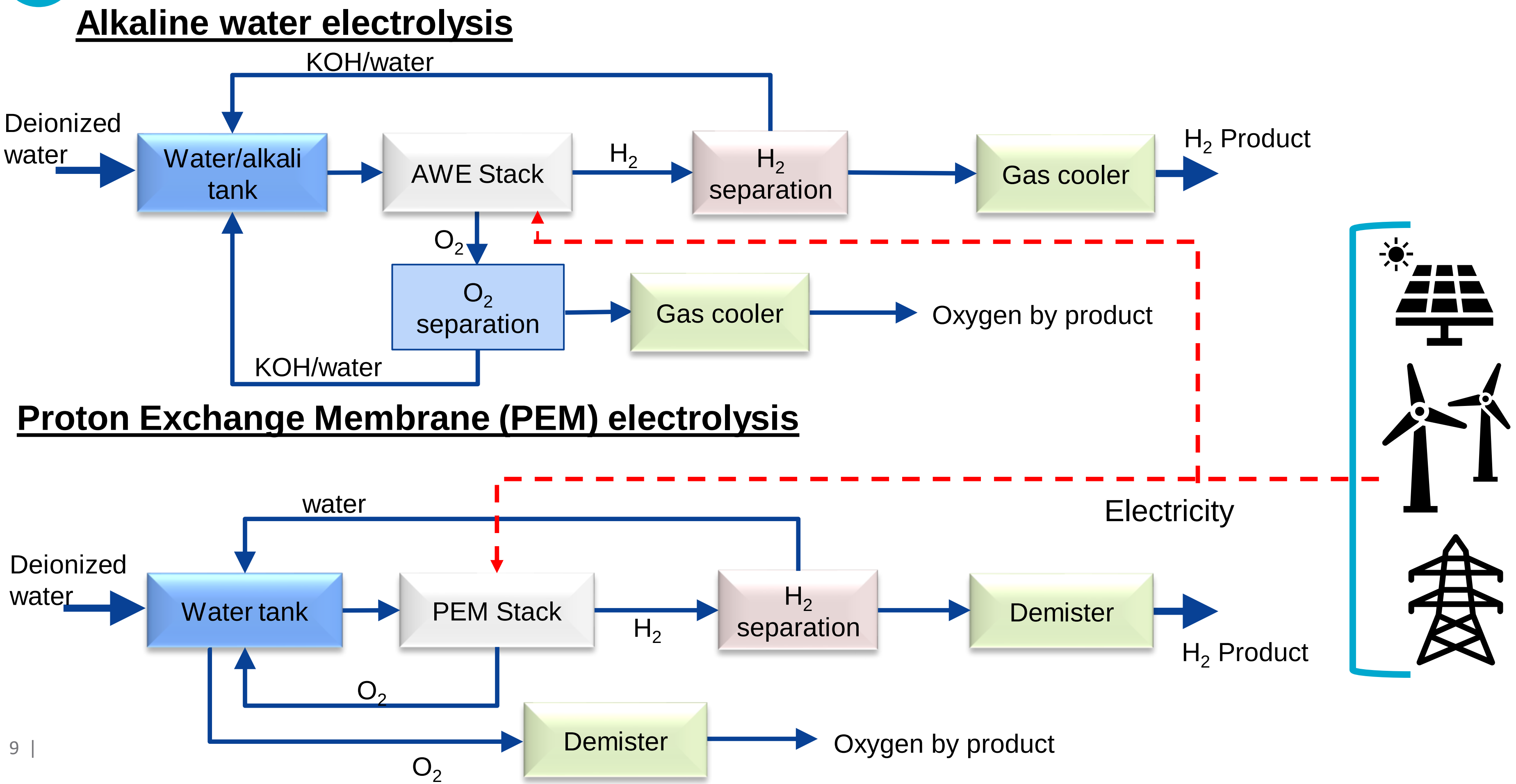
Biomass Pyrolysis



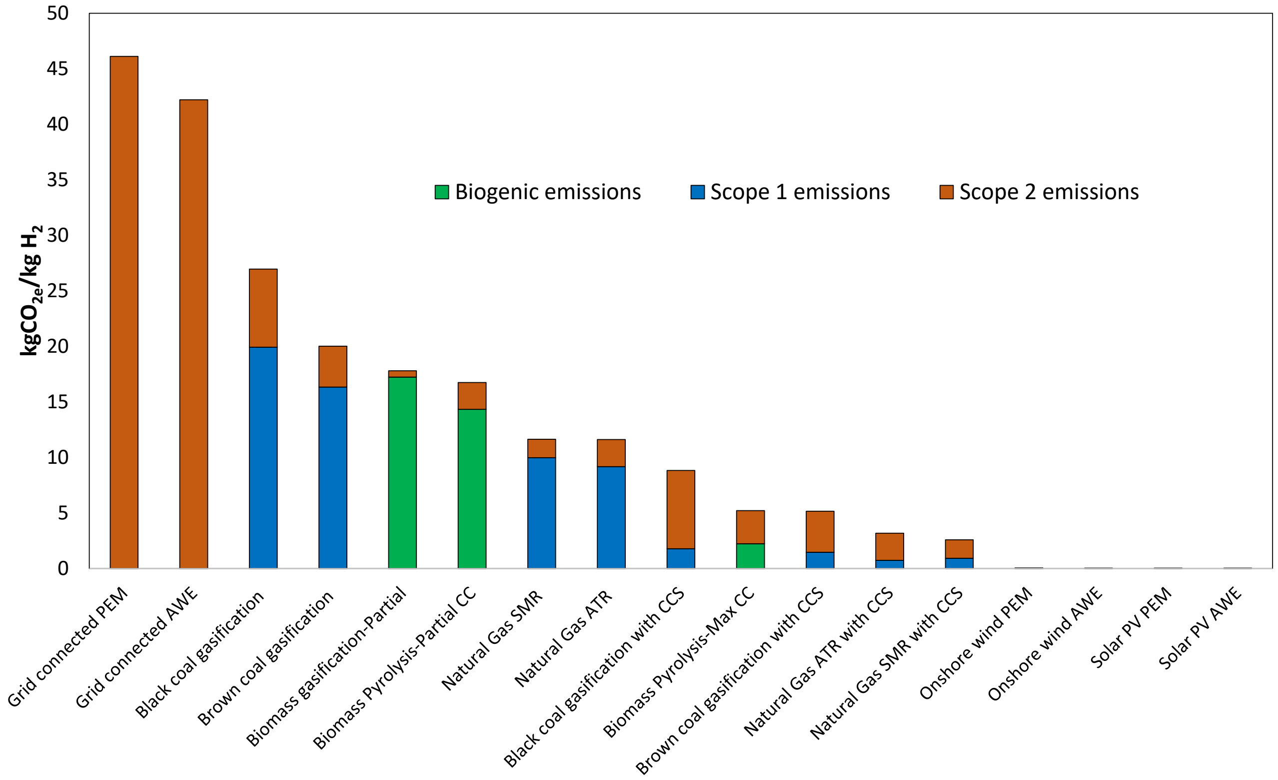
Biomass Gasification



Water electrolysis routes



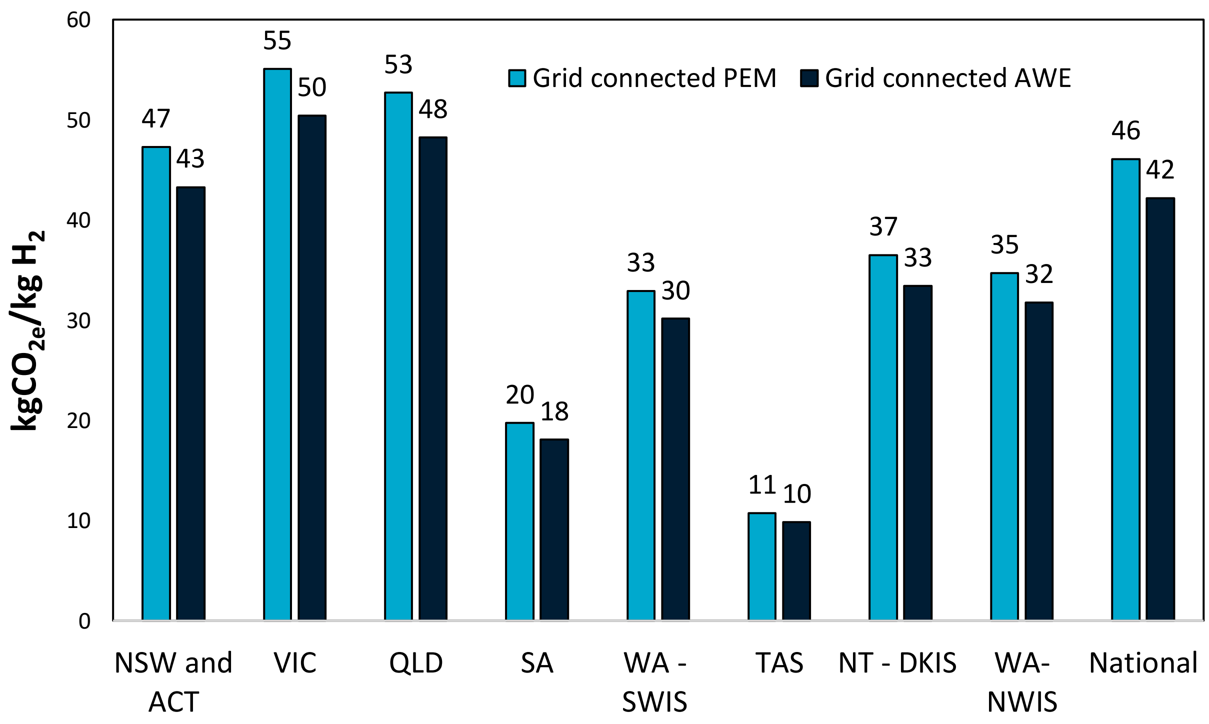
Comparison of carbon footprint



- Grid connected electrolyser is the largest CO_2 emitters
- Black coal gasification releases more CO_2 in comparison to other fossil fuel routes
- The biomass routes, release large amount of CO_2 but could be considered biogenic CO_2
- The renewable energy connected electrolysers are the cleanest technology with CO_2 emission in the range of 42-58 g/kg H_2

- The CO_2 emission for the renewable energy connected electrolysers are from SimaPro software - AusLCA

Emissions from grid-connected electrolysers



DKIS: Darwin Katherine Interconnected System

SWIS: South West Interconnected System NWIS: North Western Interconnected System

- Tasmania has the lowest emission
- An electrolyser connected to grid in Victoria emits 50-55 $kgCO_{2e}/kg\ H_2$

Australian National Greenhouse Accounts Factors (dcceew.gov.au)

Conclusions

- With considering the emission intensity of national grid, grid-connected electrolysers have the highest CO_2 emissions
- States with highest renewable energy penetration rates (like Tasmania and SA) are the best locations for grid-connected electrolysers
- Black coal to hydrogen emits ~27 $kgCO_{2e}/kg\ H_2$ is the highest CO_2 emitter after the grid-connected electrolysers
- Biomass gasification and pyrolysis emits more CO_2 than natural gas cases but the CO_2 emitted from this process is a biogenic CO_2, so this technology is amongst the lowest CO_2 emitters.
- Natural gas SMR and ATR pathway emits similar CO_2 (~11.6 $kgCO_{2e}/kg\ H_2$)
- The renewable energy connected electrolysers are the cleanest technology.

Future works

- Including other pathways for hydrogen production to the analysis (such as white hydrogen and pink hydrogen)
- Including more detailed analysis of CO_2 emissions related to the scope 3 emissions (e.g. coal and natural gas transport, CO_2 transport etc)
- Extending the carbon footprint analysis to a full impact category assessments

Acknowledgement

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Thank you

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