Hydrogen Research in Australia

CSIRO ENERGY
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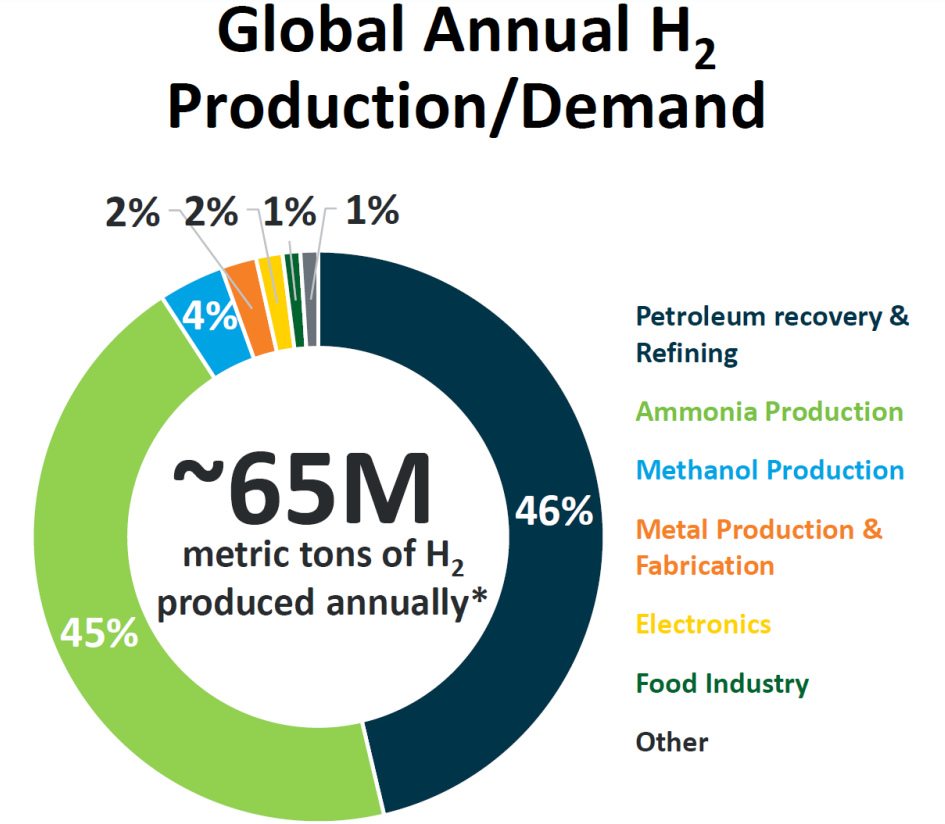
Hydrogen - facts



- The global hydrogen generation market to grow at a CAGR of 5.99% during the period 2017-2021
- US$180 billion by 2024
- Steam-methane reforming is by far the most cost-competitive process ……currently

IEA 2017

▪*Satyapal, ee.doe.gov, 2017*

MONASH University

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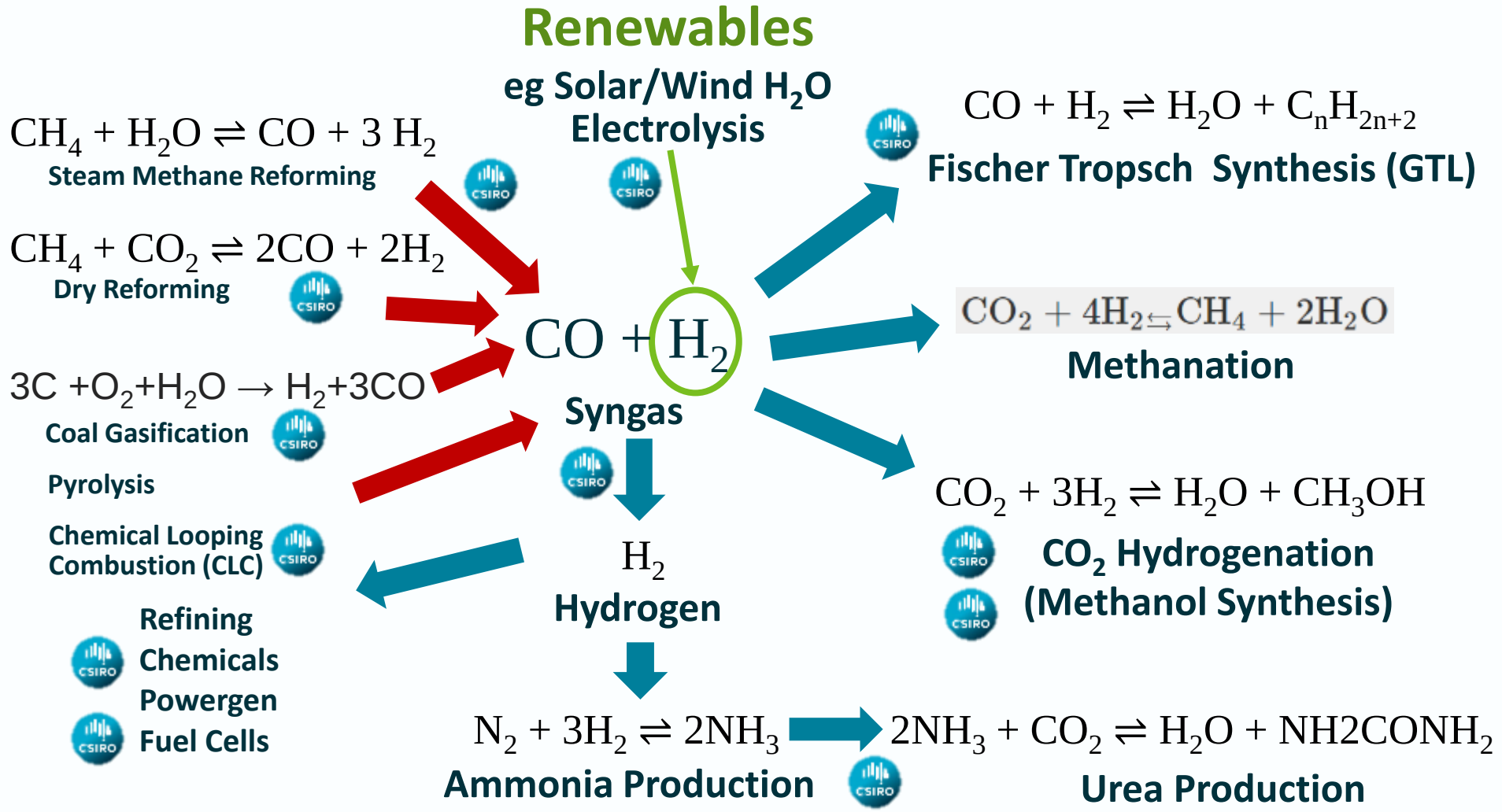
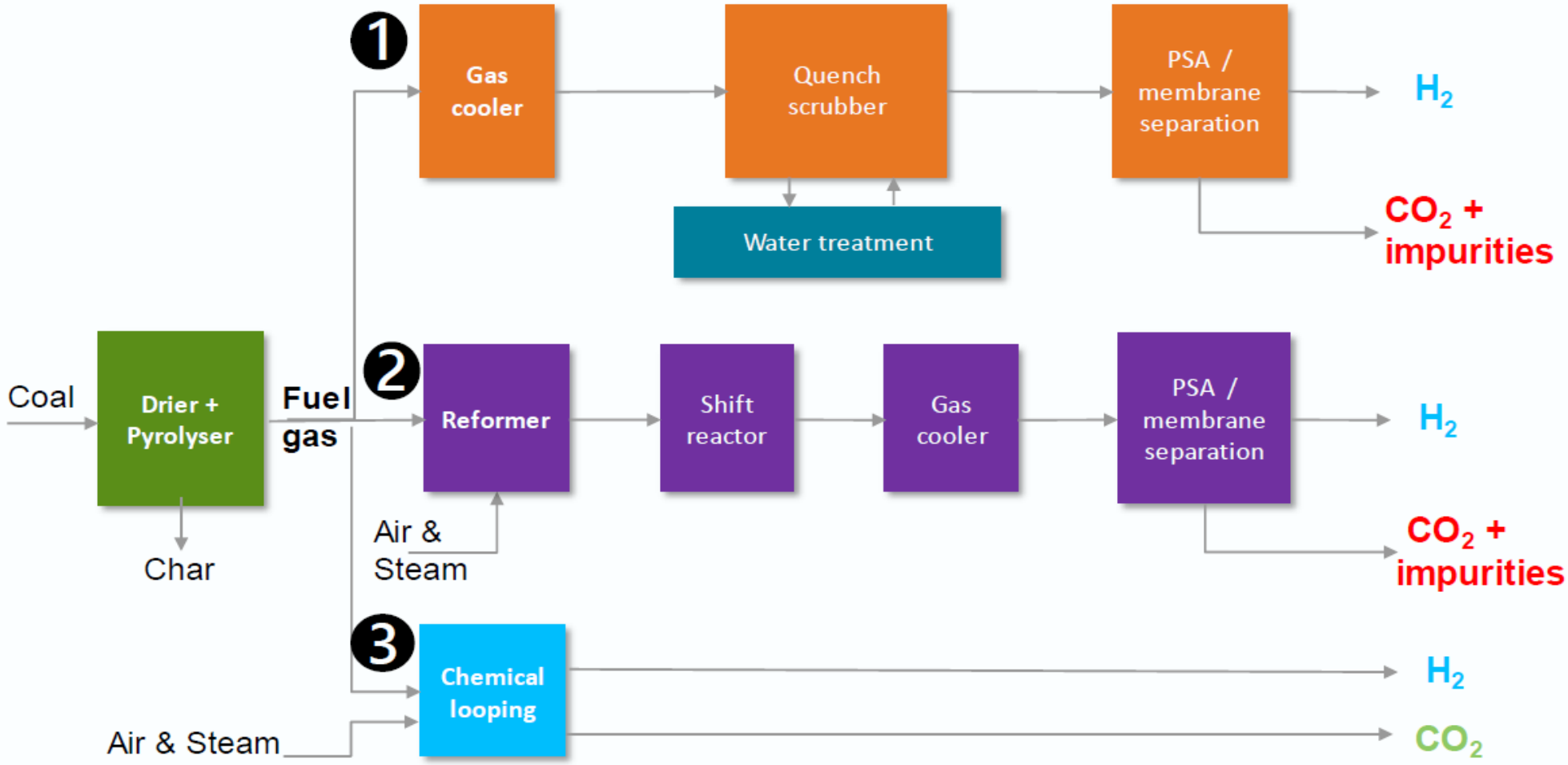
Hydrogen R&D Areas - CSIRO and others

- Coal/Biomass gasification / gas separation - Monash
- Low temperature (PEM) water electrolysis for hydrogen production.
- Carbon assisted water electrolysis (high and low temperatures).
- MeOH, EtOH assisted water electrolysis.
- High temperature steam electrolysis.
- CO_2 / H_2O conversion to Syngas and value added fuels & chemicals (RE integration).
- Pyrolysis of NG/LPG to produce hydrogen for fuel cells.
- Chemical looping - Monash
- Membrane technology for hydrogen separation from other gases (coal gasification; NG, MeOH, EtOH reforming; ammonia cracking).
- Solar thermal reforming of natural gas.
- RE export potential: Electrochemical and membrane ammonia production.
- Ammonia conversion to hydrogen in a membrane reactor.
- Direct solar water splitting.
- Hydrogen storage in MOFs.
- Hybrid Energy Systems including hydrogen/fuel cell systems and integration with renewable energy sources.

Syngas Research



Pyrolysis gas options for H_2 production



Research Scale Gasification Studies

Investigations at larger-scale allowing technology-specific issues related to feedstock gasification behaviour to be explored.

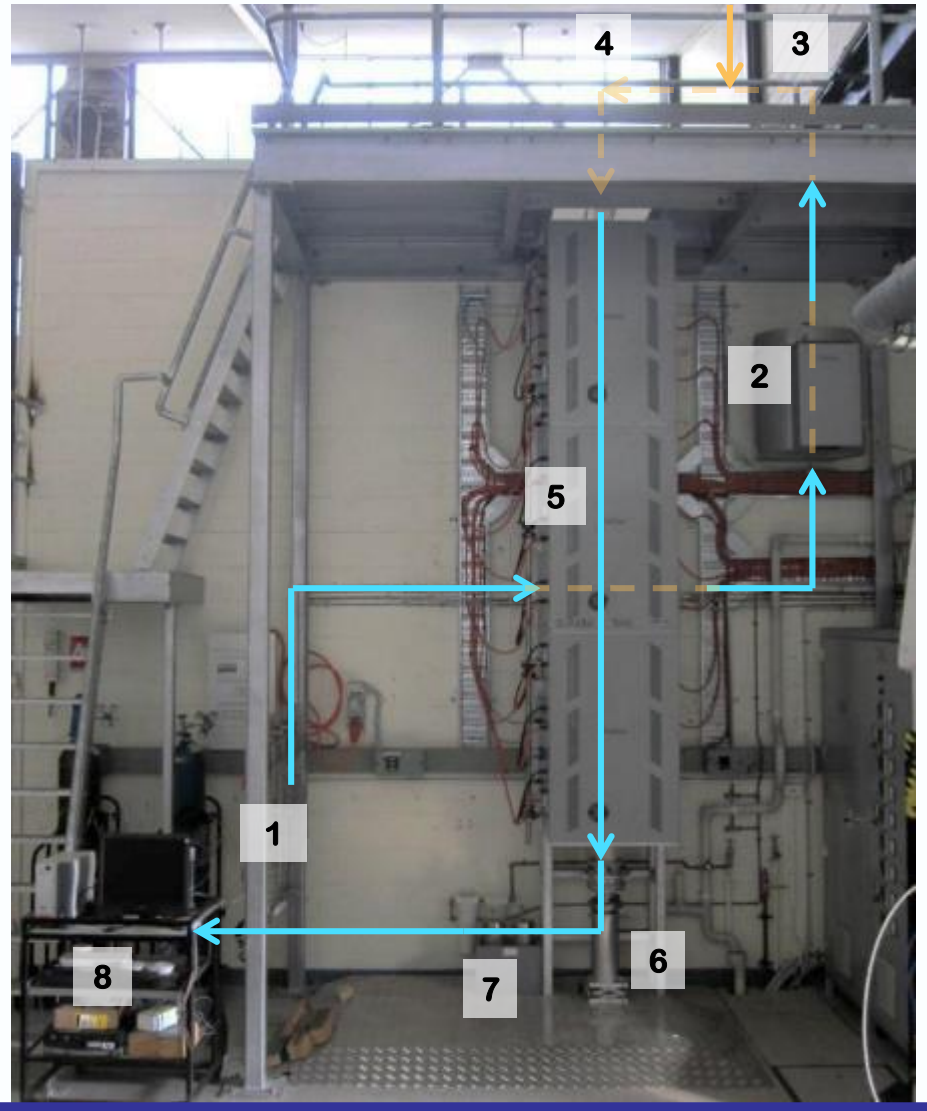
Interrogation of the complex gasification process – difficult using pilot or full-scale systems

Validation of fundamental and modelling studies.

High Temperature Entrained Flow Reactor – 1600C

for gasification and combustion – *flexible system for biomass/coal/pet coke or blends*

1. Reaction gas manifold
2. Reaction gas preheater
3. Steam injection system
4. Solid fuel feed system
5. Main furnace
6. Solids collection system
7. Syngas cooling and cleaning
8. Syngas analysis



Viscosity of slags at high temperature

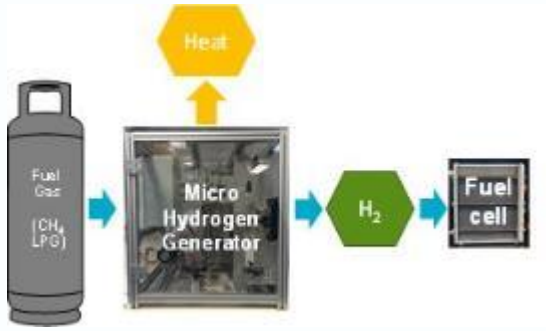
For entrained flow gasification

High temperature Viscometer assembly – with BCIA support

Other Approaches

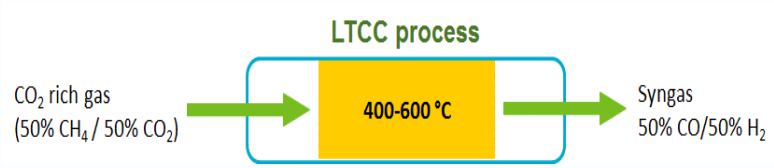
Small Scale

- Micro scale H_2 from C_1 & C_2+

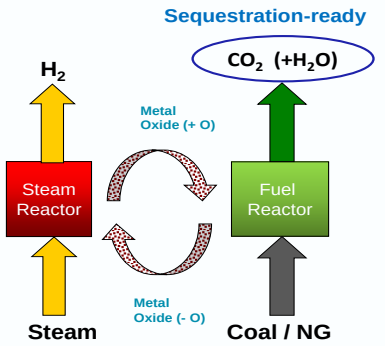


Mid to Large Scale

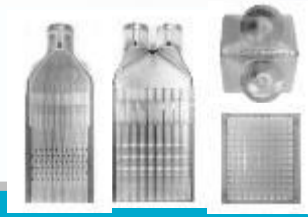
- H_2 from CO_2 – rich CH_4 sources



- Direct H_2 Chemical Looping Conversion (with sequestration ready CO_2 stream)



- Syngas to Methanol / DME Processes



Solar Reforming

$$CH_4 + H_2O_{(g)} \rightarrow CO + 3H_2$$

- 25% solar energy, 40-45% less CO2
- Proven at pilot scale to 600 kWth for hydrogen production.
- Relatively easy as based on existing mature technologies: materials, catalysts, water gas shift.
- By 2030 could produce H2 for as low as 4.49 $/kg

CSIRO SolarGas™ prototype reactor

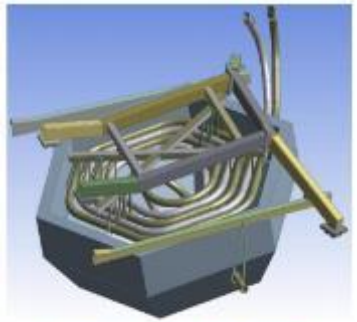
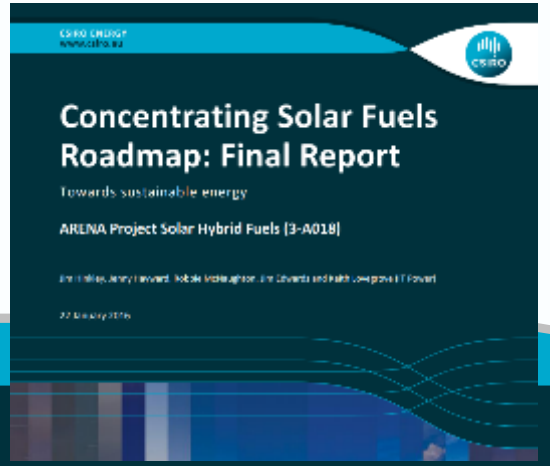


Figure 11: CSIRO 200-kW steam reformer

CSIRO solar fields with prototype reactor field on the LHS

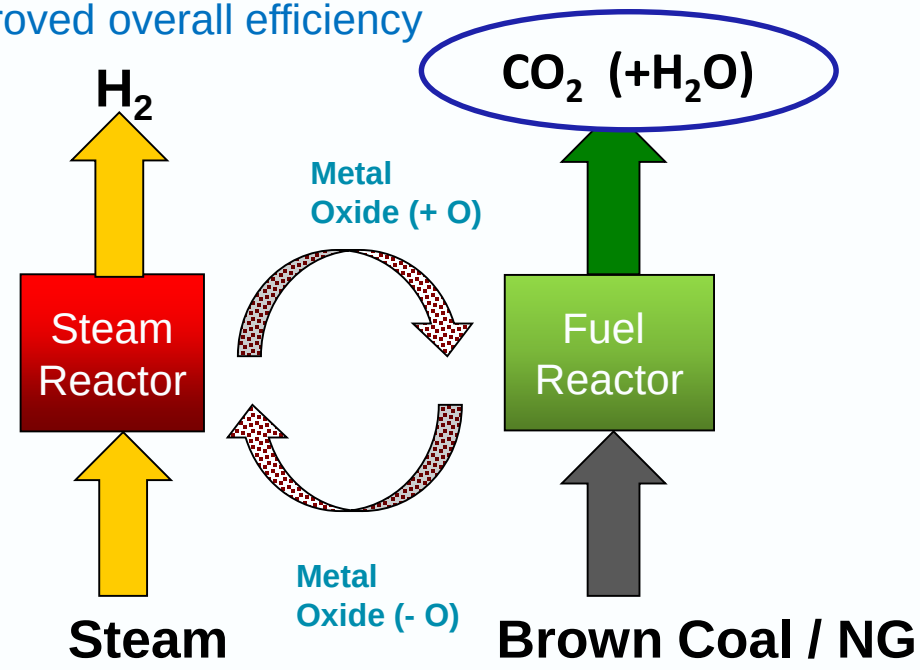


Chemical Looping Conversion (CLC)

Low emission H_2 production

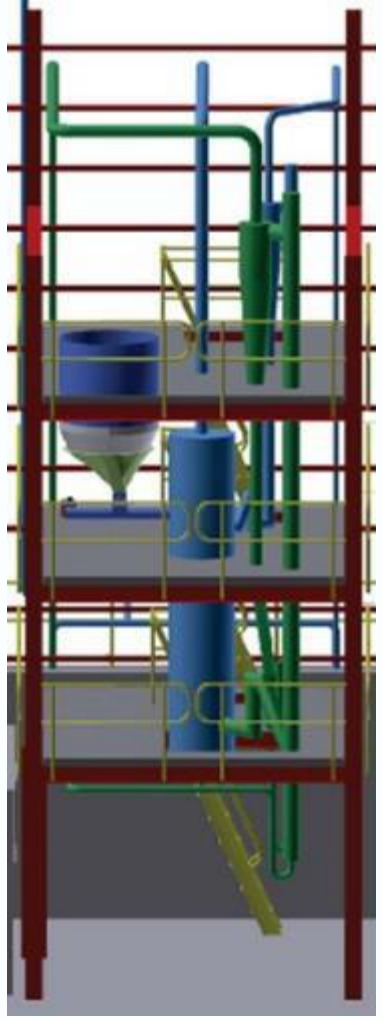
Advantages of CLC approach over other Conventional

- ✓ CO_2 sequestration-ready option
- ✓ Elimination of oxygen plant (Energy / Capex)
- ✓ Avoidance of post H_2/CO2 separation and capture (Energy / Capex)
- ✓ Adapting established CFB technology
- ✓ Improved overall efficiency



Above: Trevor Hadley of CSIRO inspects the CLC Rig

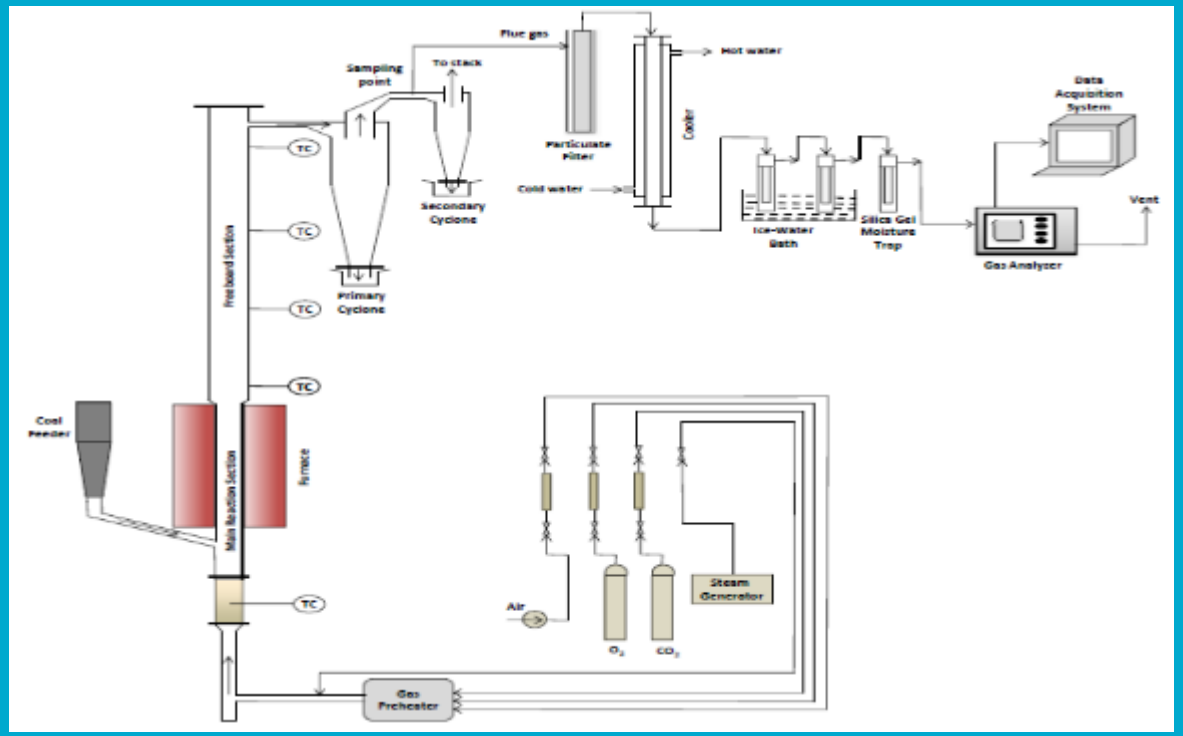
(10kW)



Current nominally 10 KW Chemical Looping Reactor Test Facility at CSIRO

Proposed nominally 200 KW Chemical Looping Reactor Pilot Facility for Combustion and H2 production

Fluidized bed reactor – for chemical looping combustion



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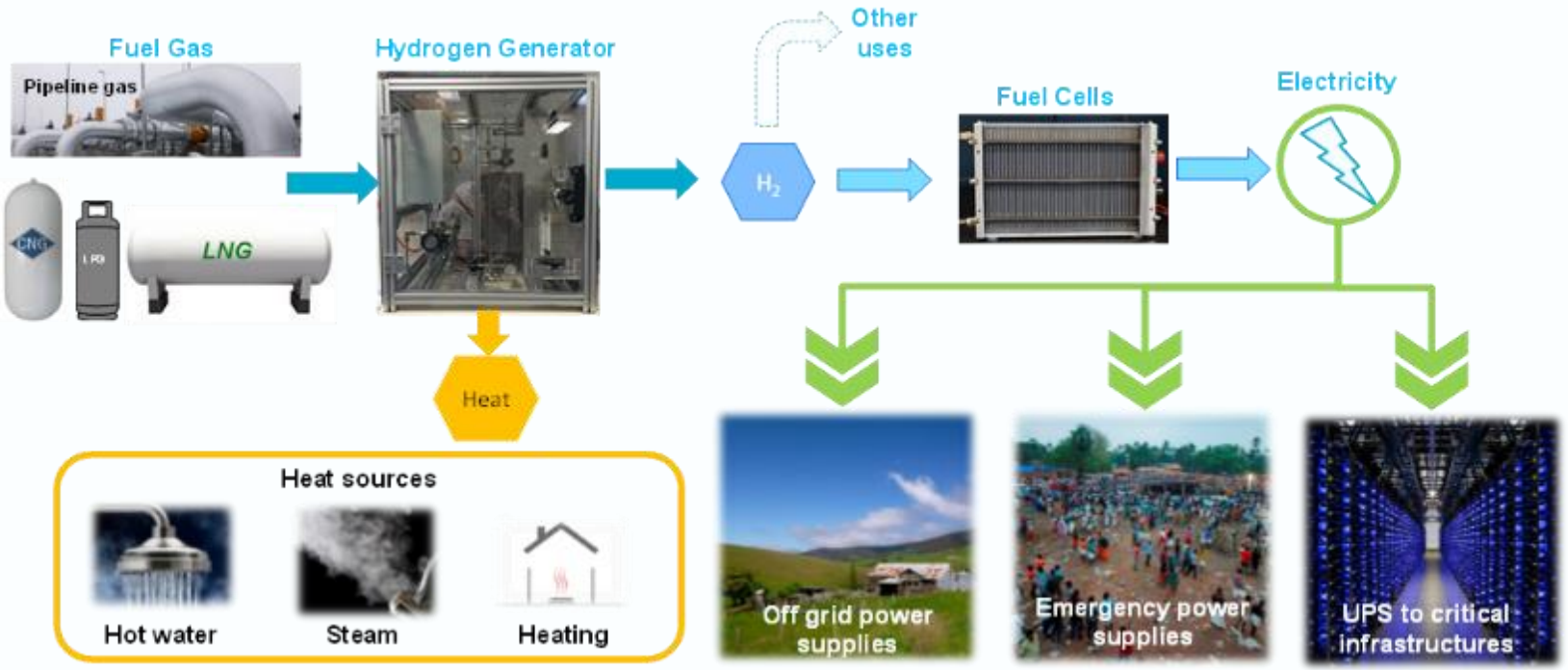
Small scale fossil systems: Hydrogen from Decomposition of Methane and LPG



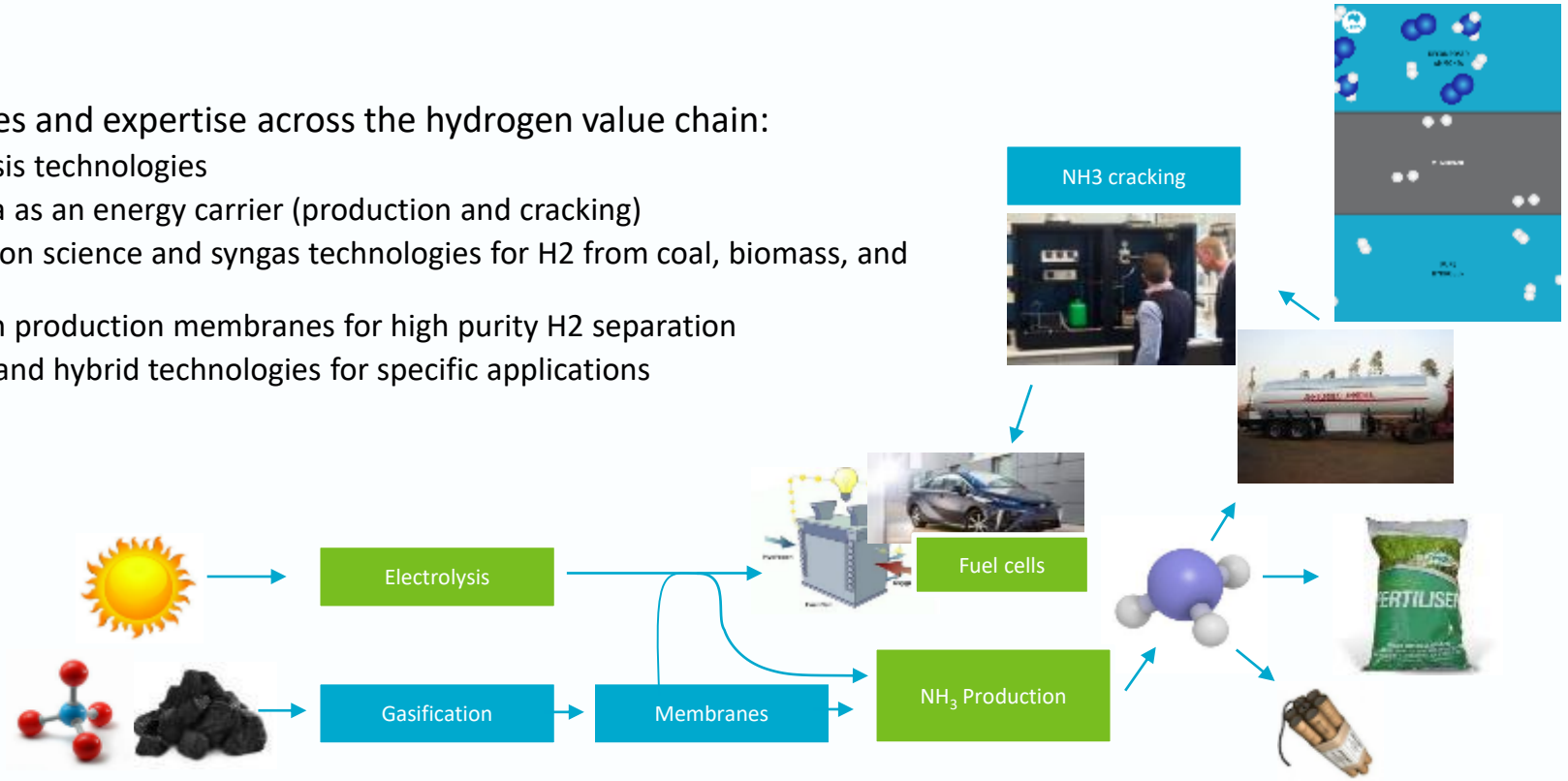
Methane: $CH_4 \rightarrow C + 2\ H_2$

LPG type fuel: $C_nH_m \rightarrow n\ C + \frac{1}{2}\ m\ H_2$

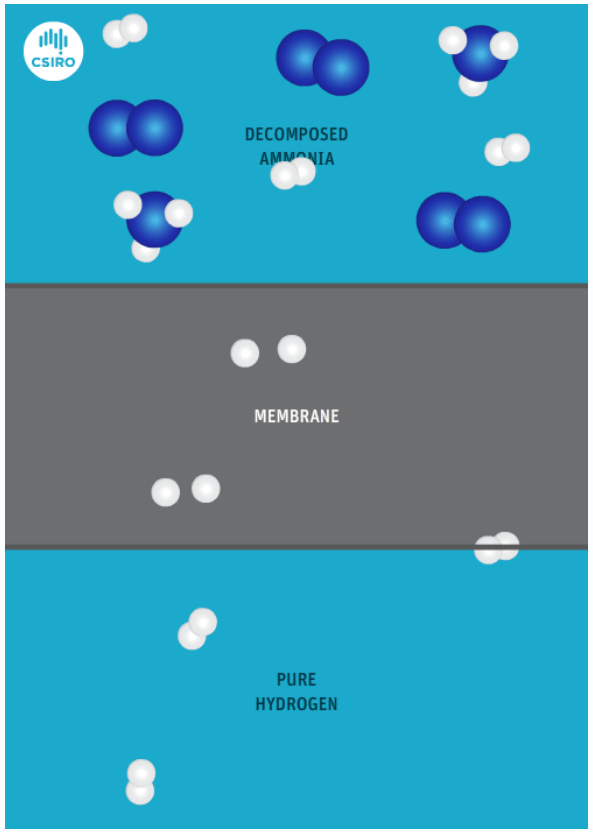
Ammonia

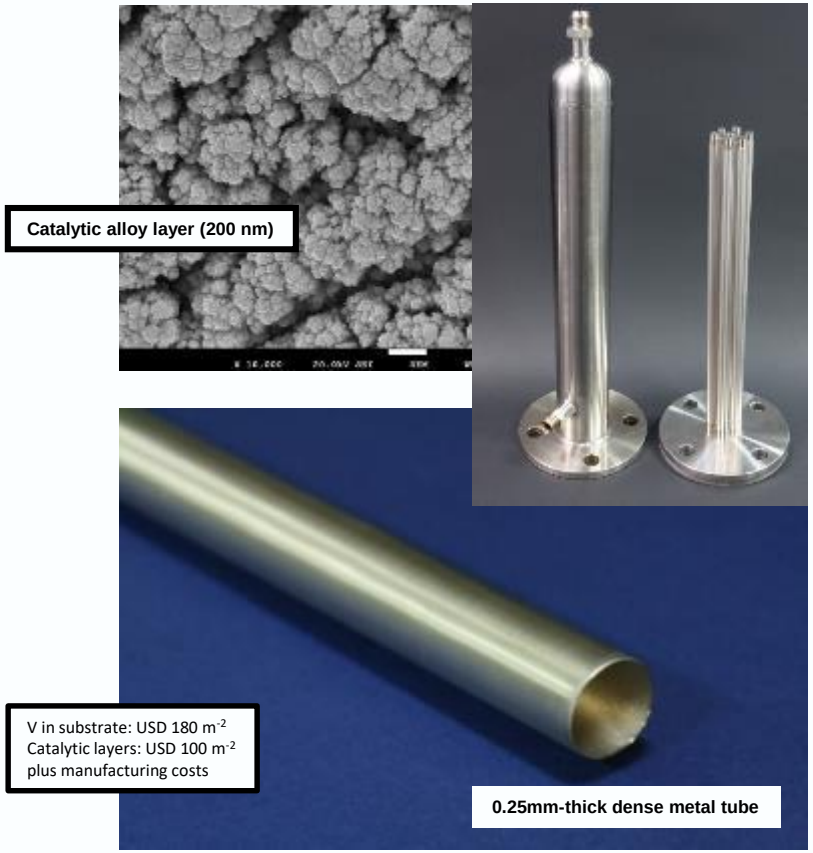
Technologies and expertise across the hydrogen value chain:

- Electrolysis technologies
- Ammonia as an energy carrier (production and cracking)
- Gasification science and syngas technologies for H2 from coal, biomass, and waste
- Hydrogen production membranes for high purity H2 separation
- Fuel cell and hybrid technologies for specific applications



Ammonia – supporting research





Industry testing

Coregas H_2 plant at Port Kembla

4-tube module

CSIRO Centre for Hybrid Energy Systems

Objective: Study / optimize integrated energy systems with multiple generation/storage/end-use components (inc. fossil and renewable H_2 production)

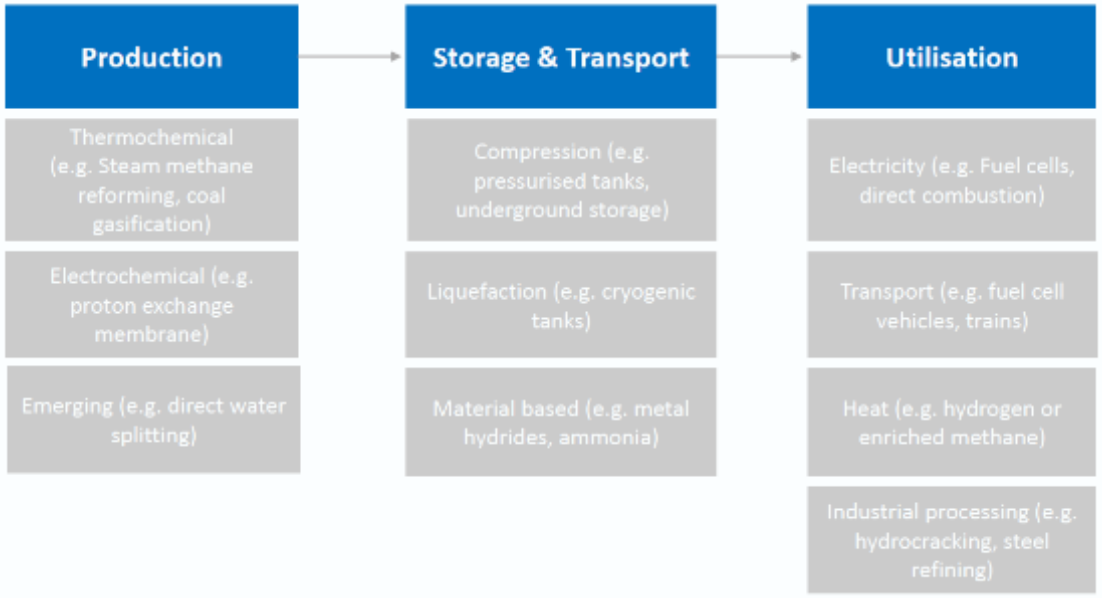
Capabilities:
Prototyping hybrid energy system configurations (eg electrolyser / fuel cell systems)
Energy system integration demonstrations
Assessment of emerging energy conversion/storage systems
Energy system environmental testing (eg battery systems)
Energy Technology innovation

CSIRO National Hydrogen Roadmap 2018

Objectives:

- **Identify key opportunities for Australia across value chain(s)**
- **Build consistent understanding of current options:**
    - **Cost**
    - **Technology Readiness(TRL)**
    - **Commercial Readiness (CRI)**
    - **Other barriers / opportunities eg new tech, regulatory**
- **Develop 'plug and play' pathways for comparison**
- **Technology work streams – Bottom up analysis**

For the bottom-up analysis, technology assessments may be divided according to the three primary elements of the value chain:



CSIRO National Hydrogen Roadmap 2018

Project sponsors

Industry:
- Kawasaki Heavy Industries
- Hydrogenics Corp
- Engie
- Sumitomo Australia
- Siemens
- KPMG
- Norton Rose

Peak bodies:
- Energy Networks Association
- Australian Gas Networks
- EvoEnergy
- ATCO Gas Australia
- Coal Energy Australia
- APGA

Government:
- Victorian State Government
- Austrade