Global Hydrogen Market Prospects

And Synergies with LNG

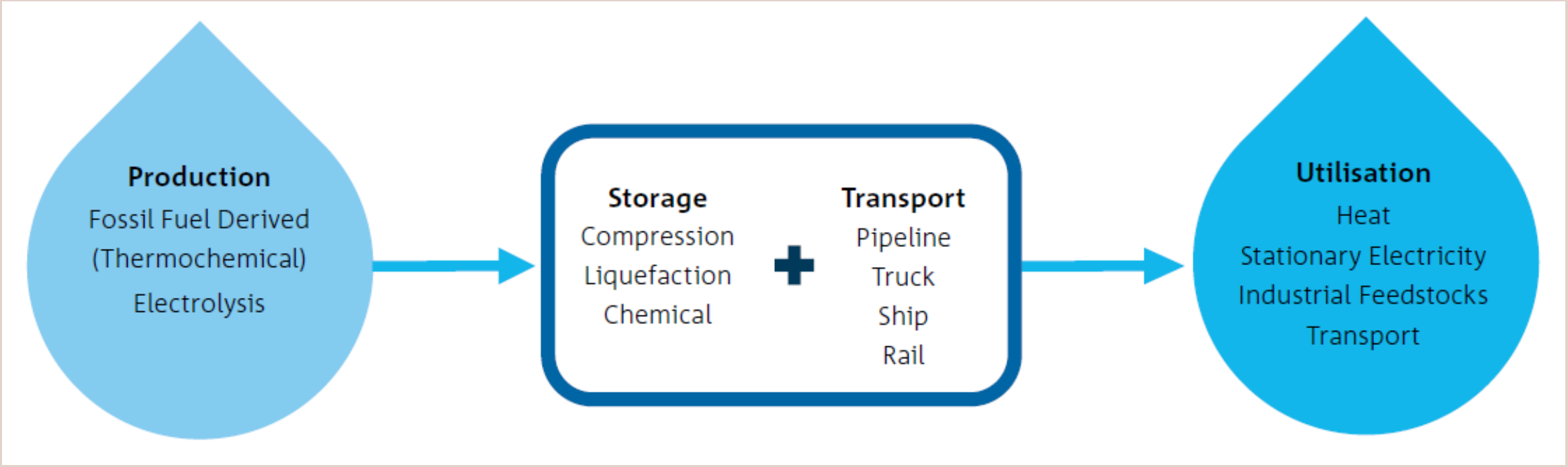
Roberto F. Aguilera

Curtin University
OIL AND GAS INNOVATION CENTRE

Outline

- Hydrogen value chain and applications
- Blue versus Green H2
- Natural gas, liquefied natural gas (LNG) markets & prospects
- Synergies between LNG and H2
- Opportunities and constraints for H2 transition
- Outlook for H2 in energy mix

Hydrogen value chain



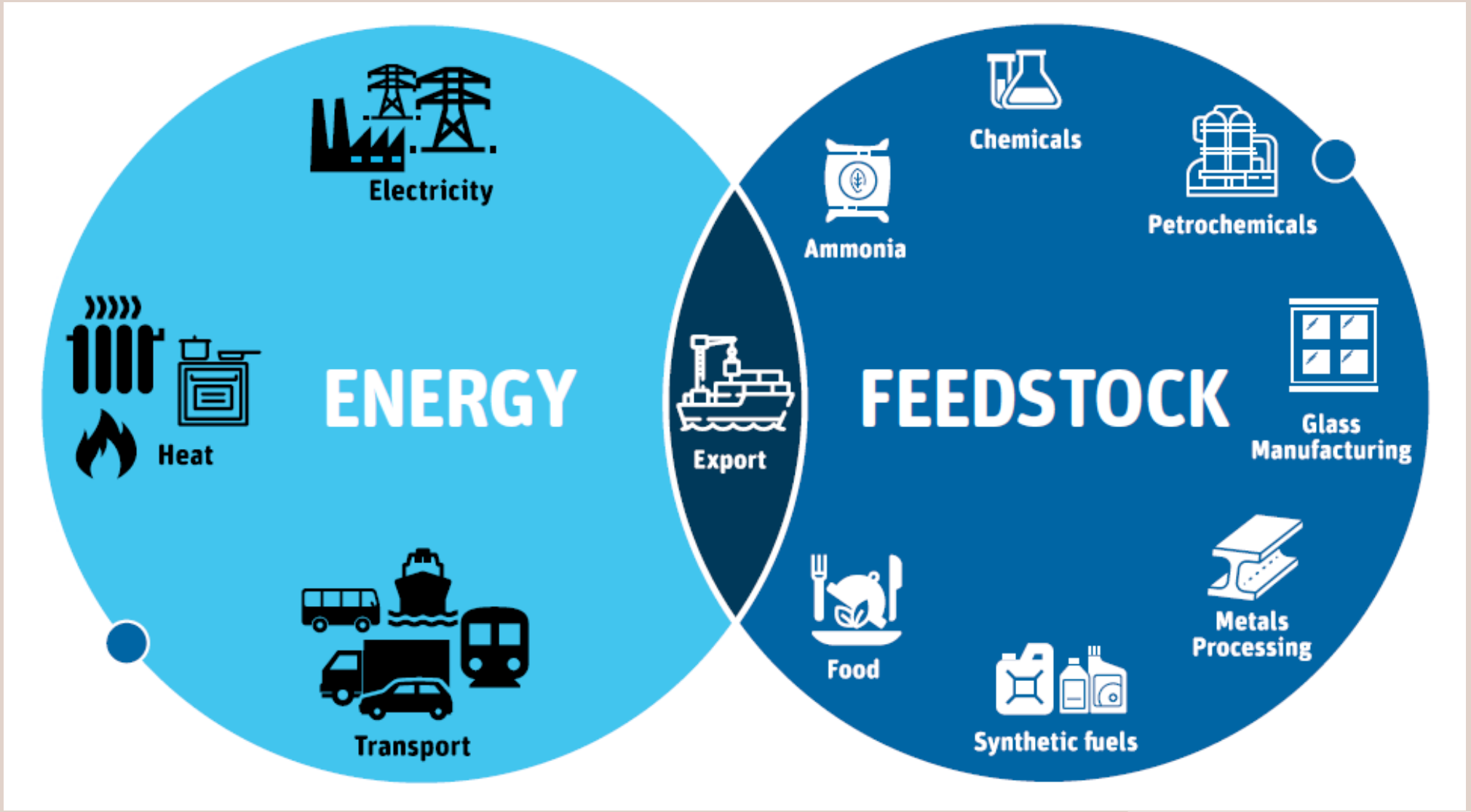
- Source: CSIRO (2018)

- H2 produced using various sources
- Several H2 transport methods
- Application in many end use sectors

Curtin University
OIL AND GAS INNOVATION CENTRE

Hydrogen applications

- Like oil & gas, H2 useful as energy source or feedstock



- Source: CSIRO (2018)

Generation | Conversion | Storage / Transportation | Application

Green/clean hydrogen

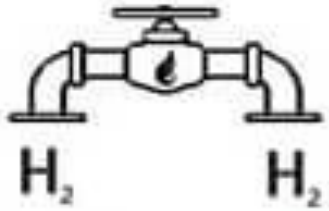
Wind or solar farms generate surplus energy

Electrolysis

- **Cost: $4-6 / kg**

Liquefied Hydrogen Gas

Natural Gas terminals



Natural Gas pipelines

Fuel cell cars, trains, public transport

Householding, appliances, heating

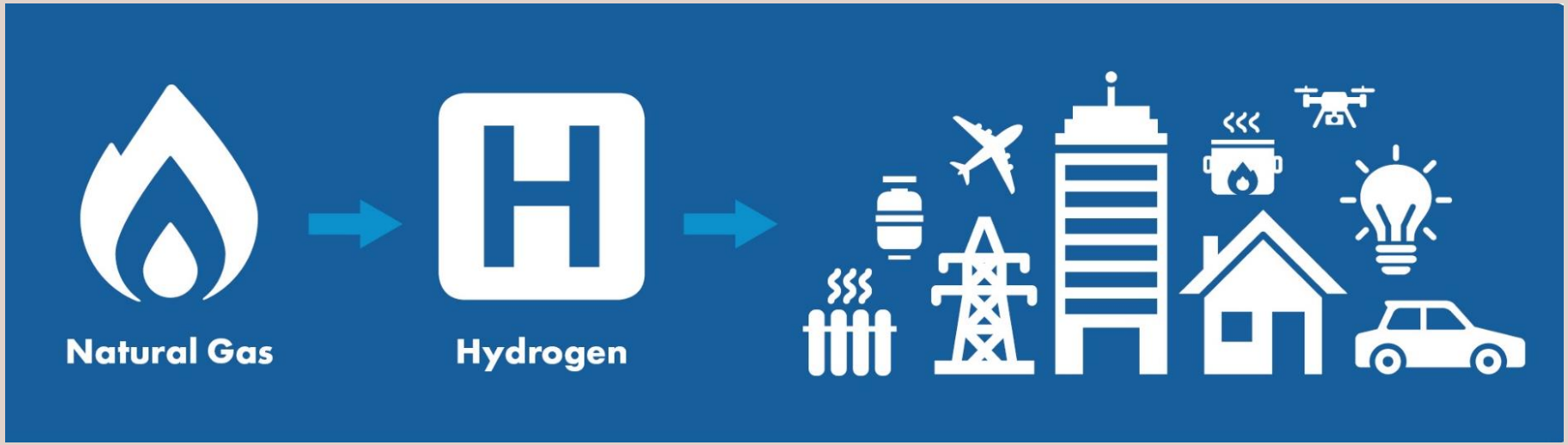
Petrochemicals, steel, refineries

Direct use electricity

Curtin University
OIL AND GAS INNOVATION CENTRE

- Source: Venture Insights (2017)

Blue hydrogen (sometimes grey)



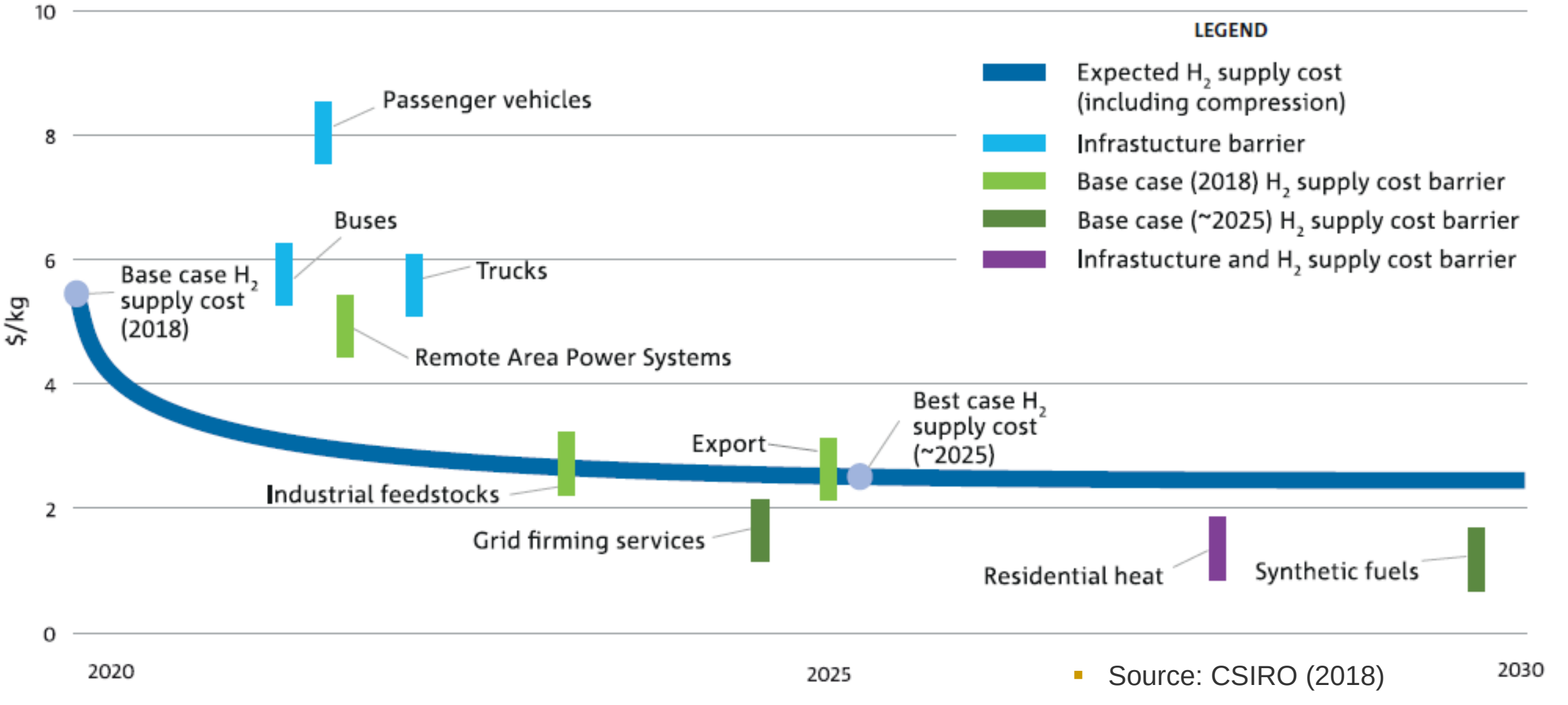
Steam methane reforming

Partial oxidation

- **Cost: $2-3 / kg**

- Source: Energy Information Australia (2019)

Hydrogen competitiveness

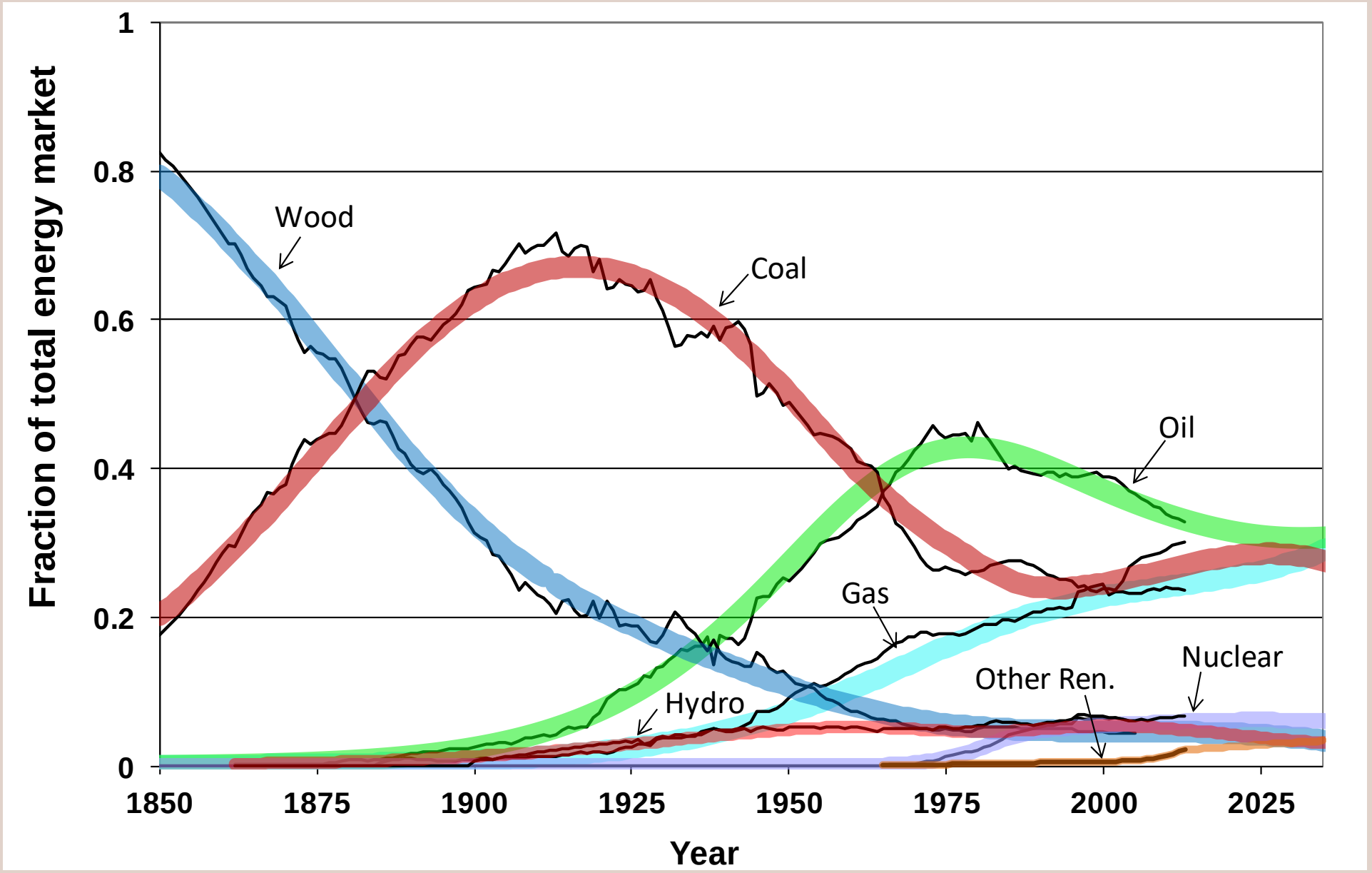


- Source: CSIRO (2018)

- Still too expensive, but costs falling

Curtin University
OIL AND GAS INNOVATION CENTRE

Primary energy mix (1850 - 2035)

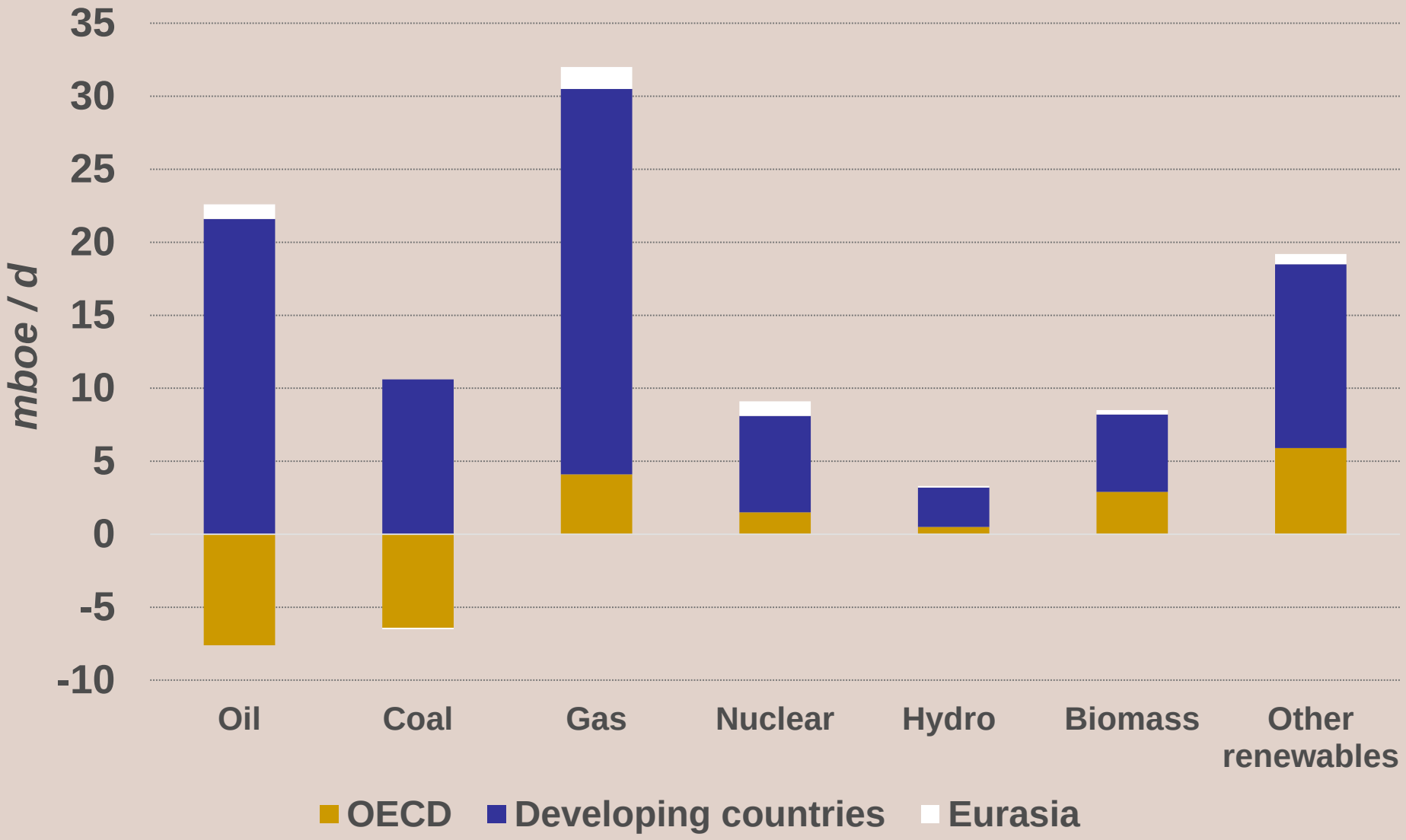


- Low prices extend oil & gas use for longer time period

- Source: Aguilera and Aguilera, Mineral Economics (2018)

Curtin University
OIL AND GAS INNOVATION CENTRE

Energy demand growth; fuel type & region (2015 - 2040)

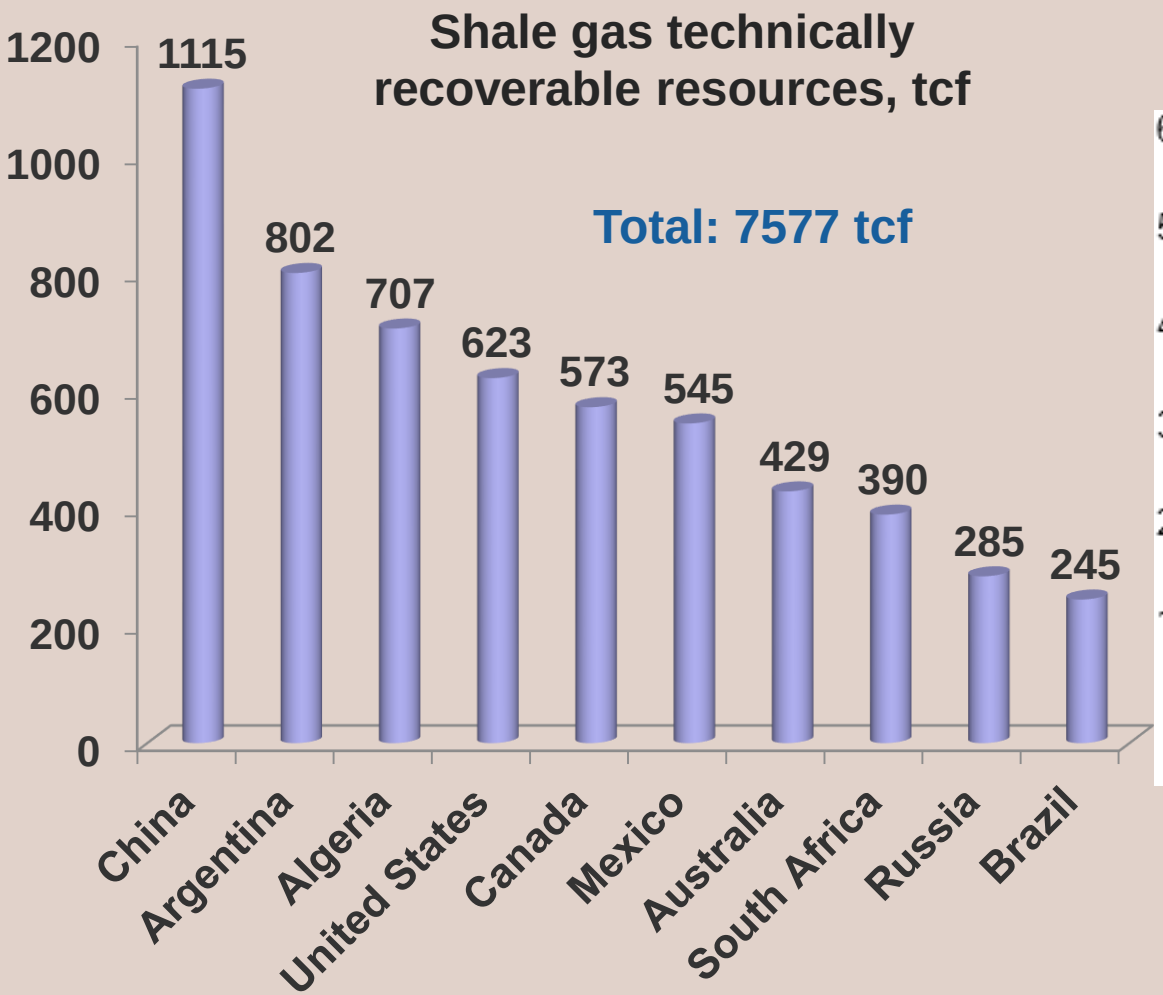


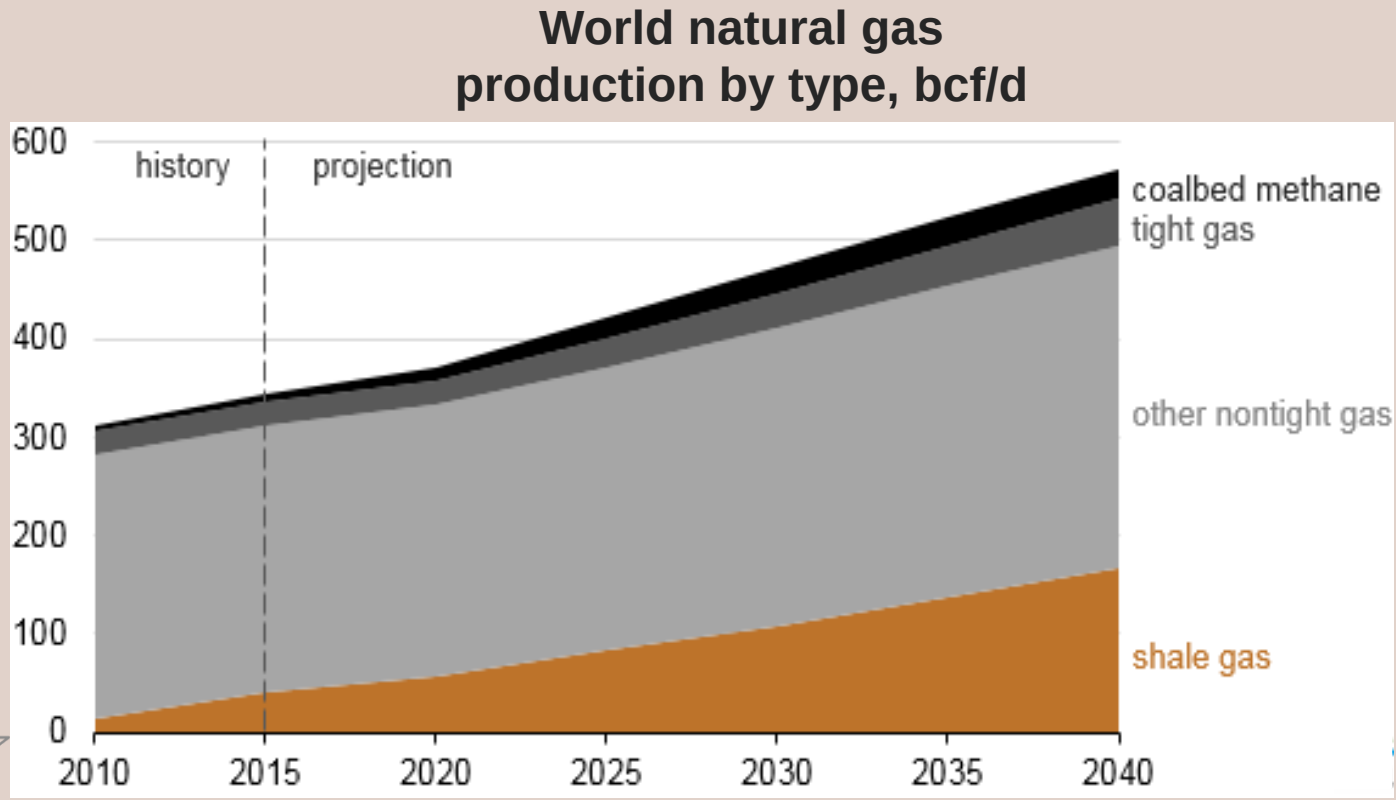
- Demand led by developing Asia
- Gas fastest growing energy source

- Source: OPEC World Oil Outlook (2018)

Curtin University
OIL AND GAS INNOVATION CENTRE

Unconventional gas

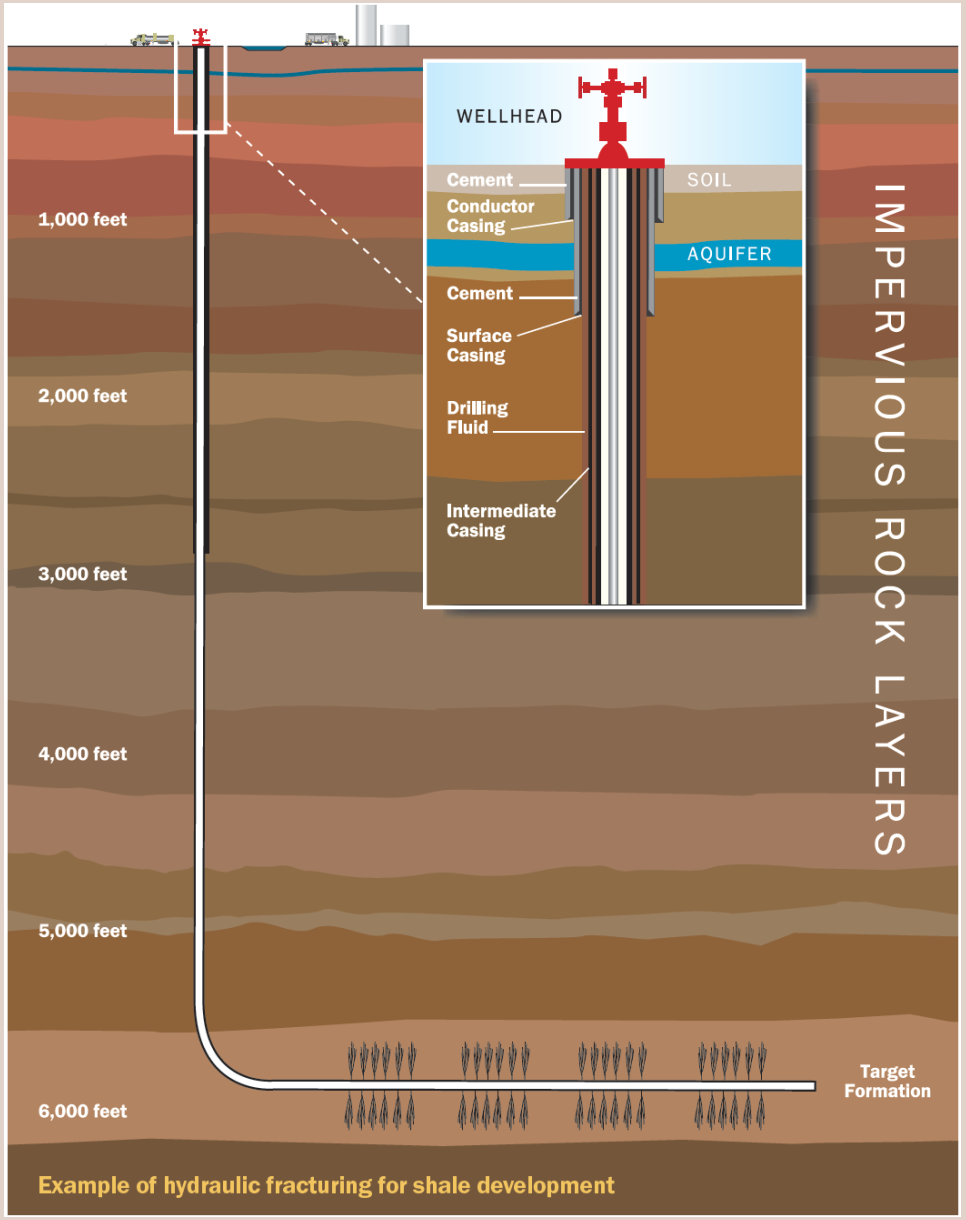




- Source: EIA, Advanced Resources International (2015)

Curtin University
OIL AND GAS INNOVATION CENTRE

Environmental impacts – unconventional gas

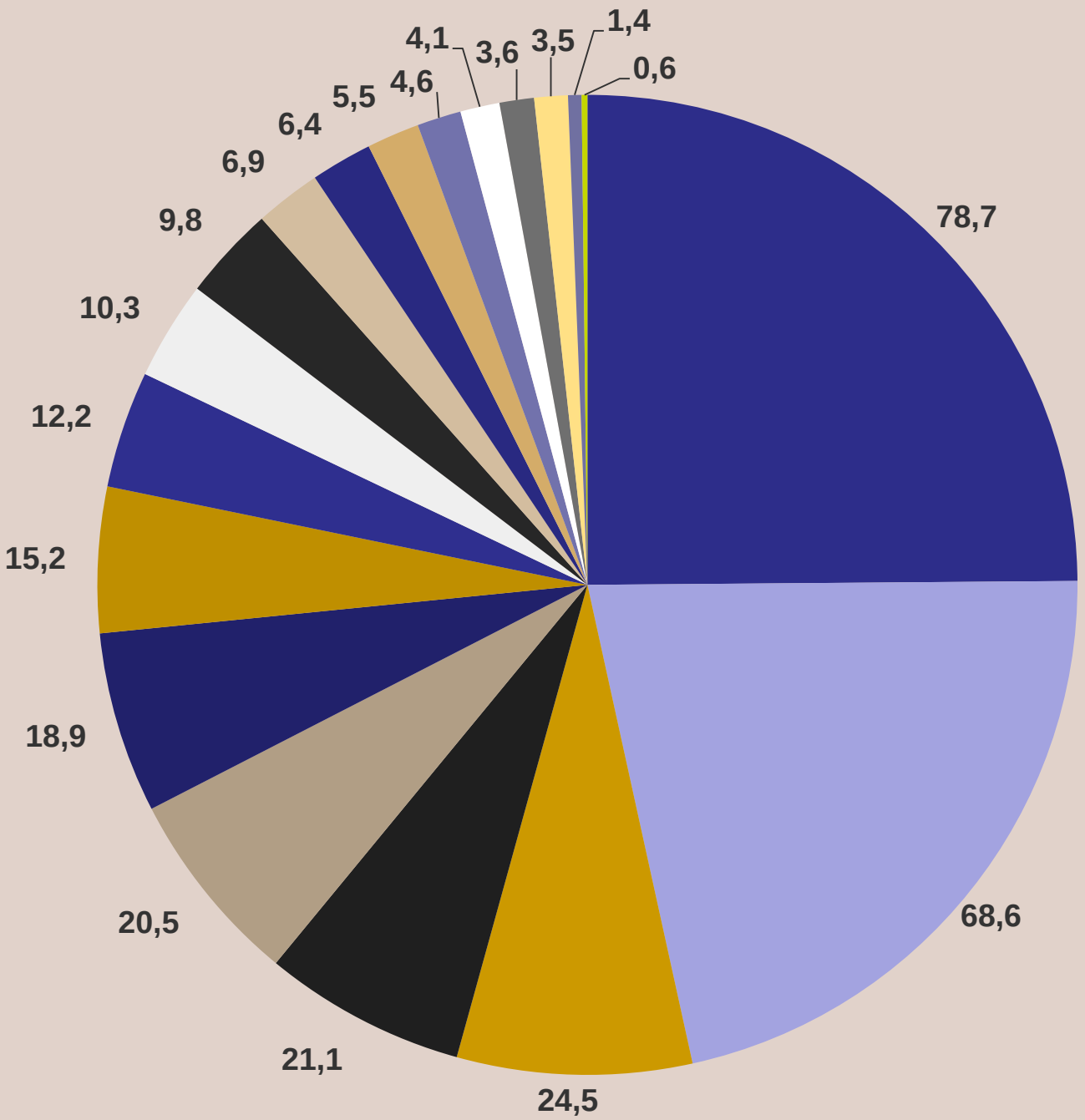


- Most concerns relate to hydraulic fracturing:
  - Intensive water use
  - Water contamination
  - Methane leakage
  - Induced seismicity
- There are indeed environmental risks from extraction methods, though often exaggerated by media
- Damage caused by infant industry, but hazards will be overcome as industry matures

Source: American Petroleum Institute

H2 links with natural gas: a valuable bridge

- Blue hydrogen
  - Domestic gas for H2 production, for consumption or export
- Gas pipeline networks can:
  - Supply gas as feedstock for H2
  - Be converted for H2 transport



LNG exports (2018), mtpa

- Source: International Gas Union (2019)

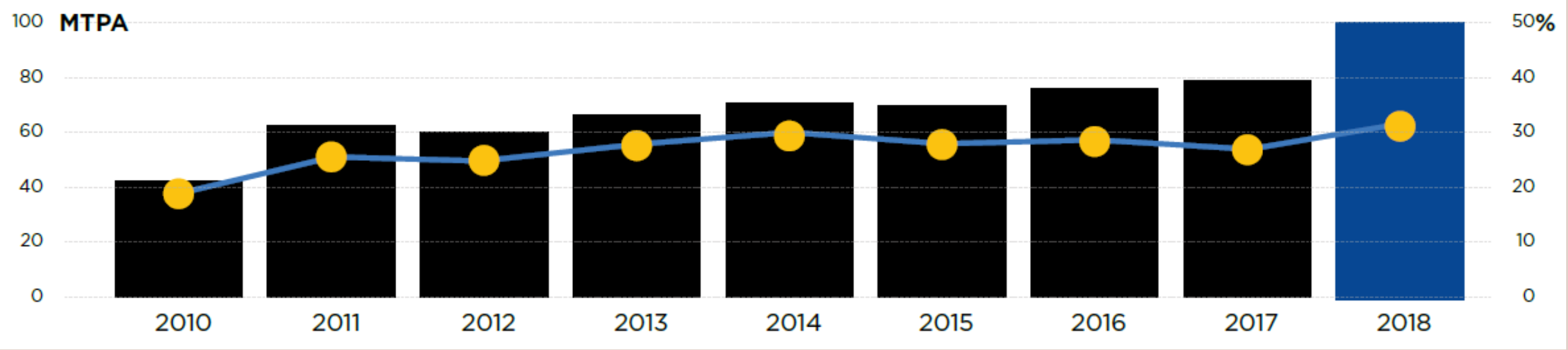
Curtin University
OIL AND GAS INNOVATION CENTRE

H2 links with LNG

- Export LNG for H2 production abroad
- Some LNG infrastructure works with H2
  - But liquid H2 colder than LNG
- Transferrable expertise and skills
  - Industry, academia, government
- Market structures
  - Short term vs. long term

Curtin University
OIL AND GAS INNOVATION CENTRE

Spot and short-term vs. total LNG trade

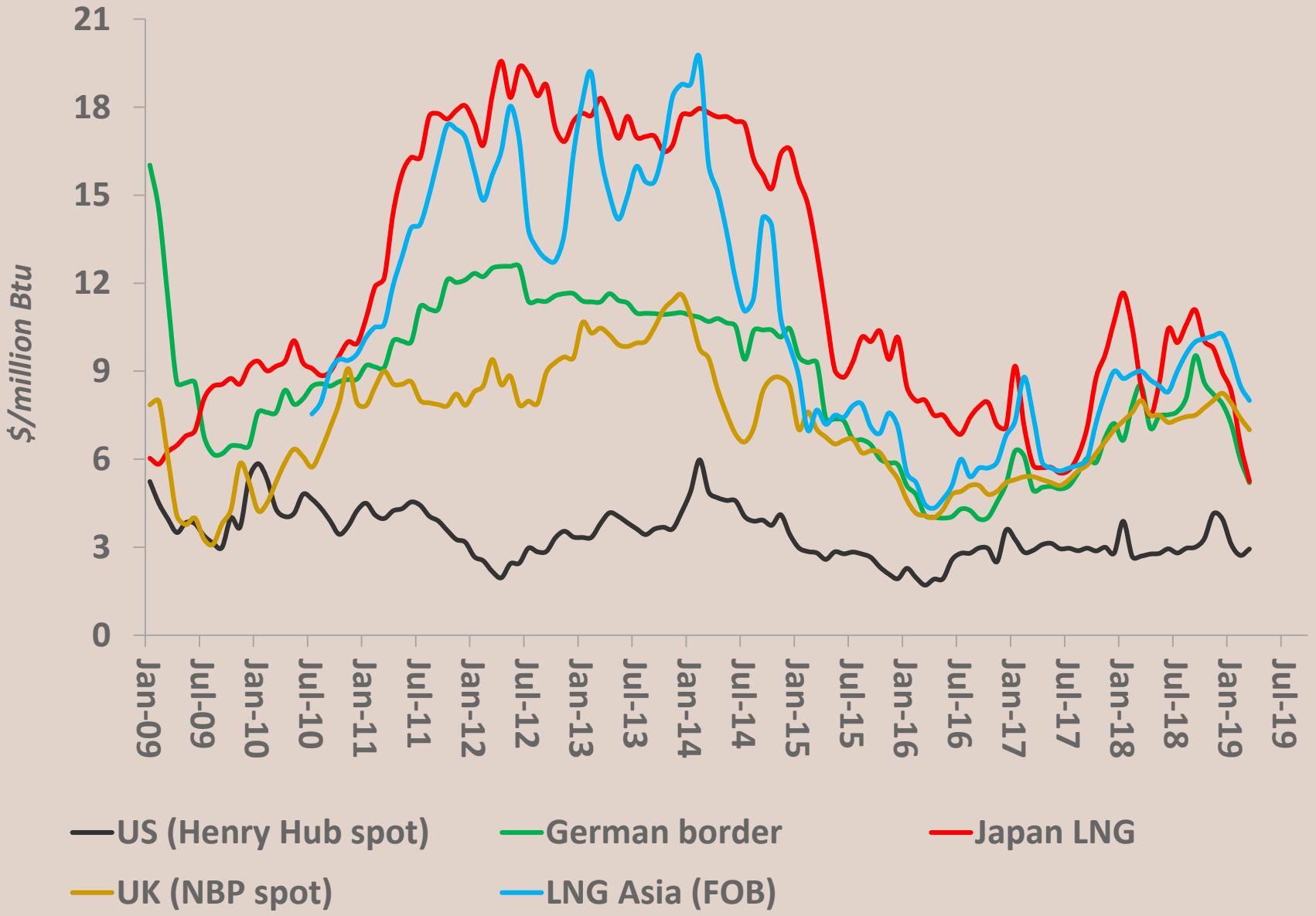


- Source: GIIGNL (2019)

- Gas-on-gas pricing growing with global LNG trade
- But progress not so quick

Curtin University
OIL AND GAS INNOVATION CENTRE

Natural gas price developments



- Regional prices diverged as shale gas supply & oil price rose
- Divergence narrowed with low oil price & expanded global gas trade

- Source: IMF, Cedigaz

Curtin University
OIL AND GAS INNOVATION CENTRE

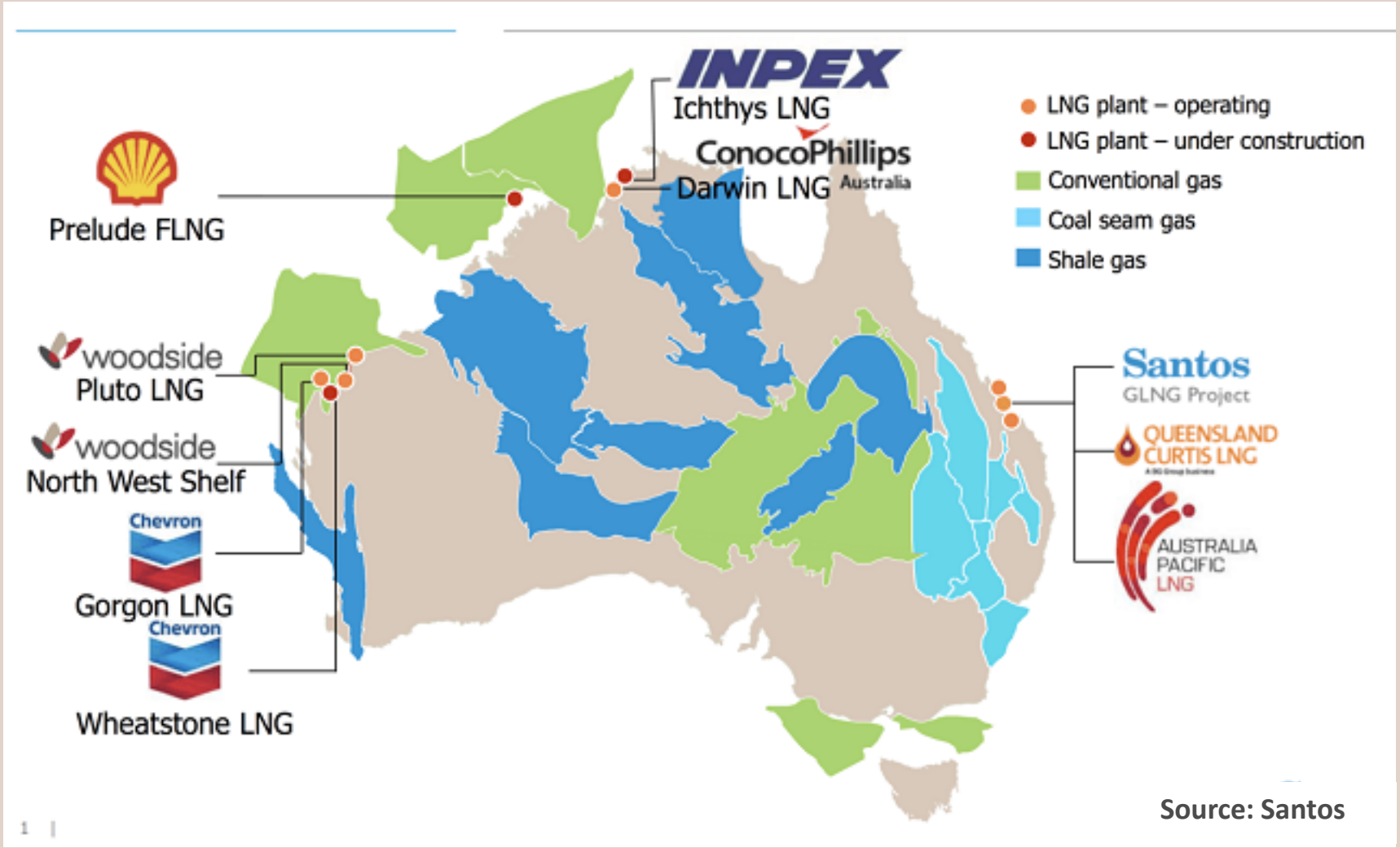
With low prices, LNG industry bringing costs down

- Improved productivity and operational efficiencies
- Better planning, cooperation, standardisation, simple construction, floating LNG
- On consumption side, floating LNG enables poor countries to increase gas use
- Lessons applicable to H2

Curtin University
OIL AND GAS INNOVATION CENTRE

Australia: $200 billion investment in LNG projects

- By 2020, Australia to export 85 mtpa of LNG
- Proximity to Asia makes ideal destination for exports (low shipping costs)
- Plans to leverage LNG experience for H2 development



Curtin University
OIL AND GAS INNOVATION CENTRE

Hydrogen development obstacles

- Demand
  - Sufficient H2 demand?
- Supply
  - Commercially competitive H2?
- Infrastructure & logistics
  - Sufficient storage & delivery?
- Transition
  - Sizeable share in energy mix?

Hydrogen transition challenges

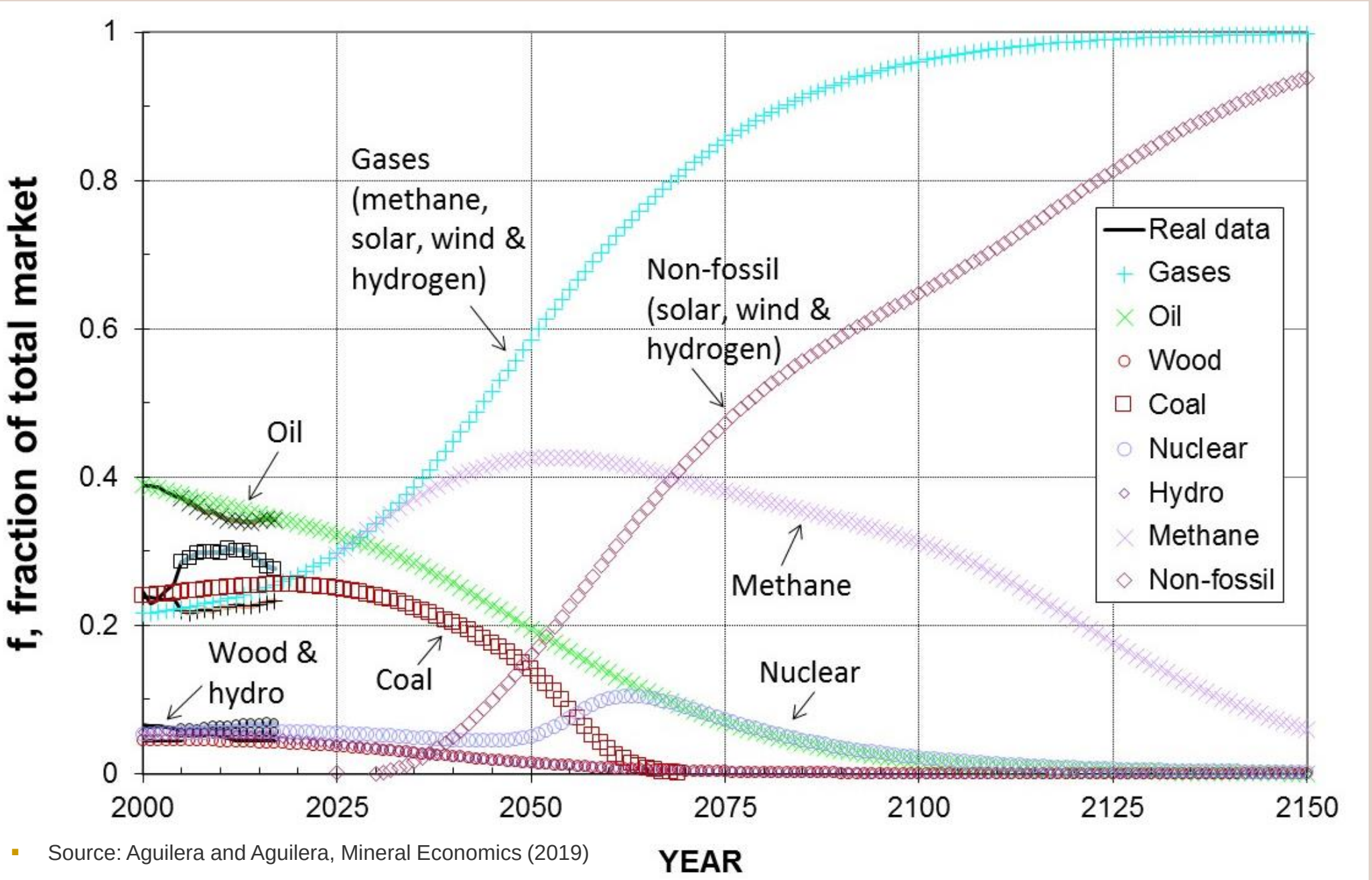
- Scale
  - Transitions start small, yet scale required
- Complexity
  - Energy market huge, H2 technically complex
- End-use limits
  - Demand-side technical innovation needed
- Policy & technology uncertainty
  - Keeps risk-averse investors away
- Comparative advantages
  - Speeds or slows transition

- Source: IIASA (2012)

Requirements for increased H2 market share

- Policy support in coming decades
  - Eventual shift from policy- to market-based use
- Benefit from synergies with established industries
  - Natural gas & renewables
- Cost reduction
  - Versus fossil fuels & renewable sources
- Learning by doing at regional scale
  - Regional approaches based on natural strengths

Primary Energy Mix (2000 - 2150)



- Source: Aguilera and Aguilera, Mineral Economics (2019)

- Natural gas share peaks near 2050
- Non-fossil energy, like H2, leads market 2H 21st century

Curtin University
OIL AND GAS INNOVATION CENTRE

Conclusions

- Hydrogen transition takes time
- Policy and technical advance are key
- Utilize gas and LNG links
- H2 as part of energy mix portfolio
- Expect experimentation period

Thank you!

Questions?

r.aguilera@curtin.edu.au

Curtin University
OIL AND GAS
INNOVATION CENTRE