MAYER | BROWN

Hydrogen – Hot Topics

Arbitration Breakfast

Moderator:
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Speakers:

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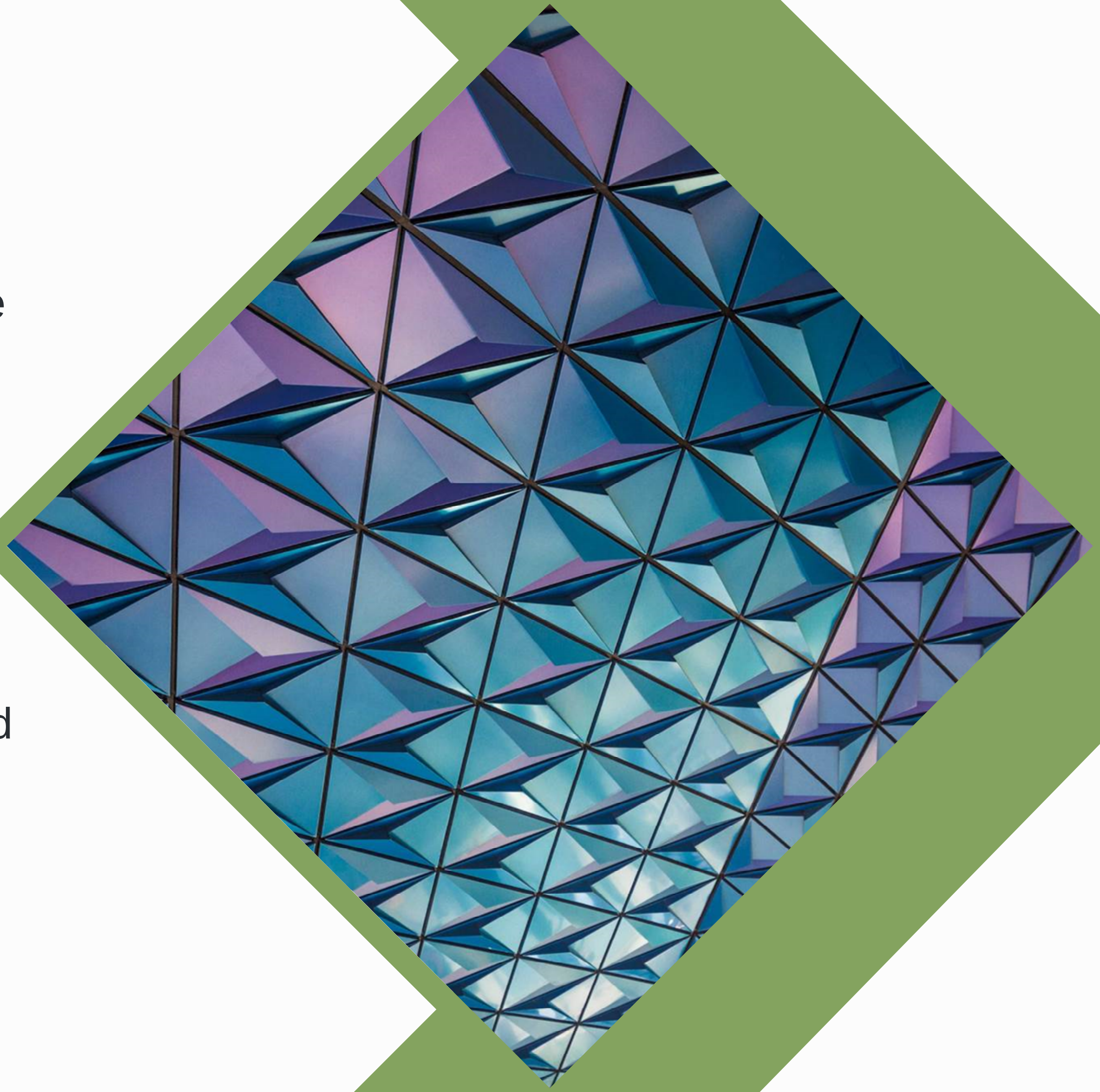
Hydrogen

- **Why:**
  - Highly versatile energy vector
  - No greenhouse gases at the point of use
  - High energy per unit mass (energy density)
  - Burns to reach high temperatures
  - Can be stored in large quantities
  - Possible uses: - industry, power generation, transport, domestic heating
- **Why not:**
  - Low density means large volume needed for a given mass – not ideal for cars etc.
  - Costs of liquefying H_2 prohibitive – 30% of total energy content used to liquefy
  - Generating hydrogen requires a large amount of energy



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Hydrogen “colours”

Grey: *natural gas reforming without CCUS*

Brown: *brown coal (ignite) as feedstock*

Blue: *natural gas reforming with CCUS*

Green: *electrolysis powered through renewable electricity*

Pink: *electrolysis powered through nuclear energy*

Turquoise: *methane pyrolysis*

Yellow: *electrolysis powered through electricity from solar*

Orange: *electrolysis powered through electricity from wind*

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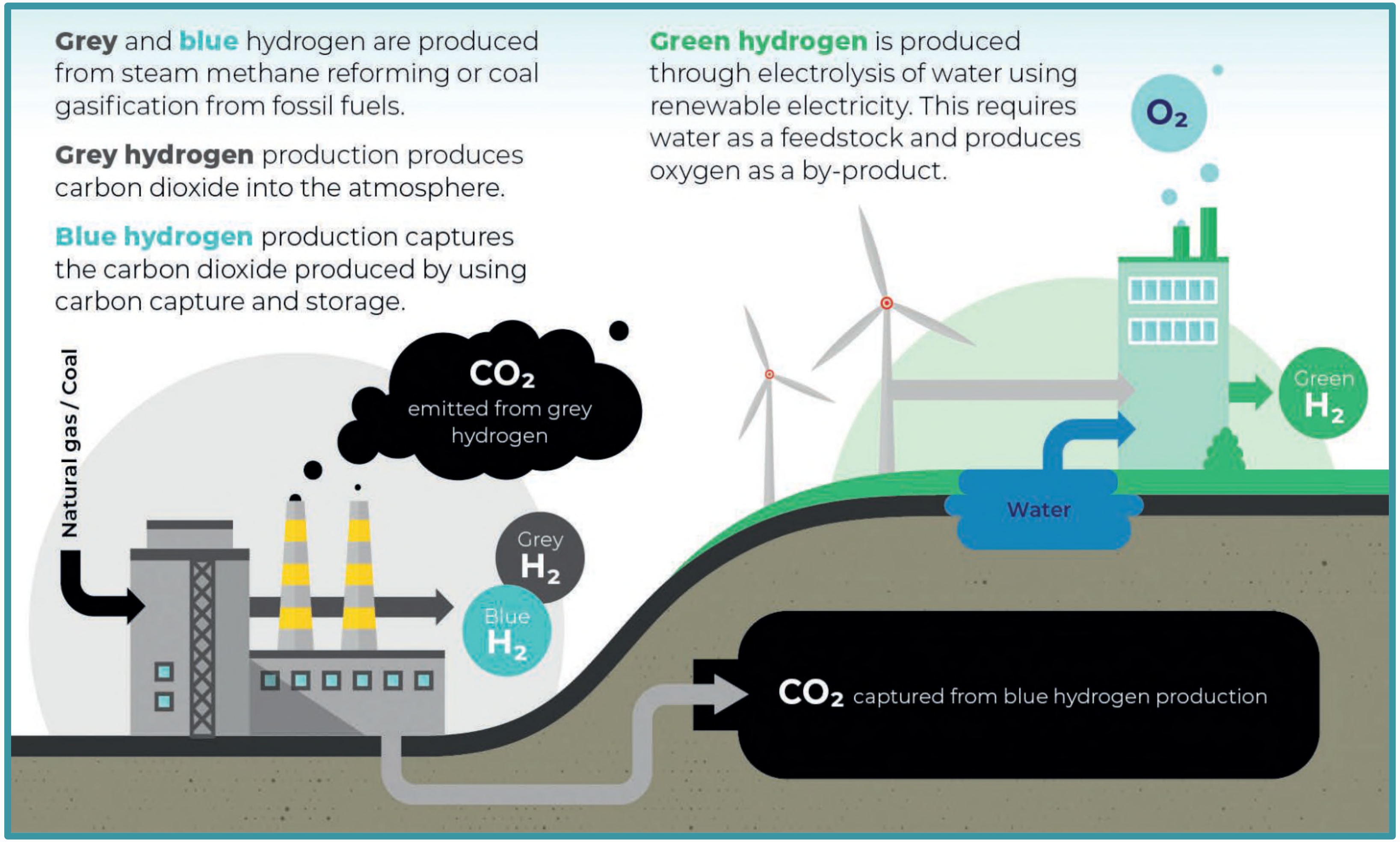
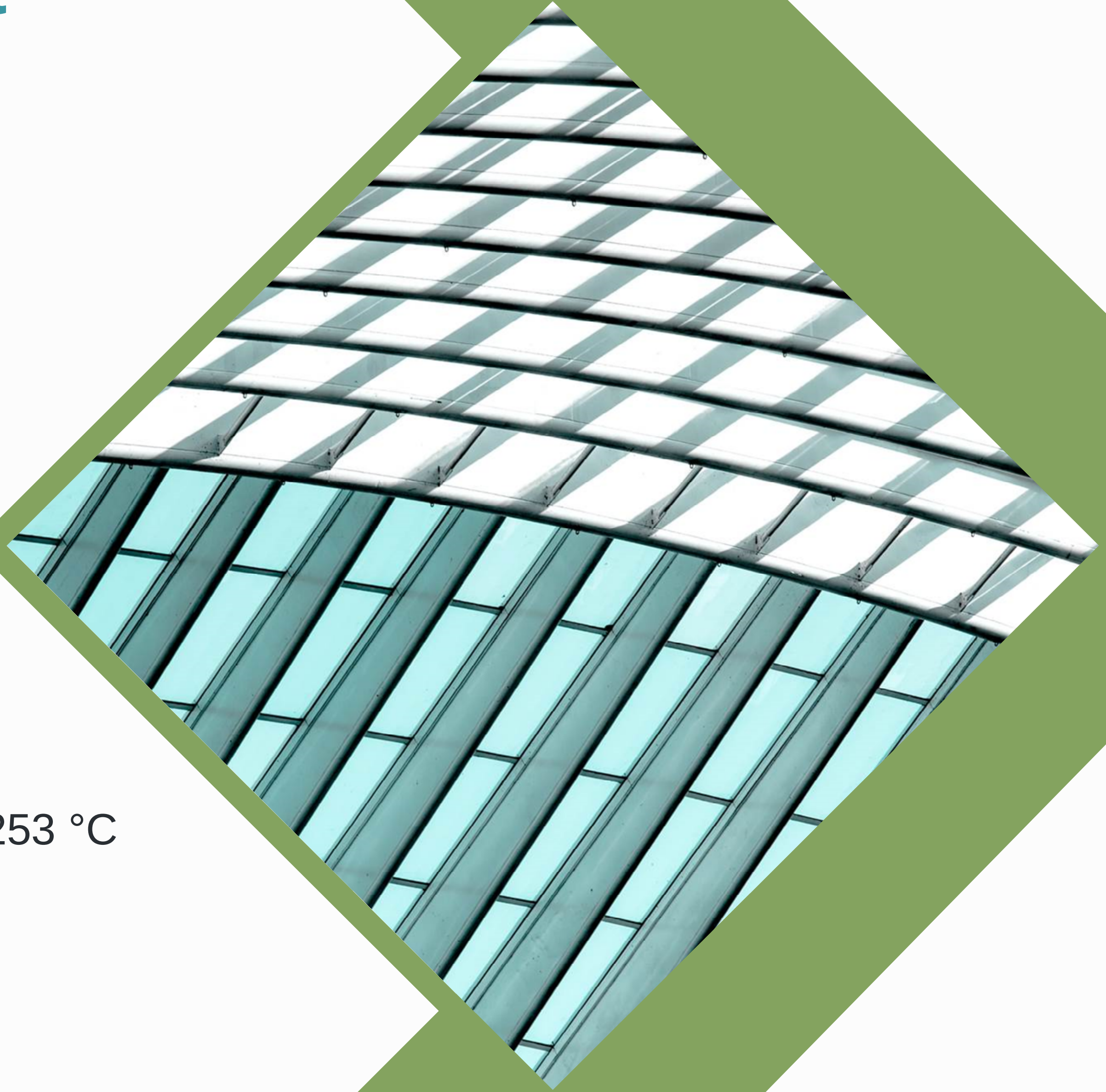
How grey, blue and green hydrogen are produced



Thermochemical Plant

- **Feed:**
  - Natural Gas (CH_4) and Water (H_2O)
- **Chemical Reaction:**
  - Steam reforming
    $CH_4+H_2O(+heat) \rightarrow CO+3H_2$
  - Water gas shift reaction
    $CO+H_2O \rightarrow CO_2+H_2$
    (+small amount of heat)
- **Physical State:**
  - Gas to gas
- **Storage Properties:**
  - Gas – high-pressure 345 – 690 bar
  - Liquid – cryogenic temperature below -253 °C
- **Key Elements:**
  - Reformer design



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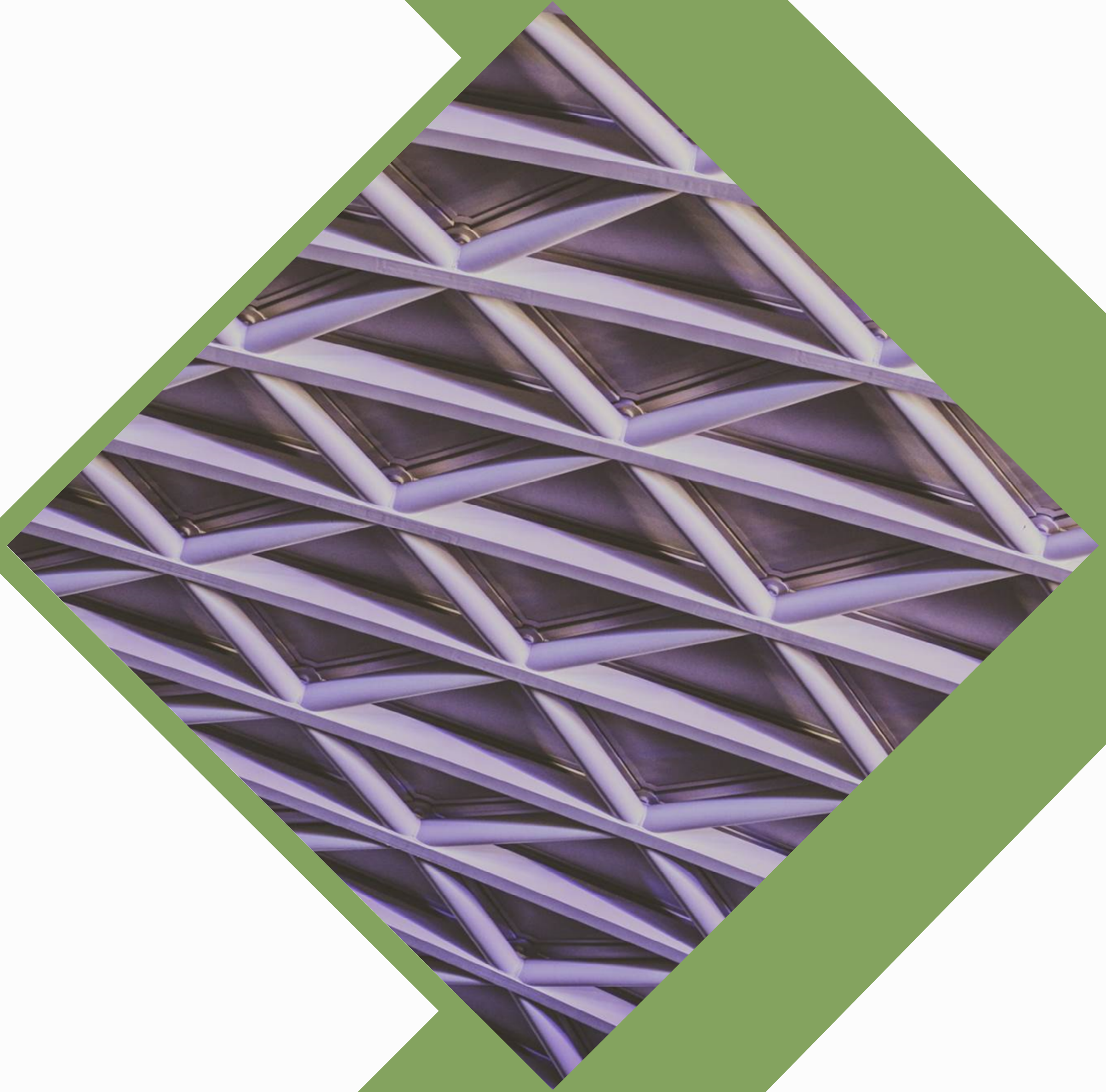
Electrolysis Plant

- **Feed:**
  - Water (H_2O) and electricity
- **Physical State:**
  - Liquid to gas
- **Electrolyte:**
  - Liquid e.g. potassium hydroxide (KOH)
  - Solid e.g. speciality plastic material or ceramic material
- **Key Elements:**
  - Electrolyte and membrane
  - Rare metals



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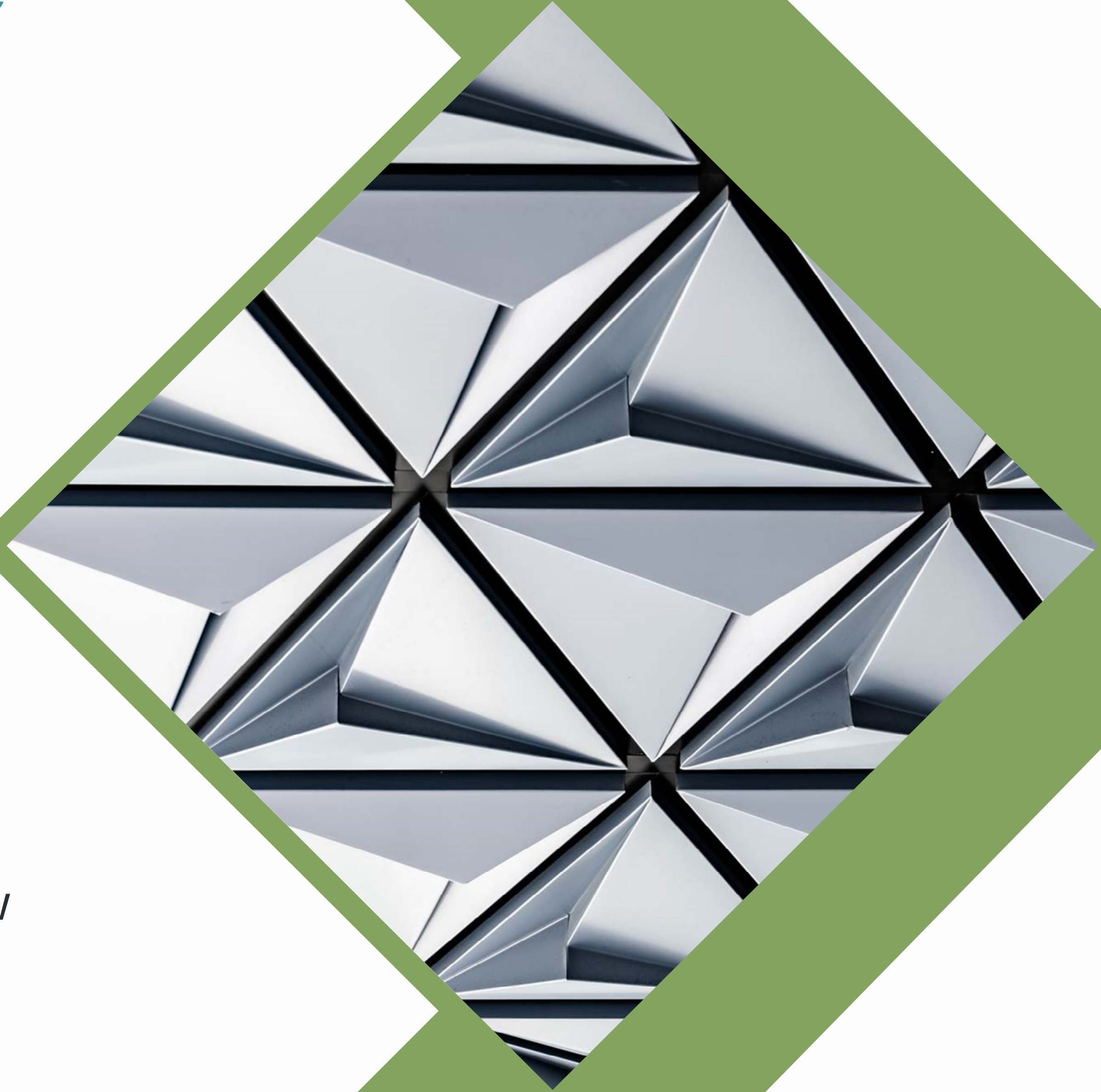
Transport and Storage

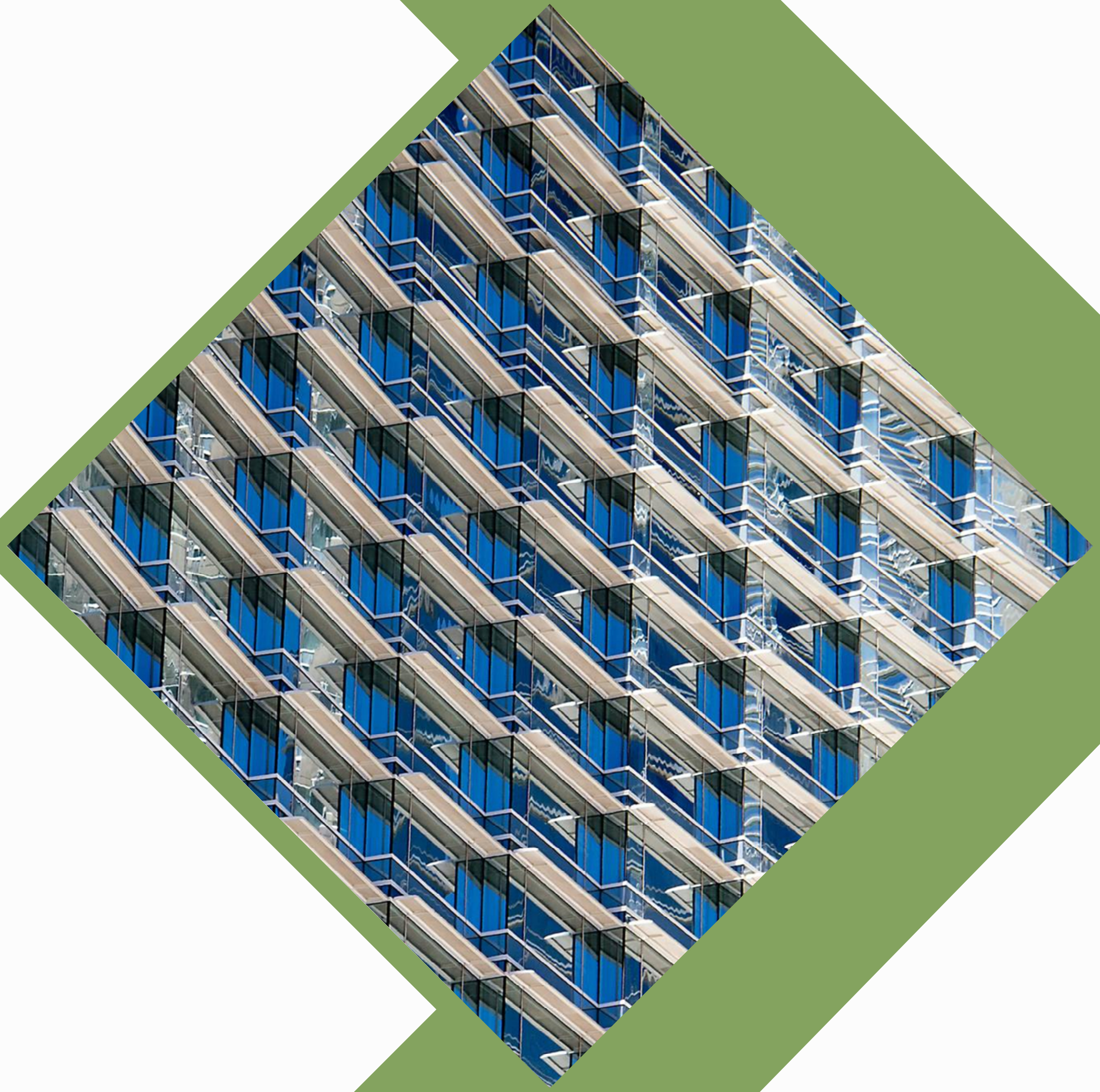
- **Transport Challenges:**
  - Liquid hydrogen has highest production cost but lowest transportation cost
  - Pipelines require high capital investment
  - Delivery by tube trailer also expensive due to loads limited by low density of H_2

- **Storage Properties:**
  - Gas: high-pressure 345 - 690 bar
  - Liquid: cryogenic temperature below -253 °C



Technical Issues

- **Scale up of Production:**
  - Production currently from a few KW to 100MW
- **Metallurgy:**
  - Hydrogen embrittlement
  - Material properties at cryogenic temperatures
  - Permeability
- **Safety and Environmental Issues – across all aspects of the hydrogen economy i.e. generation, storage, transmission and usage:**
  - Fire
  - Explosion
  - Hydrogen leakage – greenhouse gas effect
- **Evolving technology – often unproven:**
  - New materials e.g. high performance composites, metal hybrids
  - Production technologies e.g. photolytic



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How it can go wrong

- Plant design
- During normal operation
- Maintenance
- Non-routine operations
- Defects
- Modifications
- Poor storage
- Sabotage

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