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► **To cite this version:**

Kimon Keramidas, Silvana Mima, Adrien Bidaud-Bonod. Blue and turquoise hydrogen: bridge options or mirage?. IAMC 2022, Nov 2022, Mariland, United States. , 2022. hal-03878210

HAL Id: hal-03878210

<https://hal.science/hal-03878210>

Submitted on 29 Nov 2022

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Blue and turquoise hydrogen: bridge options or mirage?

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MOTIVATION – OBJECTIVE

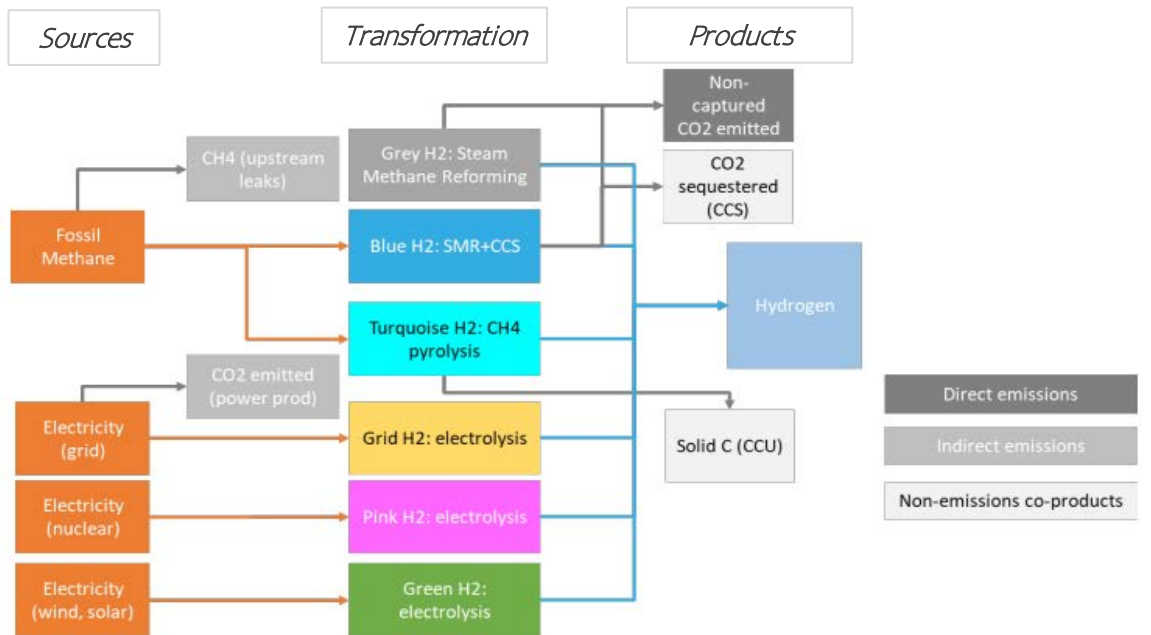
- Hydrogen (H₂): promising vector in the race to reach to net-zero
- Many announced national strategies & investments: RePowerEU, Japanese H₂ Strategy...
- Current production based on gas and coal (70 MtH₂, 750 MtCO₂)
- How to supply large enough quantities of H₂ while making it a lower-GHG vector than the fuels it replaces?

METHODS

- POLES: global energy system model (multi-regional partial equilibrium) – results here for USA
- Endogenous modelling of H₂ demand for energy uses and industry feedstock + 13 H₂ production technologies
- Scenarios: 1.5C (global carbon price) + 1.5C with 20-year delay in CCS deployment

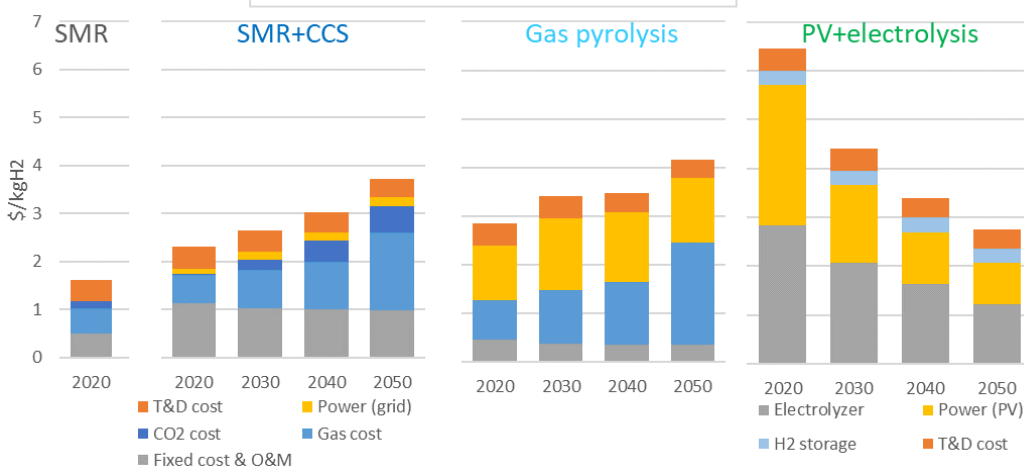
TECHNOLOGIES for H₂ production:

- **Green H₂** (wind/solar + electrolysis): decreasing costs in renewable electricity and electrolysis technologies, but needs H₂ buffer storage
- **Pink H₂** (nuclear + electrolysis): relevant only for countries with large nuclear power deployment plans
- **Blue H₂** (steam methane reforming with CCS): challenges of CO₂ capture, transport and long-term sequestration
- **Turquoise H₂** (gas/biomass pyrolysis): no emissions, no impact of carbon price; possibility of using existing supply infrastructure; black carbon reuse



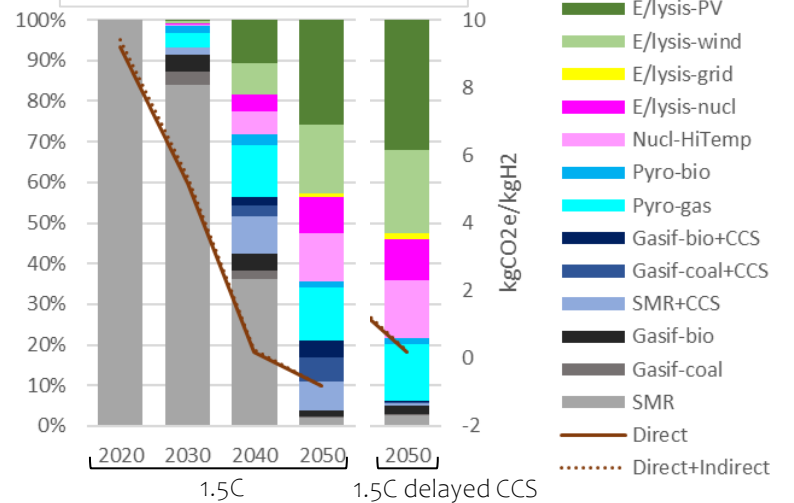
RESULTS

Supply costs, USA, 1.5C scenario



- Turquoise: nearly as competitive as blue (needs both fossil gas and electricity)
- Green: becomes cost-competitive only long term with climate policy

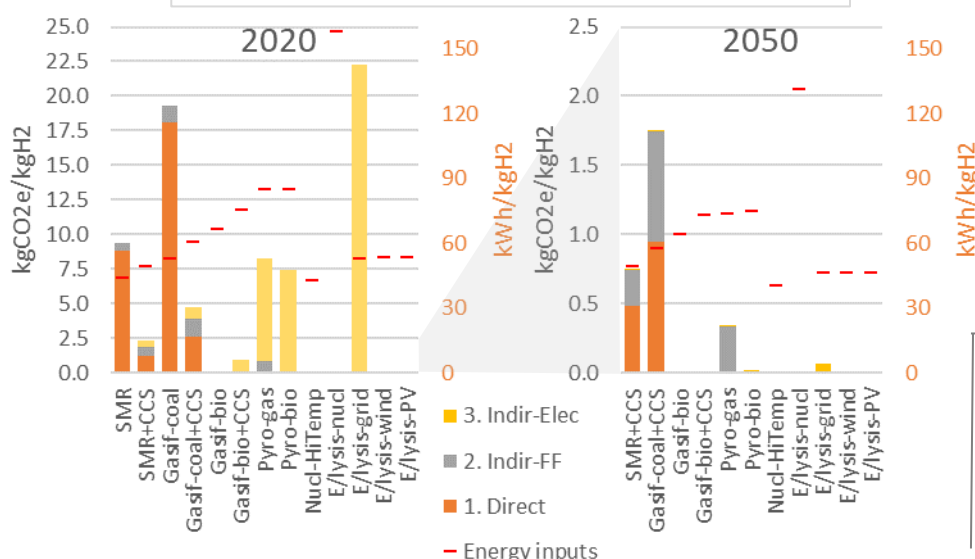
Production mix, USA



2050 market shares:

- | | |
|-----------------------------|----------------------------|
| 1. Green+Pink 64% | 1. Green+Pink 78% |
| 2. Turquoise 15% | 2. Turquoise 15% |
| 3. Blue / CCS solutions 17% | 3. Blue / CCS solutions 1% |

Hydrogen direct and indirect emissions, 1.5C, USA



1. **Direct emissions: fuel combustion, CH₄ reforming**
→ mostly captured in blue (max 95% capture rate)
2. **Indirect emissions: upstream fossil fuels supply chain**
→ partly reduced with climate policy
3. **Indirect emissions: electricity production**
→ reduced to nearly zero by 2050 with climate policy

Total emissions content vs fossil gas, USA:

2020: blue 3x less, turquoise same / 2050: blue 9x less, turquoise 20x less

> CONCLUSIONS & POLICY RECOMMENDATIONS

- Turquoise H₂ potential bridge, subject to gas market and geopolitical conditions; could get credits from selling carbon black
- Blue H₂ presents additional risk issues related to CCS infrastructure
- Green H₂ only true low-GHG option, long-term
- Investment in blue/turquoise H₂ risks resulting in gas supply infrastructure lock-in
- Early investment in green H₂ will allow learning and cost reductions