Challenges for Fossil-Based Hydrogen Production

Panel Introduction

NETL-GTI Workshop – Enabling an Accelerated & Affordable Clean Hydrogen Future – Fossil Energy Sector Role

Sept 28, 2021

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Panel – Challenges for Fossil-Based Hydrogen Production

- **Examine critical issues, research needs, and technology challenges for producing hydrogen from various feedstocks**
  - Dan Williams, MD Wabash Valley Resources
  - Rob Hanson, CEO Monolith Materials
  - Perry Babb, KeyState to Zero, KeyState Natural Gas Synthesis and CCS Chairman and CEO

~ 10 min/each

~15 min Q/A/discussion

Clean [Blue] Hydrogen

H2 generation from fossil source with CCS/CCUS

- **Ways to generate blue hydrogen:**
  1) **SMR w/ CCS** [Steam Methane Reformer]
     - **Fired**
     - **Renewable Electric**
  2) **ATR w/ CCS** [Auto-Thermal Reformer]
  3) **Gasification w/ CCS**
  4) **Pyrolysis w/ CCS**
  5) **SER w/ CCS** [Sorbent Enhanced Reformer]
     - **GTI CHG**[GTI Compact Hydrogen Generator]
  6) **OSU CL** [OSU Chemical Looping] w/CCS
  7) **Other**

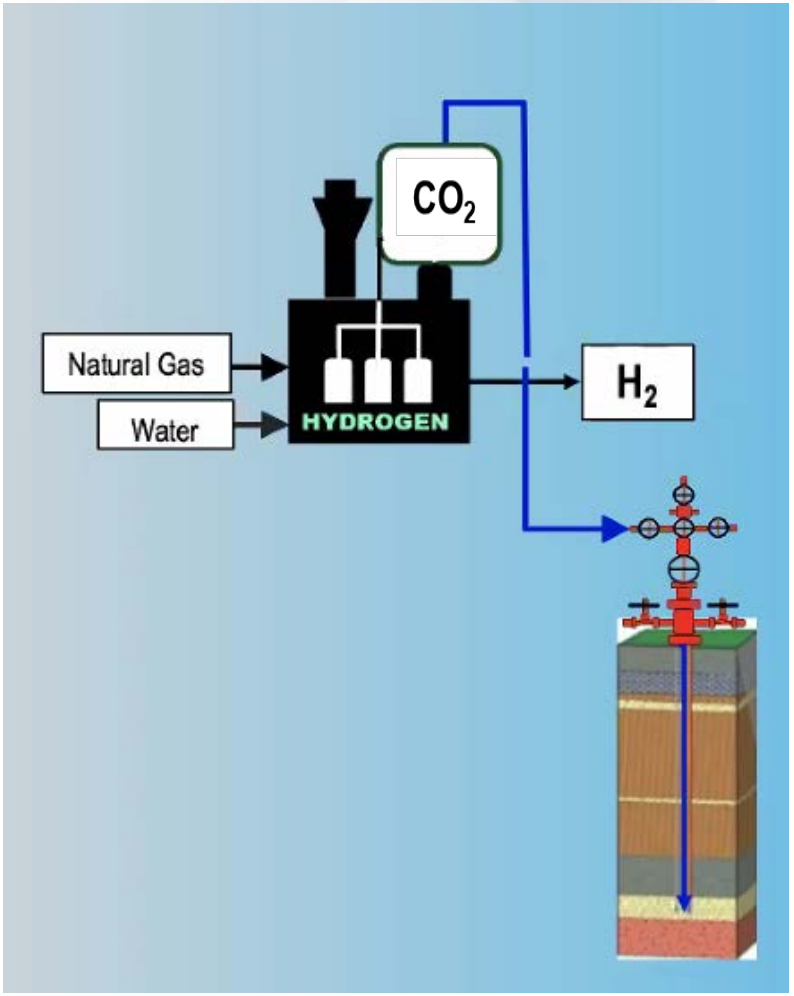
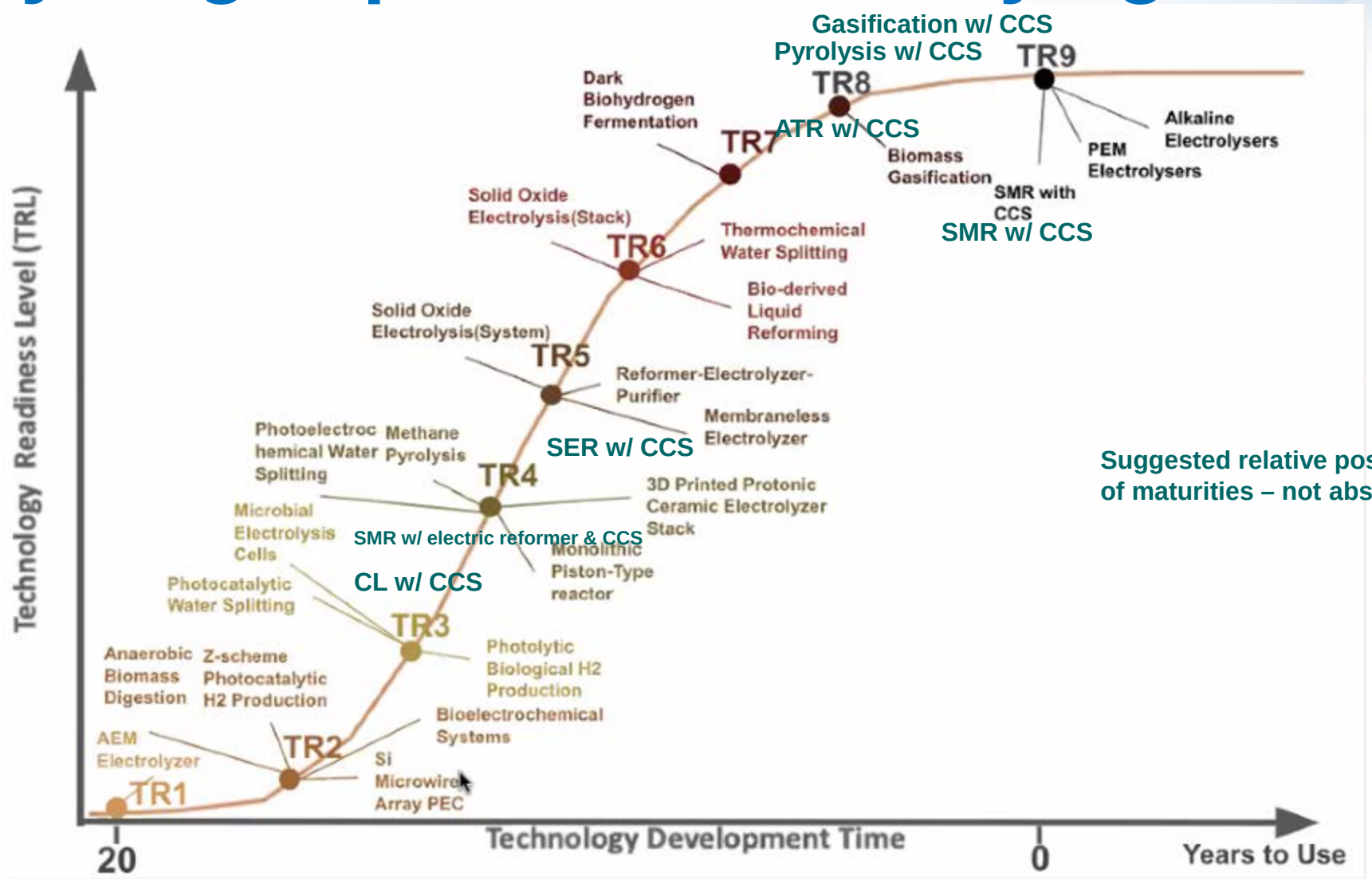


Figure Ref – Friedmann – Aug'21

Clean Hydrogen production – Varying Maturities



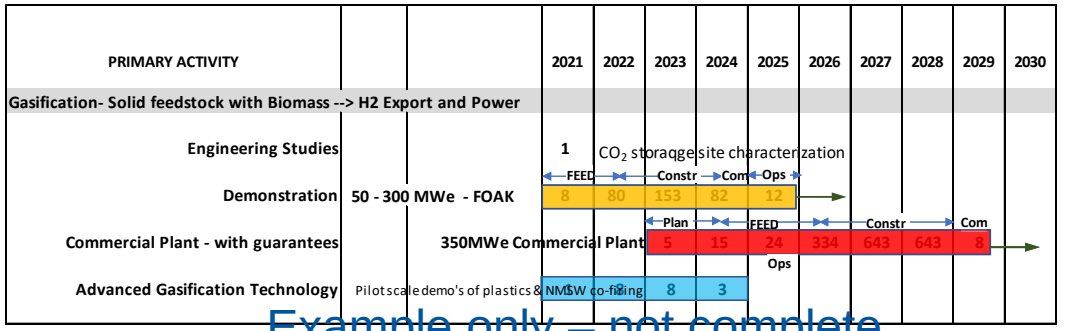
Suggested relative positioning of maturities – not absolutes

Ref: modified from Friedmann, 2021

Blue Hydrogen Production & Power Generation R&D&D Roadmaps - CURC

- Strawman roadmaps in development for 10 technical approaches:
  - 6 for gas & 4 for solid feedstocks
  - All with 90% CO2 capture and include potential for zero or net negative carbon emissions by co-firing biomass feedstocks
  - Each considers latest development status, time steps, costs for: Bench Scale, Engineering Studies, Small Pilots, Intermediate pilots, Commercial Scale demo's/FOAK, and finally commercial scale with guarantees

Gasification with co-firing biomass and with CCS

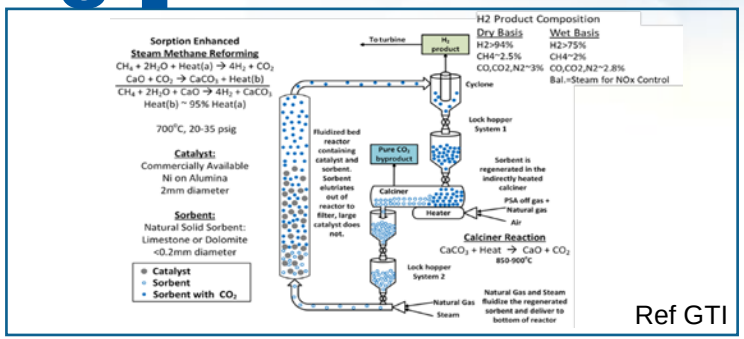


Example only – not complete

www.CURC.net

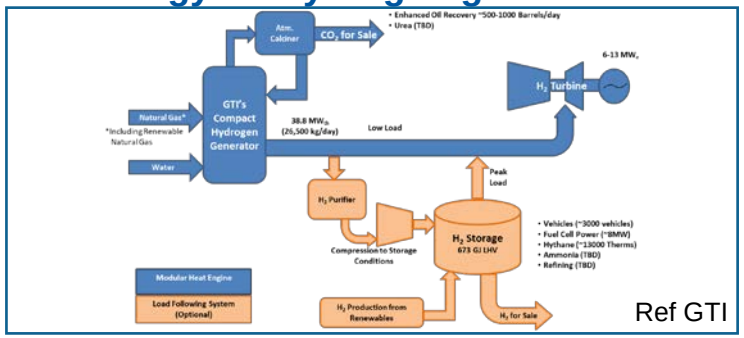
CURC Blue Hydrogen Roadmap - example: SER [Sorption Enhanced Reforming]

- Current TRL = 4-5
- **Estimated costs*: 20-30% cheaper H2, 15 - 25% cheaper electricity vs alternate of SMR or ATR with CCS**
- **Development steps:**
  - **Updated pilots** (**USA** 0.10 MMSCFD H2 & **UK** 0.45 MMSCFD H2)
  - Increase bed pressure, Hot Lock hoppers, Steam assisted indirect calcination, Recycle gas - **Current Status**
  - **30-40 MWe integrated power plant demo** (17 MMSCFD H2)
    - Integrated system with GT, on-site H2 storage, flexible operations – **Next Step**
    - Phased – H2 production, then GT with NG/H2 mix, then up to 100% H2 and including plant H2 storage
    - High pressure bed operation, bed scale up and solids distribution, full-scale solids handling loop
  - **120+ MWe** First large utility scale demonstration
  - **345 MWe** First Commercial Plant



Ref GTI

Technology for hydrogen generation



Ref GTI

System for power generation with GT

PRIMARY ACTIVITY	Primary Activity	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
System Design & Definition	Benchscale & Engineering Studies	2	Demo Plant Design, site identification, gap analysis											
Complete CHG Pilot Demonstration	Small Pilot and Component Development	3	10	2	20MSCFD with indirect fired atmospheric calciner & 450MSCFD with prototypic c									
Develop CO_2 Capture and Compression System				5										
Demonstration Plant	Large Pilot and GT Integration		1	1	13	20	10	5	5	17.1MMSCFD H_2, CHG & H2 Storage DVT				
Turbine Genset Retrofit	Commercial Demo Plant & FOAK				10	10	5	Purchase & Phased DVT 40 MWe turbine for H_2 combustion						
Scale-Up Development and Demonstration		170MWe 2x45MMSCFD H_2 w/CCUS			10	30	90	90	60	60	20	20		
Commercial Plant	Commercial Plant - W/guarantees				Commercial plant 345MWe 2x90MMSCFD H_2				175	175	145	50	50	
	MUSD	5	11	8	23	40	45	95	95	235	235	165	70	50

Ref CURC

R&D&D Roadmap

* Refs – US DOE OSTI 1692380 & UK BEIS 13333-8820-RP-001 & LCOH calc tool & GTI analysis

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