



Innovating for a Low Carbon Future

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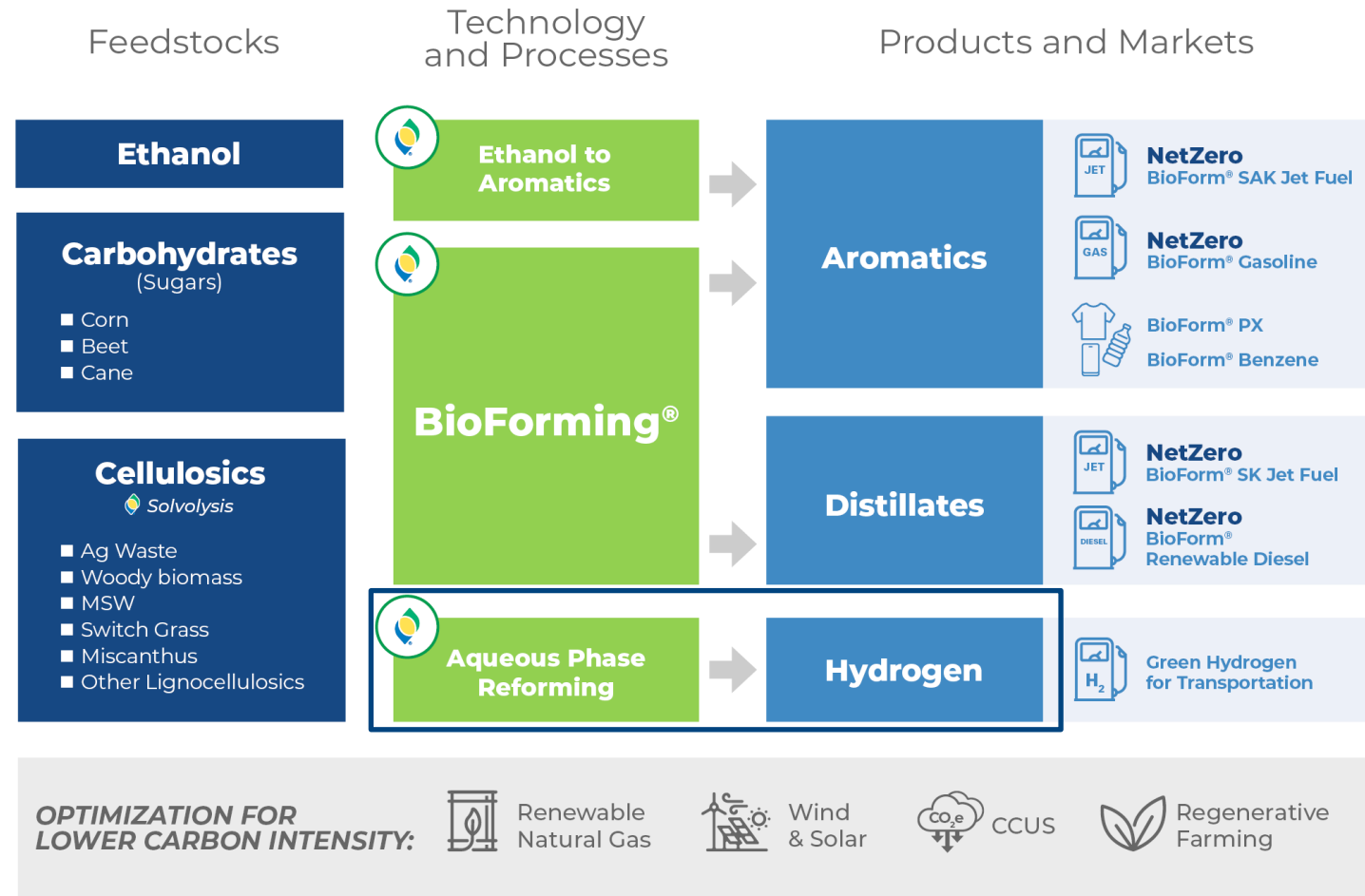
Carbon Negative H₂ Workshop, NREL

6/23/23



Virent is Creating Opportunities for Renewable Markets

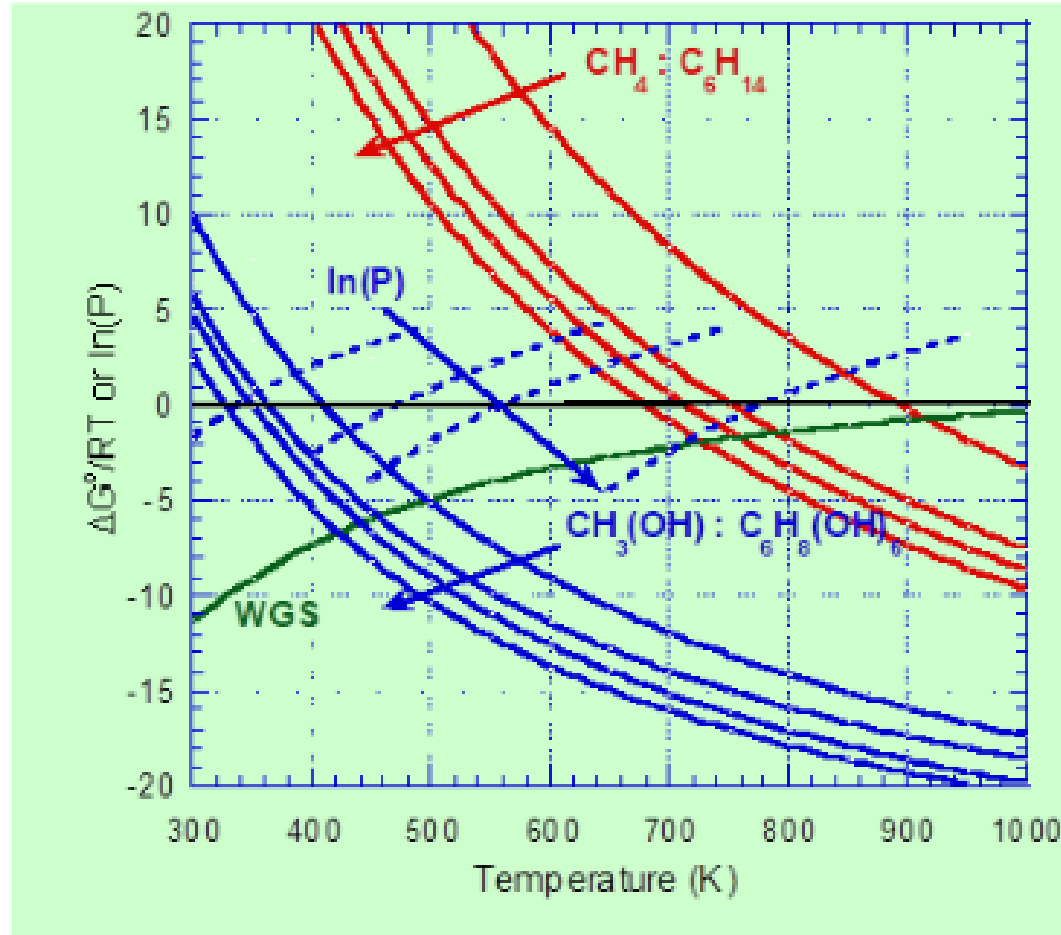
- Headquartered in Madison, WI
- Founded in 2002 on APR Hydrogen
 - Revisiting APR based on current market conditions
- Acquired by Tesoro in 2016 and as of 2018, a wholly-owned subsidiary of Marathon Petroleum
- Primary commercial focus is on Sugars to Aromatics (S2A) deployment but also pursuing other technologies (e.g. APR)





Aqueous Phase Reforming (APR)

Reformation of (renewable) oxygenated hydrocarbons effective at much milder conditions than SMR, with favorable WGS



Reforming of Hydrocarbons



Reforming of Oxygenated Compounds



Water-Gas Shift



Virent Key H₂ Development Projects



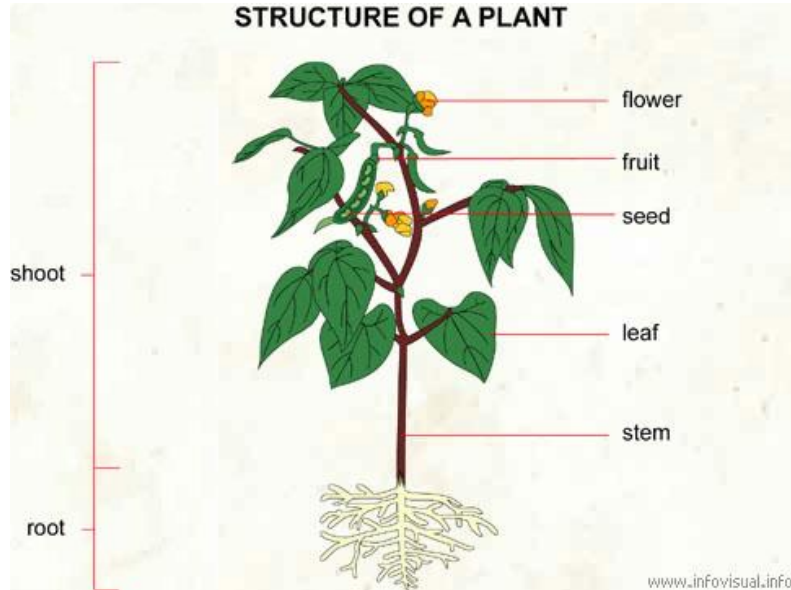
- DOE Hydrogen (2005 – 2009)
 - Renewable hydrogen production using *Sugars and Sugar Alcohols*
- Shell Hydrogen (2007-2010)
 - 3 Year development program – *Sorbitol and Glycerol*
 - Development work in Madison and Westhollow
 - 10 kg/day H₂ Process Demonstration Unit
- Office of Naval Research Projects
 - Phase I (2007 to 2008)
 - Development of catalysts and demonstration system for *Ethylene Glycol Reformation*
 - Phase II (2008 to 2010)
 - Utilize crude feedstocks (antifreeze **(EG&PG)** and **Glycerol**) and integrate the demonstration system with feedstock clean-up and H₂ purification
- Virent Internal-Current
 - Focused on Glycerol first while developing additional larger scale, low carbon intensity feedstock options.



Using Biomass Derived Liquids as H₂ Carriers



Letting Plants do CO₂ Capture (compared to e-fuels)

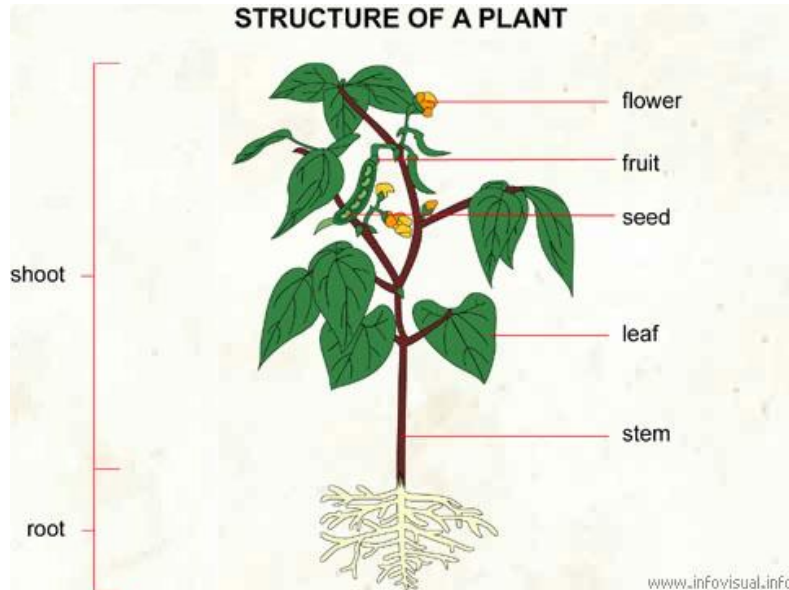


- Glucose/Mannose/
Fructose/Xylose
- Sorbitol/Mannitol/
Xylitol
- **Glycerol**
- Ethylene Glycol/
Propylene Glycol



Using Biomass Derived Liquids as H₂ Carriers

Letting Plants do CO₂ Capture (compared to e-fuels)



- Glucose/Mannose/
Fructose/Xylose
- Sorbitol/Mannitol/
Xylitol
- **Glycerol**
- Ethylene Glycol/
Propylene Glycol

- **Why Glycerol:**

- Byproduct of biodiesel, range of CI opportunities
- Easiest initial feedstock to study
- Con: limited feedstock availability

HYDROGEN PRODUCTION

Shell, Raízen, Hytron, USP and SENAI Form a Partnership to Convert Ethanol Into Renewable Hydrogen

Hydrogen Central

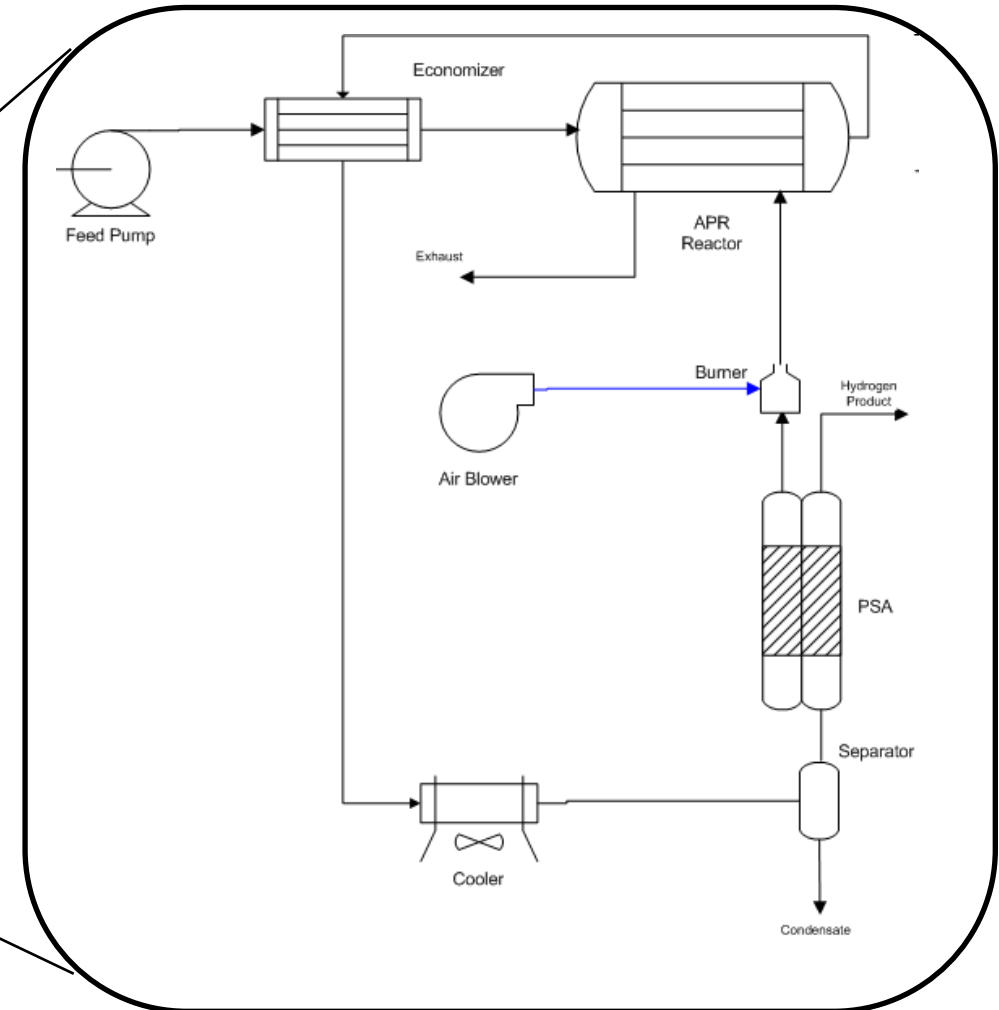
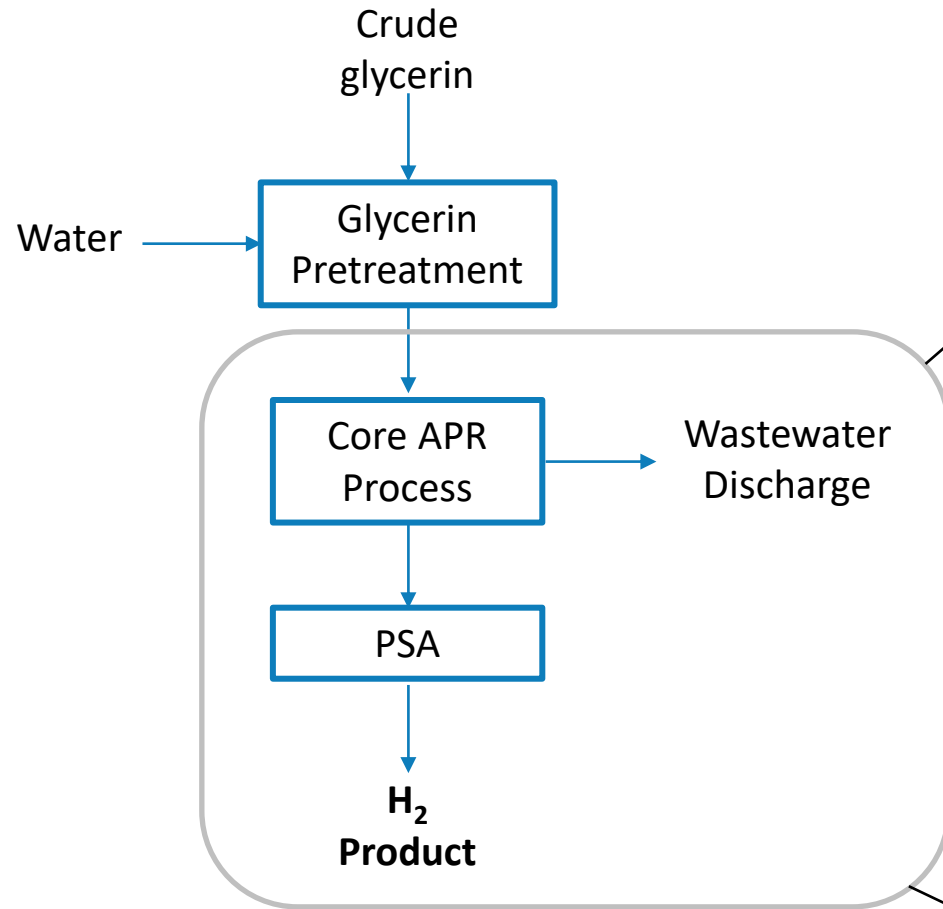
September 2, 2022 10 min read

Hydrogen Industry News & Market Intelligence



APR is a Straightforward Catalytic Process

Simplified BFD and PFD of APR Technology (Packed Bed)





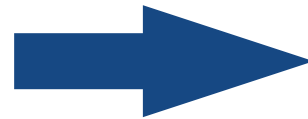
Project Considerations

- Continued technical optimization on pilot plant scale
- Development and deployment of demo skid (>300x scale-up)
- ID partners and commercial deployment strategy

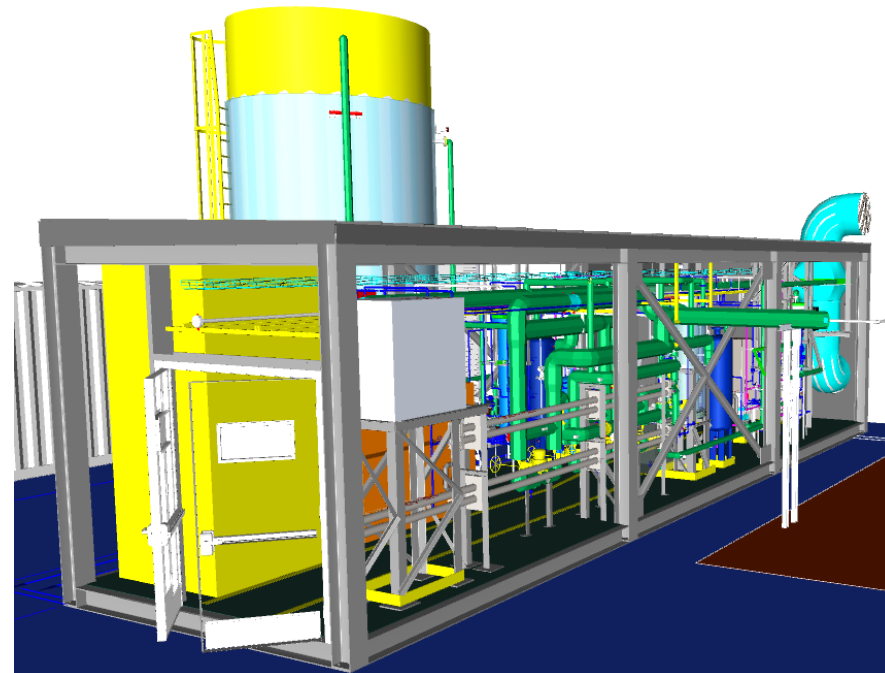
Virent Pilot Plant



>300x
scale-up

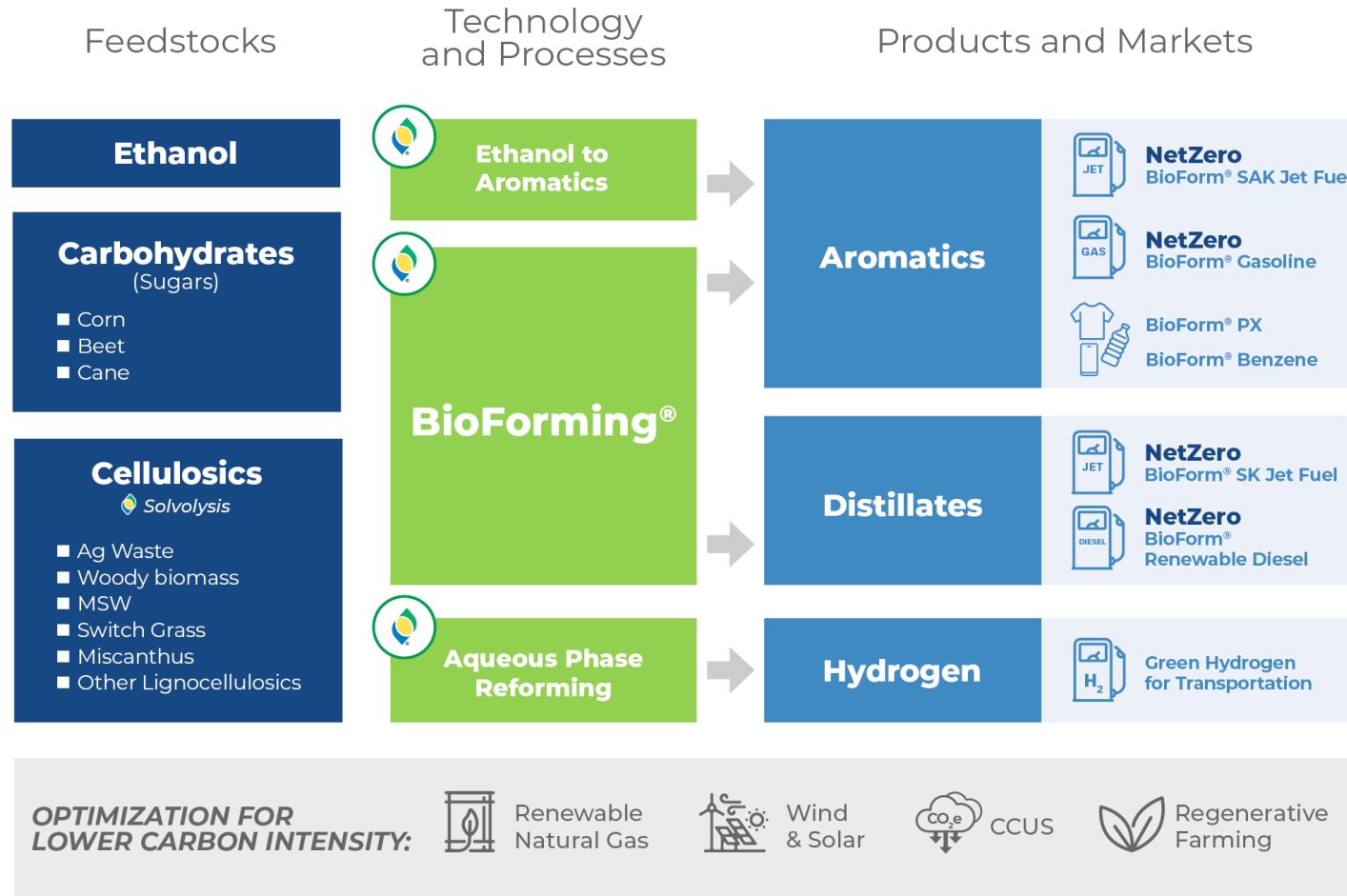


Planned Demo Plant





Virent Interested in All Low-Carbon H₂ Approaches



- Other Virent technologies require H₂ and any progress in low-carbon H₂ production is a benefit to the industry



Innovating for a Low Carbon Future