SYZYGY PLASMONICS

ENERGY. TECHNOLOGY. SUSTAINABILITY.

PHOTOCATALYTIC DECOMPOSITION OF AMMONIA

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AMMONIA ENERGY CONFERENCE

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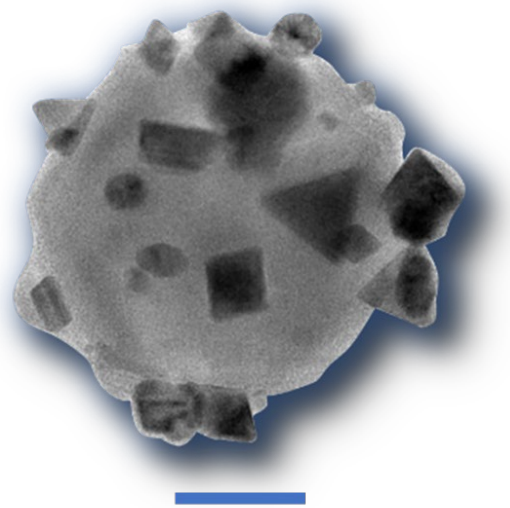
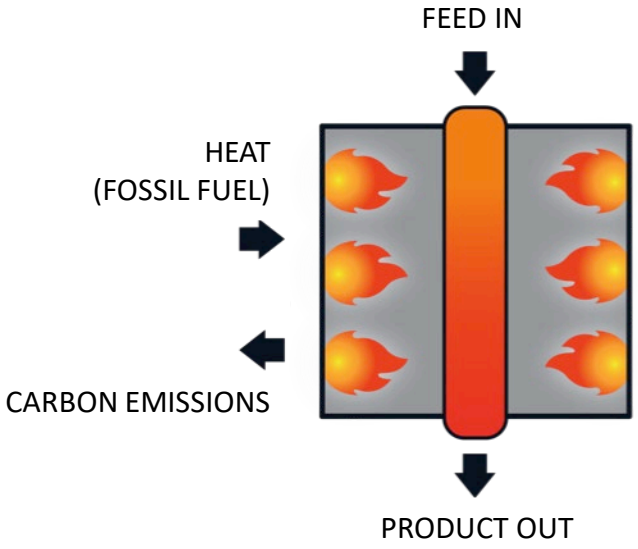
Syzygy chemical reactors replace heat from fossil fuel with light from renewable electricity

Based on novel photocatalysts developed at Rice University

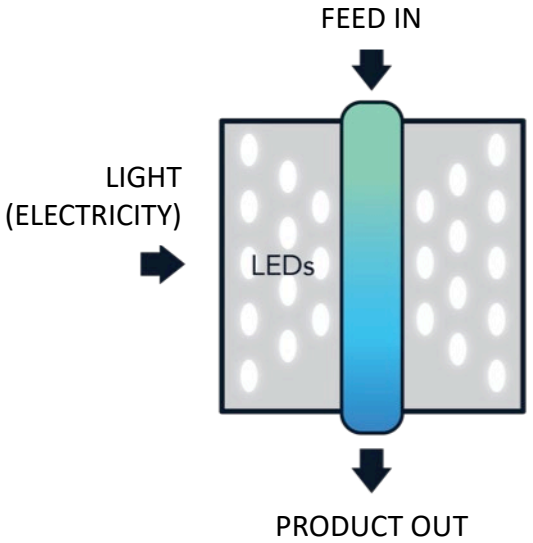


TEM image of a Syzygy photocatalyst nanoparticle

How reactors operate today



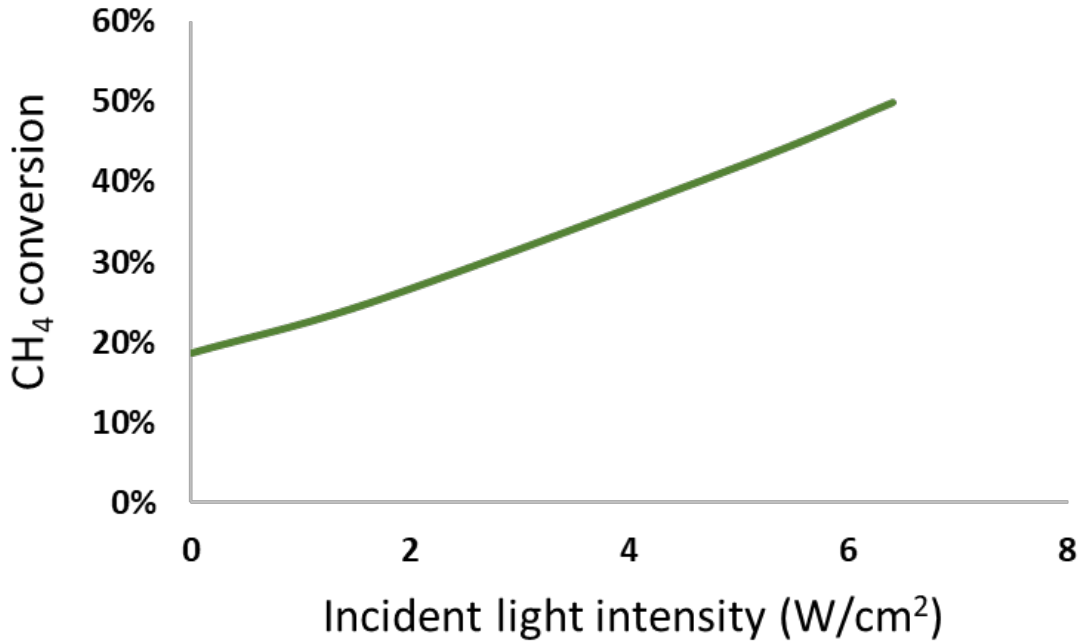
How Syzygy reactors work



<u>Our Vision:</u> Drive 1 gigaton of CO_2eq emissions reduction by 2040

Syzygy's photocatalysis technology: Unique, novel science

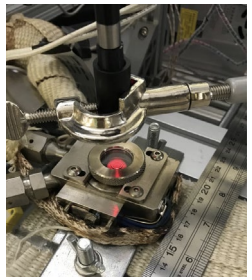
Lab test data demonstrating the increase in feed conversion with increasing light intensity in P-SMR™ photocatalyst at constant reaction temperature



P-SMR™ = Photocatalytic steam methane reforming

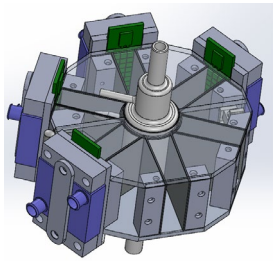
- **Conventional catalysis**: Reaction rate has exponential relationship with temperature
- **Syzygy photocatalysis**: Reaction rate has exponential relationship with both temperature and light Intensity

Syzygy Scale Up Progress to Date

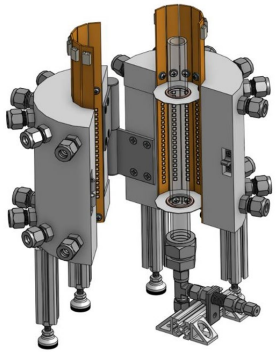


Micro Reactor

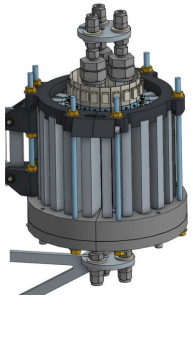
First Photocell



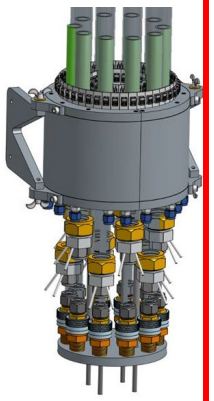
Basic Small Cell Reactor



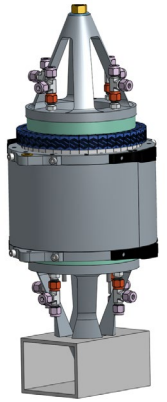
Advanced Small Cell Reactor



3-Cell Reactor



10-Cell Reactor



Large Cell Reactor
(TODAY – Multiple Iterations)

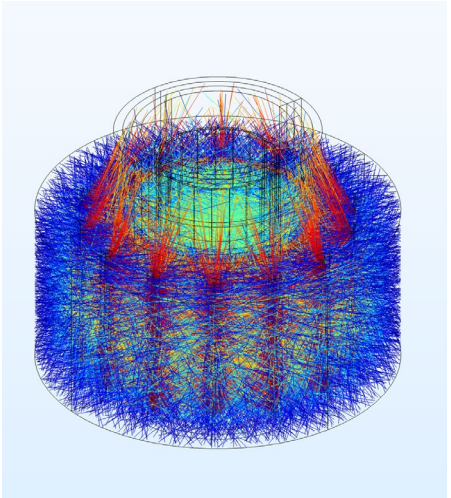
	2018	2019	2020	2021
H_2 Produced	10 mg/day	100 g/day	1 kg/day	**5.4 kg/day (P-DA)**
kWh per kg H_2	0.5 MWh	68 kWh	49 kWh	**23 kWh (P-DA)**
TRL	3	4	5	**6**

Reactor Simulation and Modeling

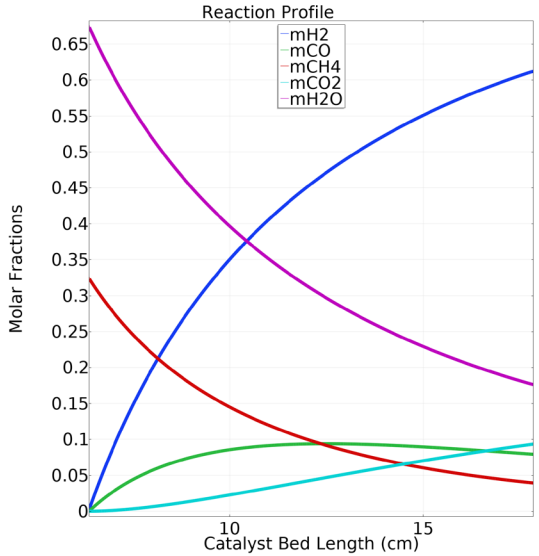
Multi-Physics computer models for photocatalysis as a Predictive Model for reactor performance

- Multi-Physics Models (COMSOL, Python) for geometric optics, ray tracing, heat transfer, fluid flow, and mass transport are combined with reaction kinetics.
- Modeling to predict the performance of a new photoreactor and/or to improve the performance of our photoreactors.
- This allows us to evaluate designs without having to build and test a reactor.

Geometric Optics



Reaction kinetics



Sample images

Syzygy IP Position

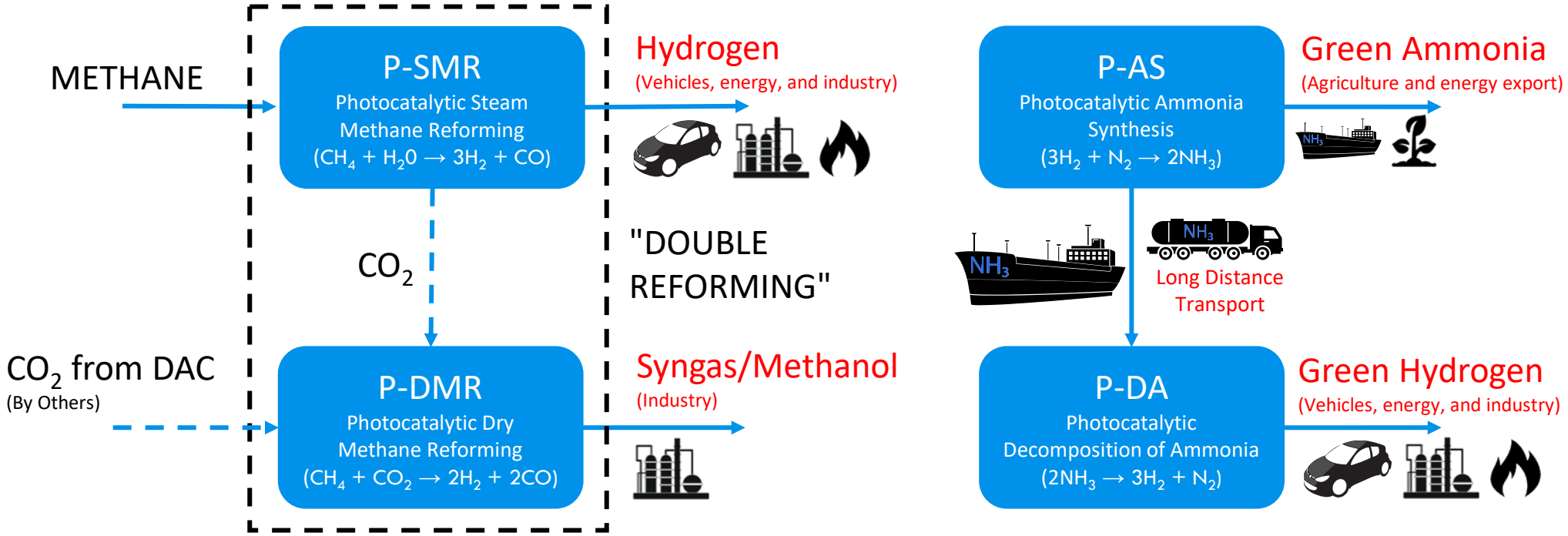
Patents

Patent Family	Unique patents	Status (combined/summary)
Photocatalyst	2	Granted: 7 jurisdictions Pending: 9 jurisdictions
Photoreactors	4	Granted: 3 jurisdictions Pending: 39 jurisdictions Provisional: 1 PCT: 1
Advanced Photoreactors	1	Provisional: 1
Chemical Production Systems	2	Provisional: 1 PCT: 1

Other IP notes

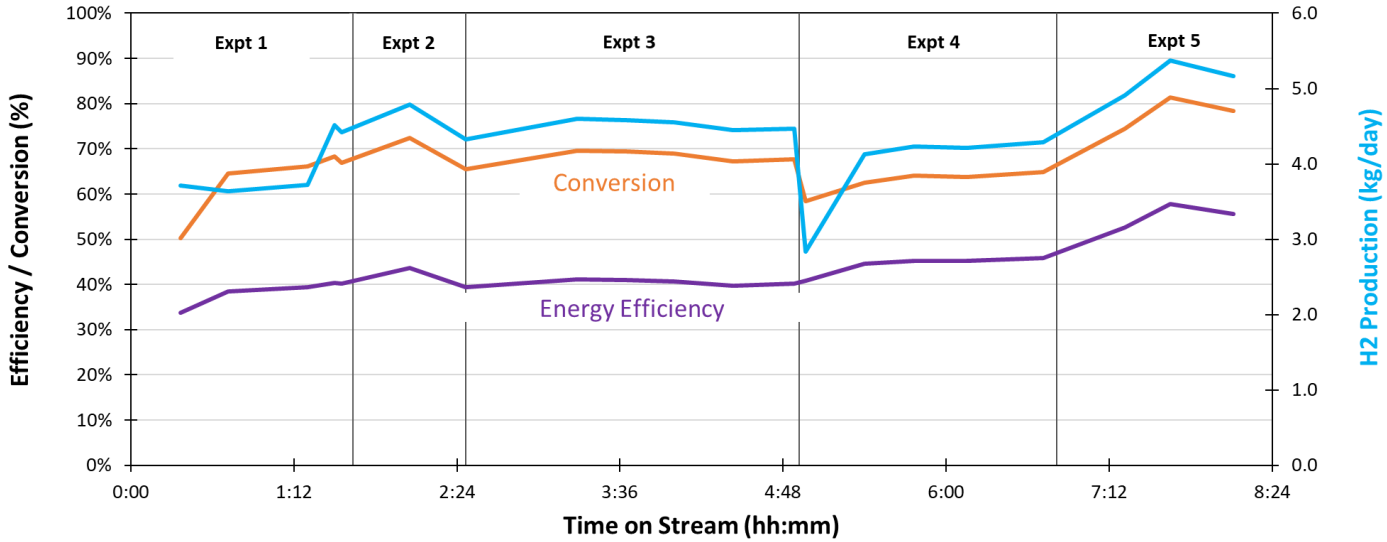
- Multiple new patents in writing
- Trade Secrets: ~2 dozen
- Trademark strategy in place

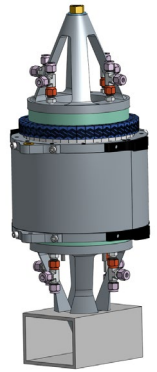
SYZYGY IS ACTIVELY DEVELOPING FOUR PROCESS TECHNOLOGIES



P-DA™ (Ammonia Splitting) Reactor Test Data

P-DA™ reactor best results	
Max energy efficiency observed (produced H_2 basis)	56%
Max conversion observed	100%
Max H_2 / day production observed	5.37 kg-H_2 per day
Next Reactor Size	200 kg-H_2 per day
Longest duration test performed with the same catalyst	200 hours
Feed	100% NH_3 1 pass
Space Velocity	~7000/h
Electrical energy in (This Test)	23 kWh per kg-H_2
Electrical energy in (Goal)	10 kWh per kg-H_2





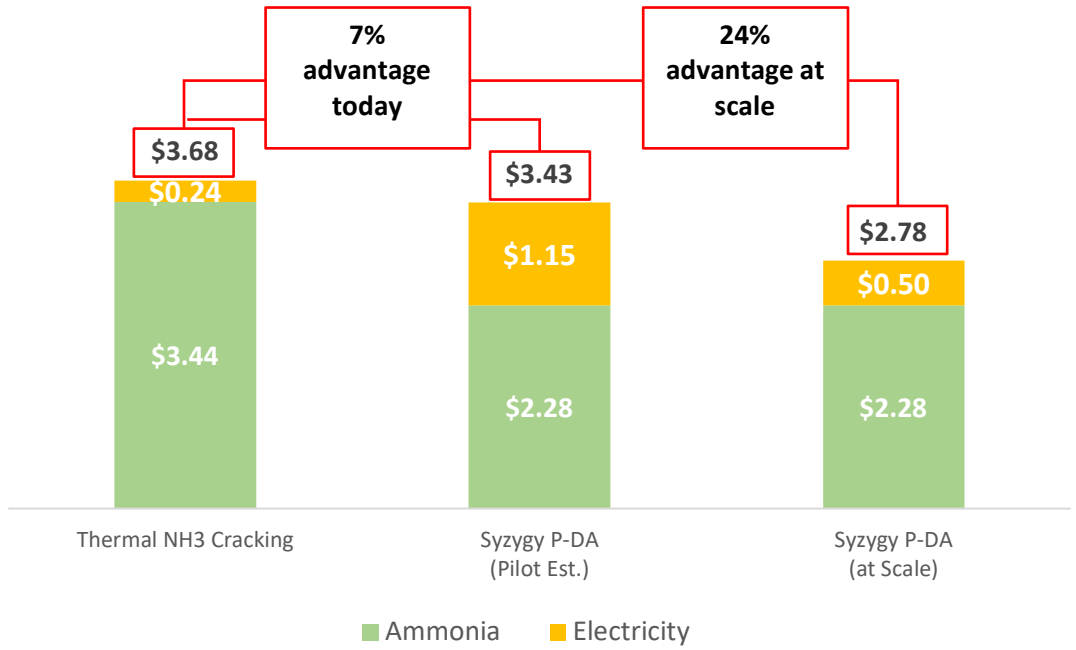
1. Test results with the Large Cell Reactor
2. Reactor made with glass, aluminum and plastic

P-DA™ produced H_2 cost estimates

Comparing Syzygy's P-DA™ To Thermal Cracking of NH_3

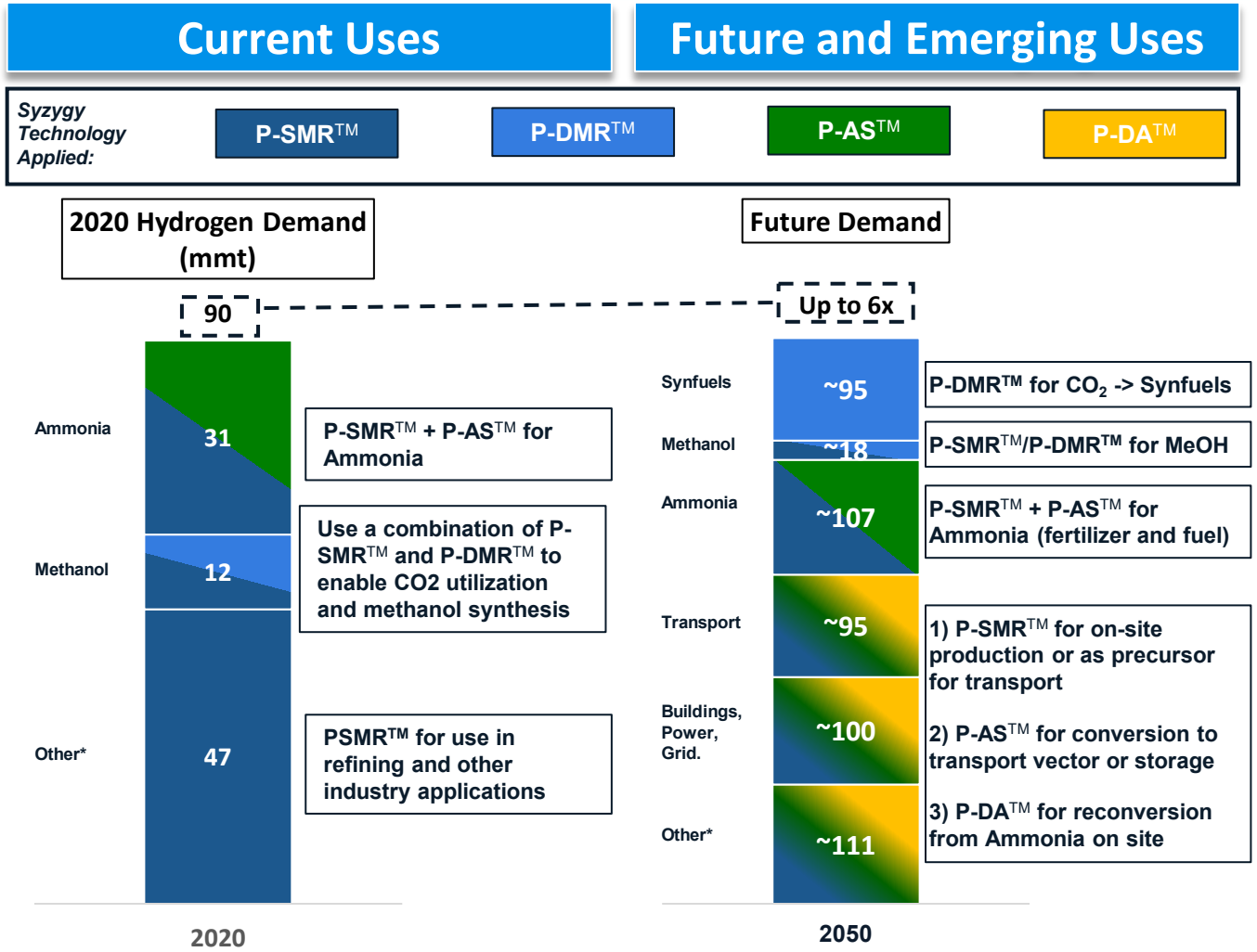
	Thermal NH3 Cracking	Syzygy P-DA (Pilot Est.)	Syzygy P-DA (at Scale)
Ammonia (kg)	8.6	5.7	5.7
Electricity (kwh)	4.8	23.0	10.0
Total Input (kwh / kg H2)	49.2	52.5	39.5
Projected Energy Efficiency	68%	63%	84%

Good technology performance translates to great economic benefit potential



Syzygy's Technology Platform Unlocks the Full Hydrogen Value Chain

- **Syzygy's platform technology will integrate at multiple points within the hydrogen value chain**
- **Primary demand for hydrogen can potentially increase 6x from 2020 to 2050**
- **Upstream hydrogen demand supports many multiples of downstream products**
  - 1kg of H_2 supports 6kg of NH_3
  - 1kg of H_2 supports 8kg of MeOH
- **Syzygy technology will be able to enable the hydrogen economy throughout the value chain**
  - Enables primary H_2 production
  - Converts H_2 into NH_3 for cost-efficient storage and for transport
  - Reconverts NH_3 into H_2 at the point of use
  - Enables CO_2 utilization for things like MeOH and other synfuels



IEA Global Hydrogen Review

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