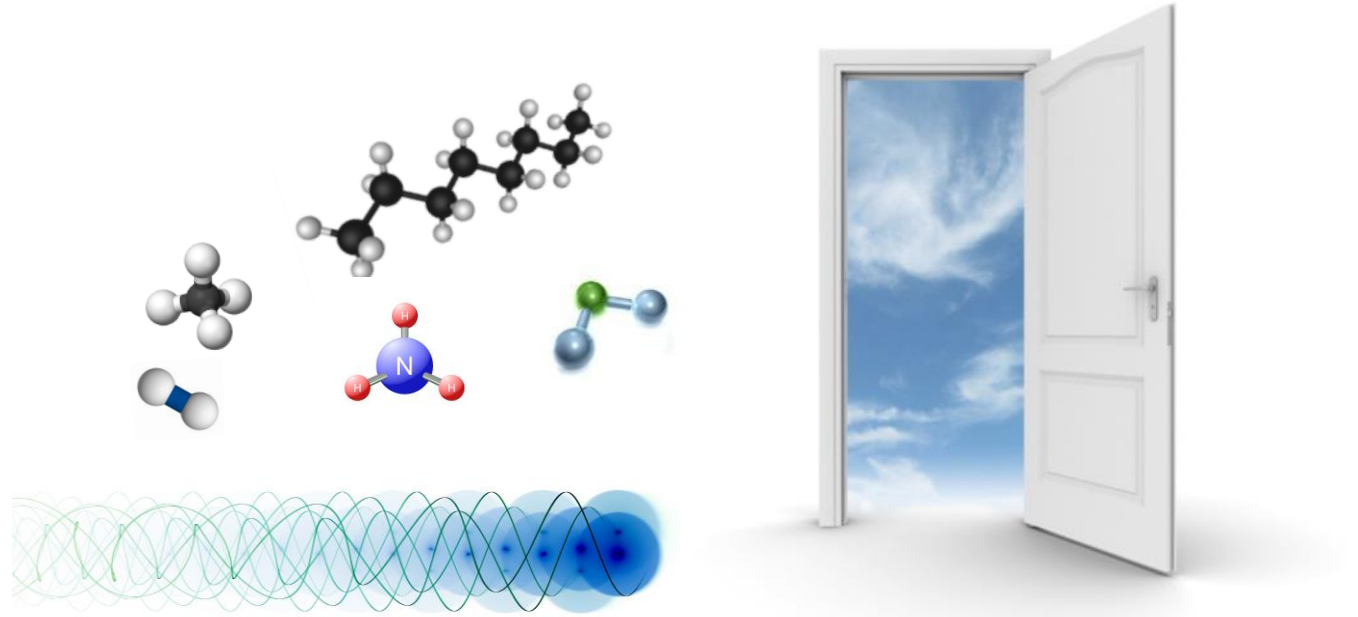


The Slow Pace of Big Change

The Future of Energy Systems



Designed for
Deloitte. 

Designed by
Garry Golden

**Every day I make an effort to move toward
what I do not understand.**

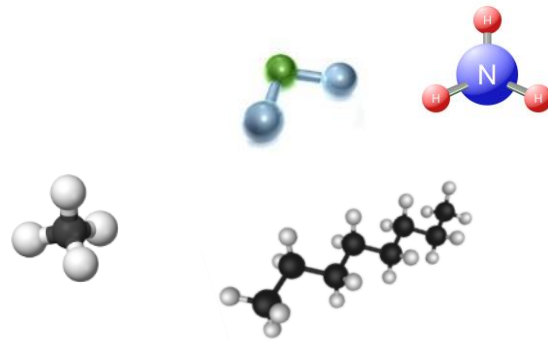
- Cellist, Yo-Yo Ma

Start

End



In the News



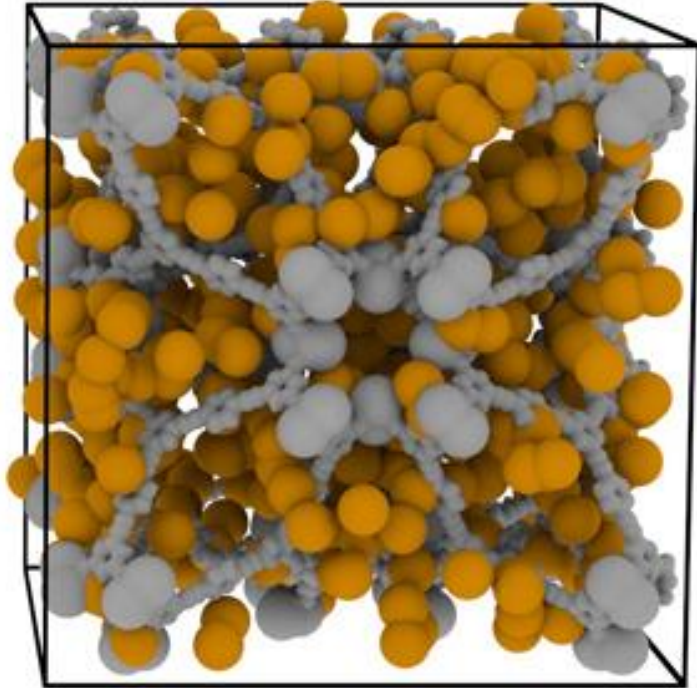
Emerging Solutions for Deep Decarbonization



In the News

High Surface Area Crystal Sponges

MOFs – Metal Organic Frameworks



Northwestern
Image by Christopher Wilmer/NuMat Technologies)



Science Journal



In 2019 Tokyo Gas will sell solid *green gas* (MOFs) in 7-11 stores as fuel for portable micro fuel cells that recharge devices.

True

 TOKYO GAS



False

Dubai Testing Retail based Fuel Distribution for EV Scooters



Scenario: Portable, Retail-Shelf Distribution of *Green Gas*



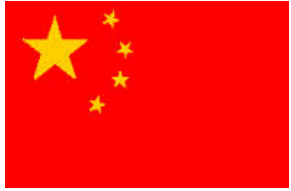
MyFC predicts that fuel cells will surpass batteries in energy density and cost efficiency in a few years

Could fuel-based micro-power systems be at same developmental stage as cell phones in mid 1990s?



Renewables Moving Beyond Electrons to Molecules

What could happen in 12 years?



China Moving Beyond Battery



Acquisitions in Portable Power



Unplugging at Burning Man



Houses without Electrical Sockets



Vision: #1 Fuel Distributors

2022

2024

2028

2030



Embedded Fuel Cell Systems: Fuel Format, Access, & Competition

One week battery life on an iPhone 6? It's possible

POSTED 1:49 PM, AUGUST 28, 2015, BY CNN WIRE



An Apple iPhone and a quadcopter, both retrofitted with hydrogen fuel cell batteries, and a hydrogen fuel cell are displayed by Intelligent Energy at ShowStoppers. Photo by Ann Singer.



**Consumerization
Adoption Curves**



**Retail Shelf
Simplicity**

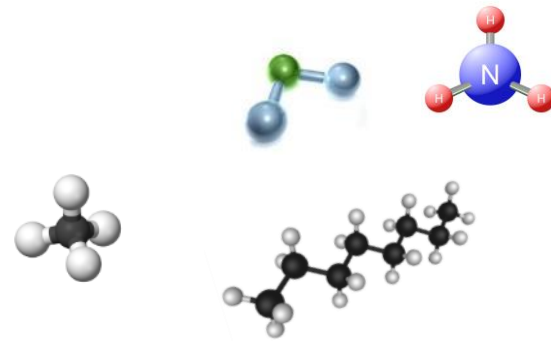


SAMSUNG

**Expanding
Partnerships**



In the News



Emerging Solutions for Deep Decarbonization

End



Decarbonization: Anticipating Transitions & Shifting Expectations



Empowered Cities



Rethinking the Role of Molecules

Empowered Cities



Rethinking the Role of Molecules





Renewables and the Age of Energy Appliances



Solar Plus Storage

BlueGEN[®]



MicroCHP



fuelcellenergy

Power Parks

Fuel cell technology
elcogen

GENCELL

DOOSAN

Nedstack
PEM FUEL CELLS

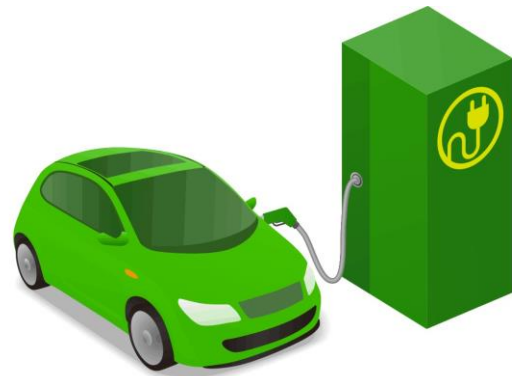
POWERCELL

Bloomenergy

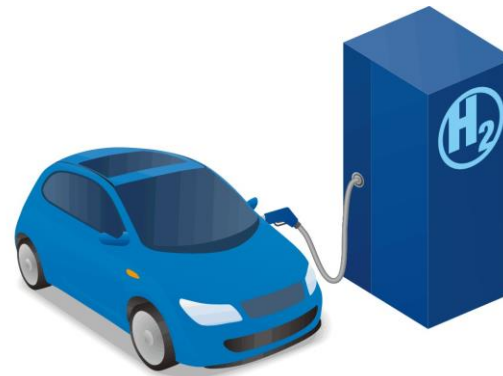
Renewables & Electrification of Vehicle Fleet



Hybrid ICEs



Plug-in EVs



Fuel-based EVs

Thinking Beyond
Passenger Vehicles:

Rail
Marine
Trucking
Aviation/UAVs

Autonomous
Last Mile / Micro
Transit
Indoor Robotics
Outdoor Robotics

BEVs 'Have Won' vs Limitations of All Electric Pathway

Battery pack = 400 miles
Daily Need = 40 miles

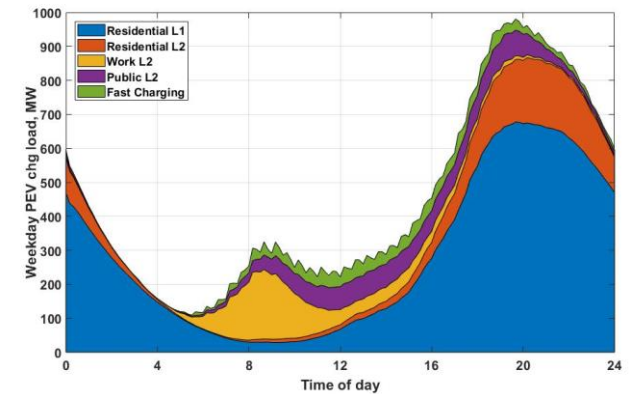


OEM Cost-to-X
vs Daily Use Demand



Uptime &
Recharging for
Urban Markets

'Duck Curve' to 'Dragon Curve'



Full Costs of
Grid Management

The Shared Strategy for Integration & Fuel-based EV Fleet



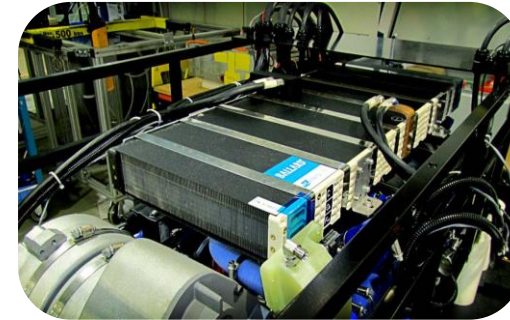
NIKOLA ONE™

Trucking



POWERCELL

Royal Caribbean INTERNATIONAL VIKING YANMAR ABB



Maritime



ALSTOM

Hydrail



Ultra Electronics | USSI | Protonex® a Ballard® company | flyH2 AEROSPACE



Aviation / UAVs

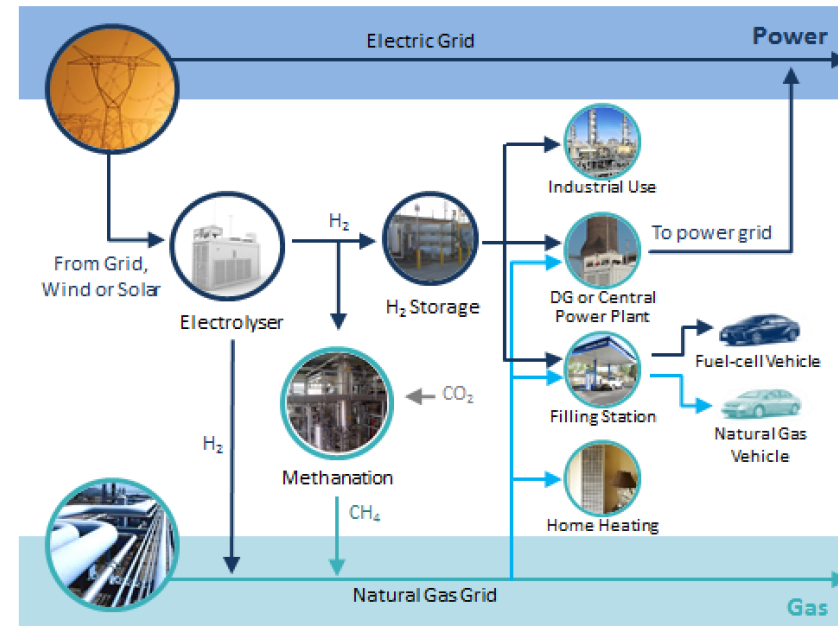
Is it (Finally) Safe to Talk Publicly about Hydrogen?

HANNOVER MESSE

GROUPEXHIBIT

HYDROGEN
FUEL CELLS
BATTERIES

Power-to-Gas – Energy Conversion and Storage



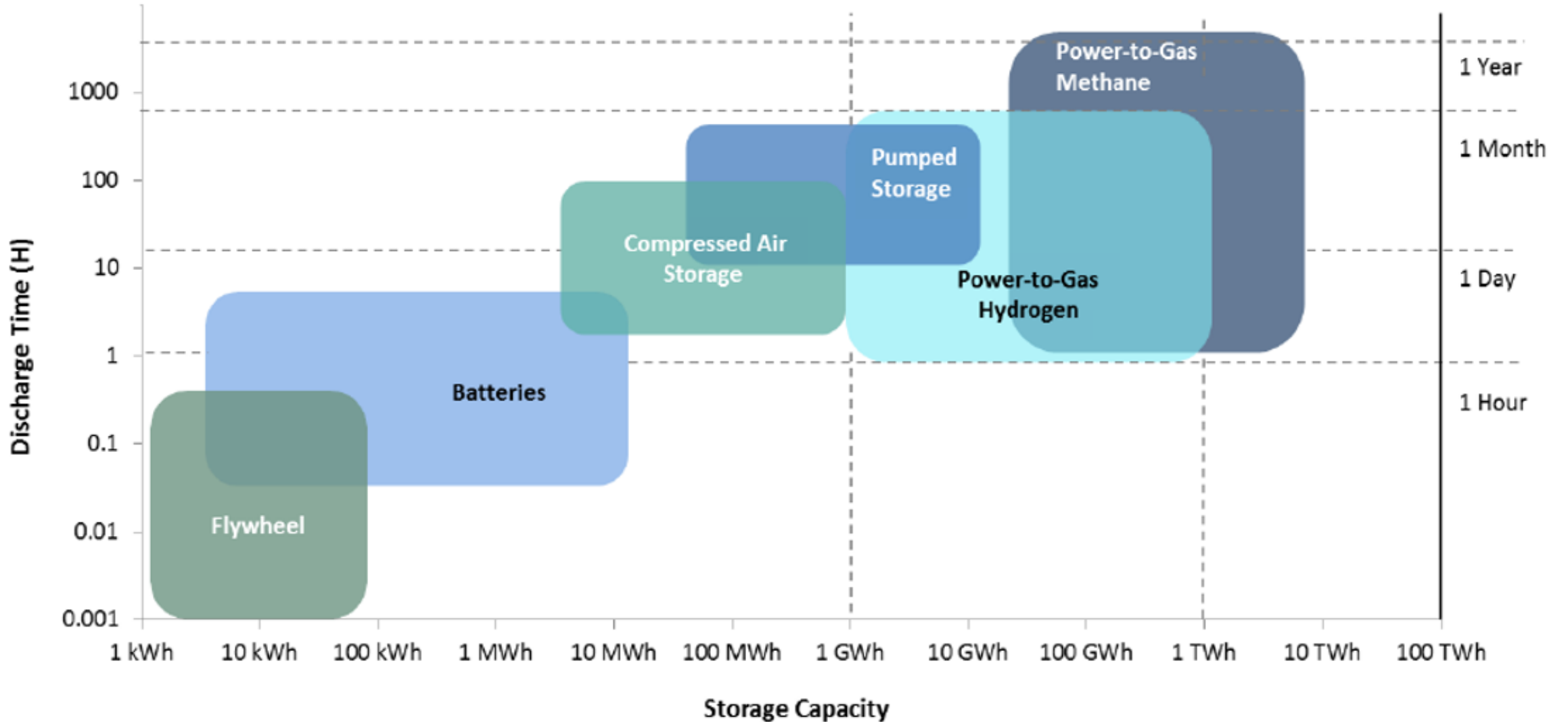
Power-to-Gas for Renewables Integration

ARPA-e REFUEL Kick-off Meeting

August 18, 2017

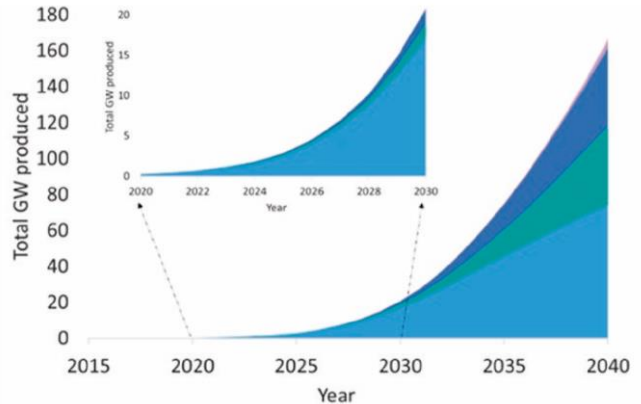
Jeffrey G. Reed, PhD
Director Business Strategy
and Advanced Technology

Renewables ♥ PtG - Scale & Versatility of Hydrogen; Brand of 'Renewable Gas'



After Fraunhofer ISE, 2015

PtG by Incumbents Who Do Scale, Versatility & Business Model Design



■ PEM electrolysis
 ■ AEM electrolysis
 ■ SOEC electrolysis
 ■ PEC
 ■ STCH

Projected hydrogen capacity (energy input) from advanced water splitting technologies in the next 25 years

PEM = proton exchange membrane; AEM = anion exchange membrane; SOEC = solid oxide electrolysis cell; PEC = photoelectrochemical; STCH = solar thermochemical.

Katherine Ayers © Materials Research Society, 2017

Production

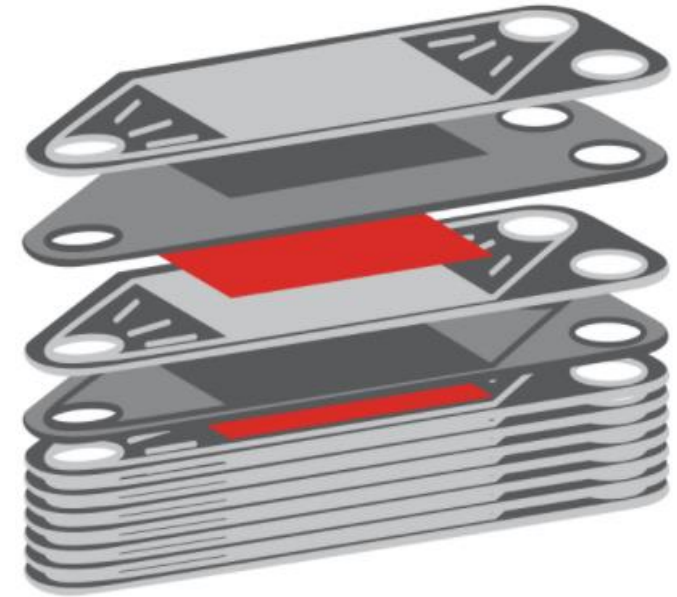
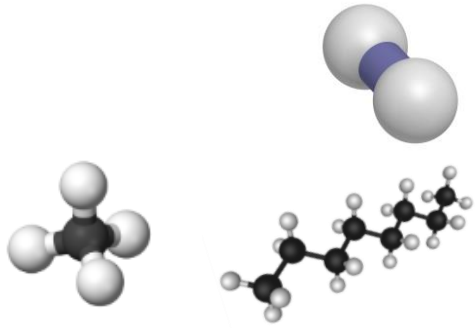


Compression



Storage

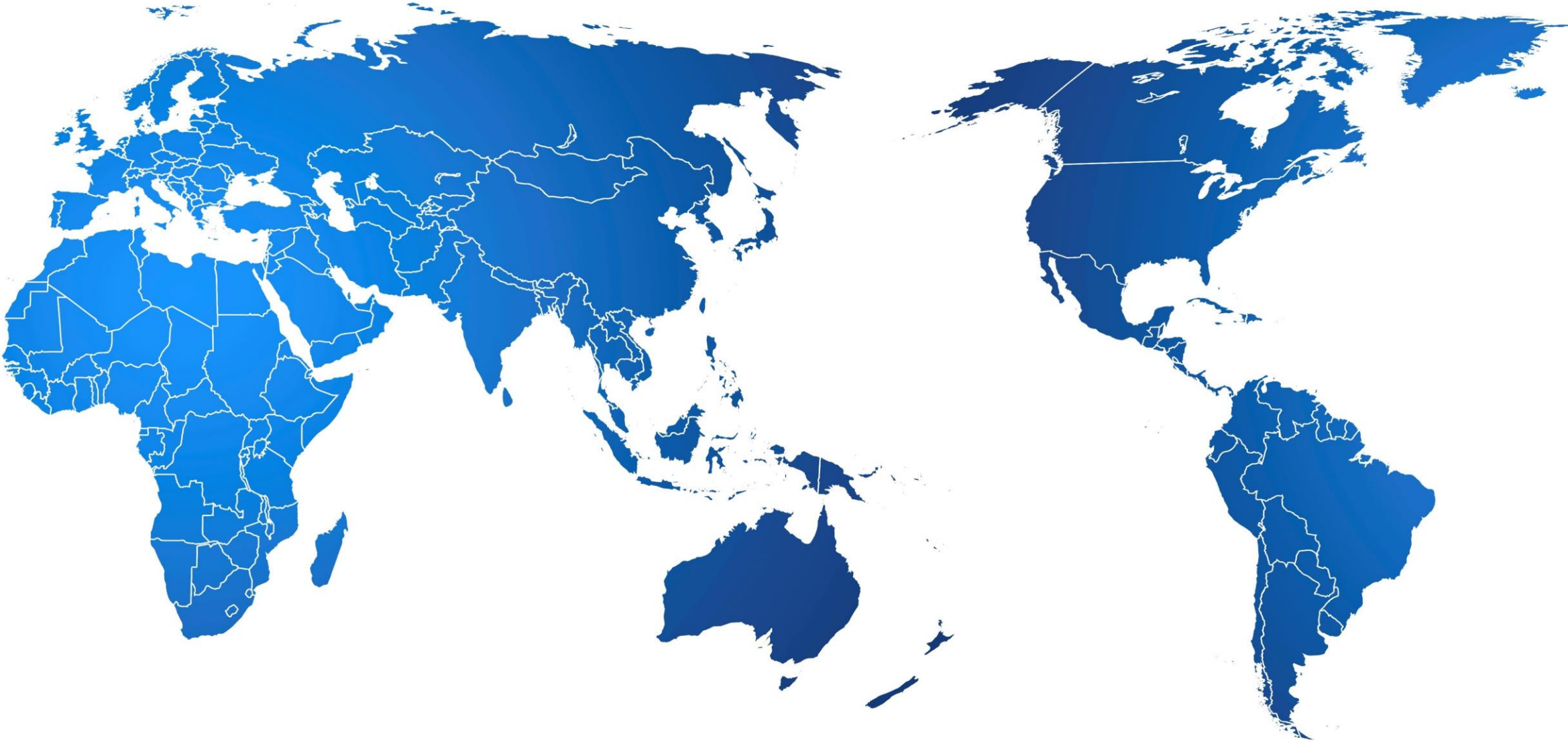
How might Oil/Natgas Incumbents React to Green Gas?



ACTIVE CERAMIC MEMBRANES

COORSTEK.

Global Lens on Market Transitions: 2020 – 2035





Thank You!!

PDF + Resources

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Two Rs