

The Slow Pace of Fast Change

The Future of Energy Systems



Garry Golden

Forward Elements Inc

October 31, 2018

The *Slow Pace* of Fast Change



20th Century Dynamics

Alternative Futures

Baseline Future

Integrated (Gas + Grid)
Cyber Security
Transactive Grid
Distributed
Design for
Behavior Change

Maintenance,
Preservation
& Renewal

21st Century Dynamics
Digitalization Decentralization Decarbonization

Start

End



**Surfacing
Uncertainties**



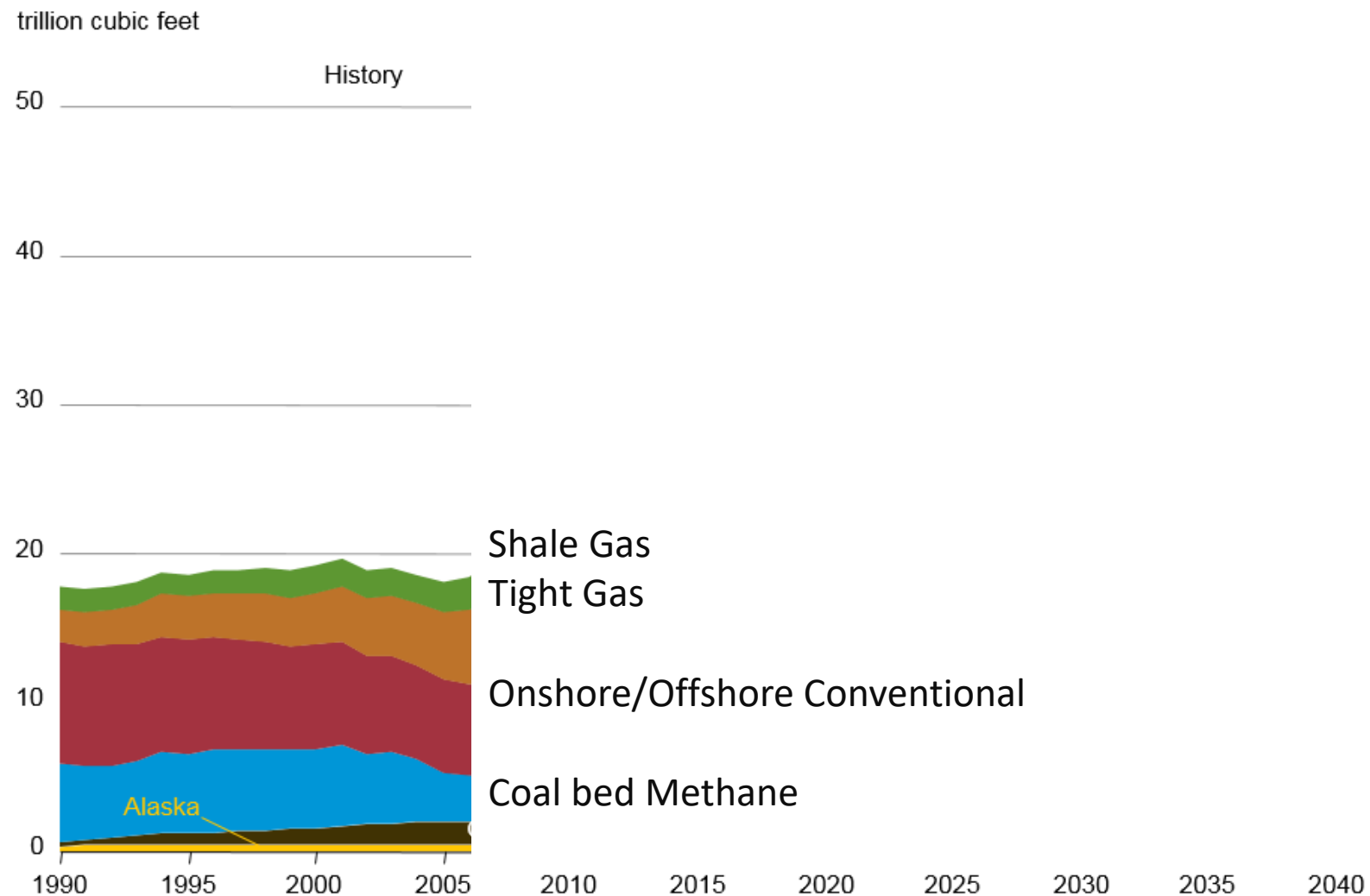
**Imagining
Transitions**



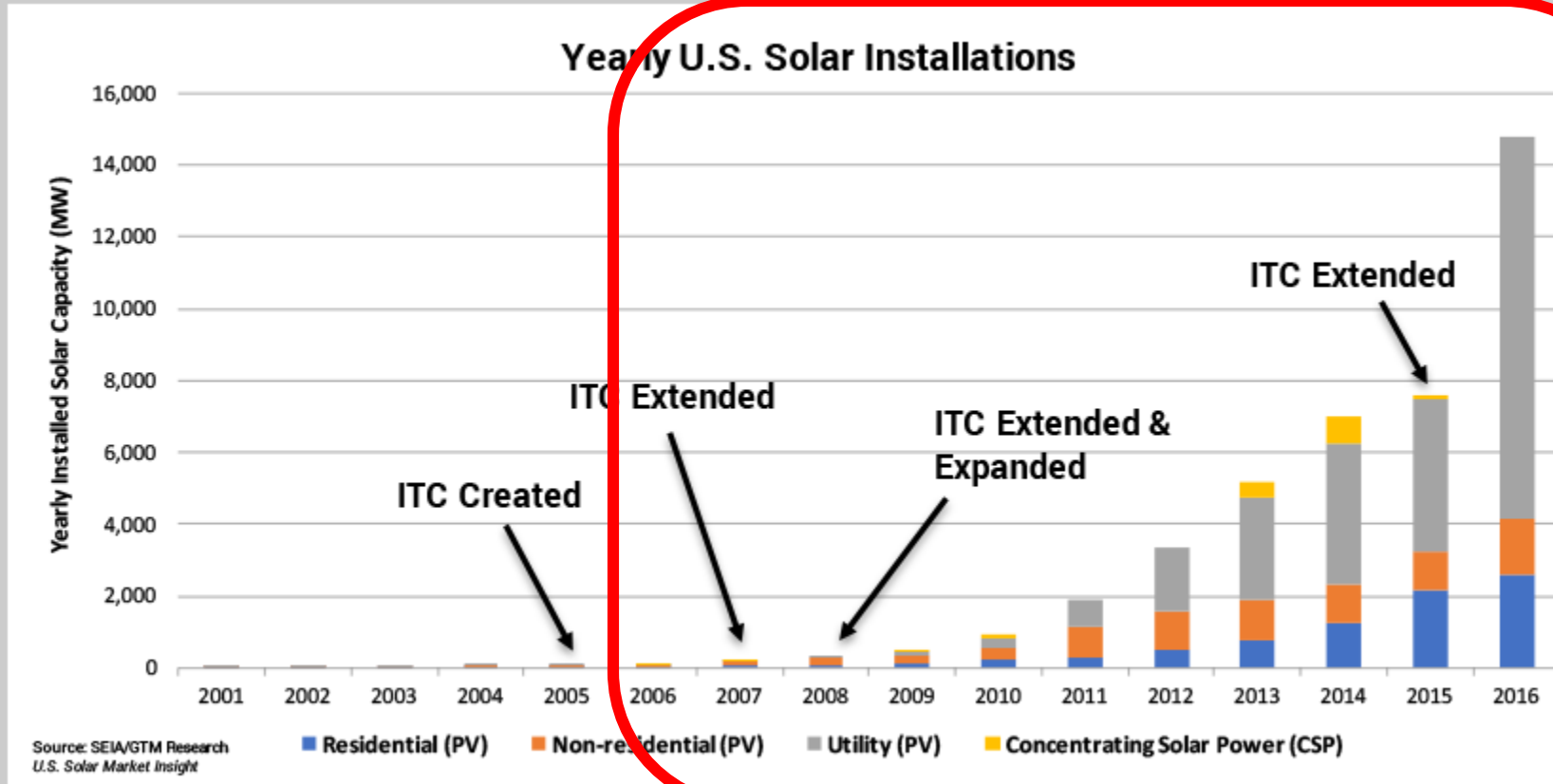
**Next
Steps**

10 Years: Uncertainties in Fuel Dynamics

Figure MT-46. U.S. dry natural gas production by source in the Reference case, 1990–2040



10 Years: Uncertainties in Policy



10 Years: Uncertainties in Players & Business Models



TESLA



Alphabet

amazon

Oil Giant Shell Wants to Sell You Electricity

Big Oil pivots to electricity,
Total leads the way

**Microsoft Is Getting Hungry
for Fuel Cells**

By **Anna Hirtenstein**

October 31, 2017, 1:00 AM EDT

Amazon acquires right to buy stake in
fuel cell maker Plug Power

**Walmart takes a page from
Amazon, invests in Plug Power**

10 Years: Uncertainties in Technology Deployment

Coal comeback? Cleaner Natgas?

Transforming Generation Asset Utilization & Longevity?

Coal plant – no CO₂ capture	500 MW	.06 (\$/kWh)
90% amine capture	400 MW	.11 (\$/kWh)
90% CO₂ capture w/ fuel cell	900 MW	.08 (\$/kWh)
5% CO ₂ capture with fuel cell	522 MW	.06 (\$/kWh)

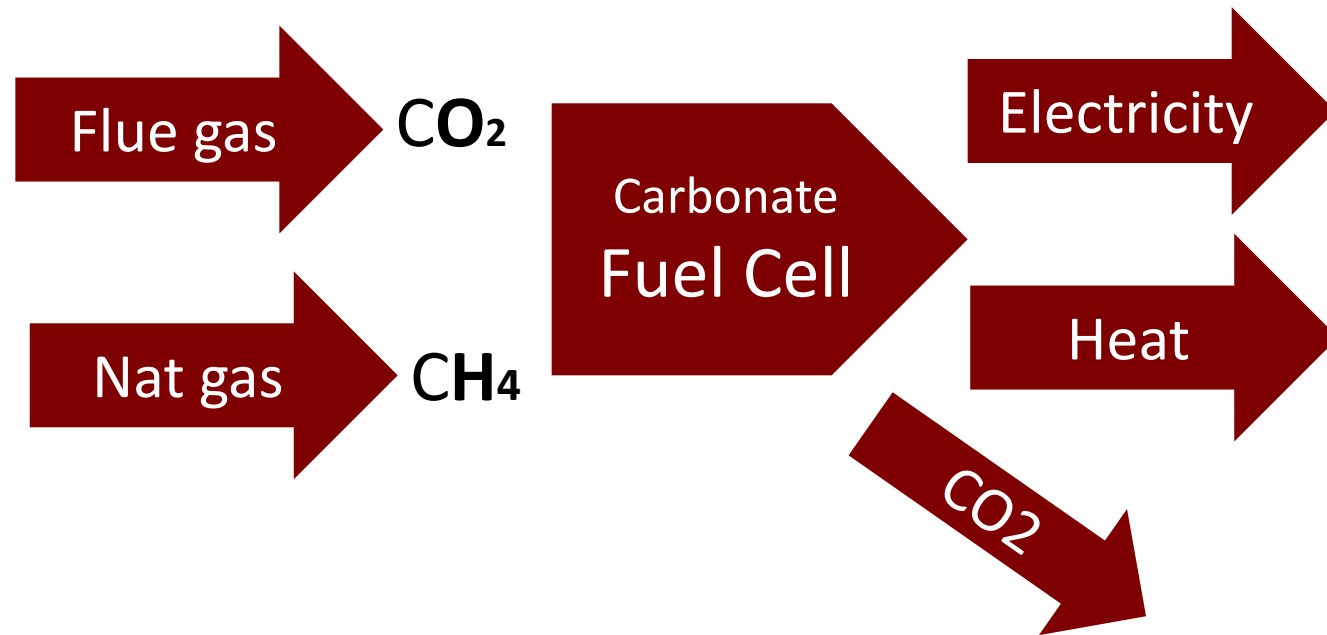
(Source: Fuelcell Energy & ExxonMobil)

ExxonMobil

fuelcellenergy



Carbonate Fuel Cells



10 Years: Uncertainties of Radical Ideas (Retail Shelf)



**Utilities & Partners:
Conversations on what we do not understand**



Four Futures Thinking

?



**Continued
Growth**

**Disciplined
Constrained**

Transformed

**Decline
Collapse**

Describing the Four Futures for The Future of...



**Continued
Growth**



**Disciplined
Constrained**



Transformed



**Decline
Collapse**

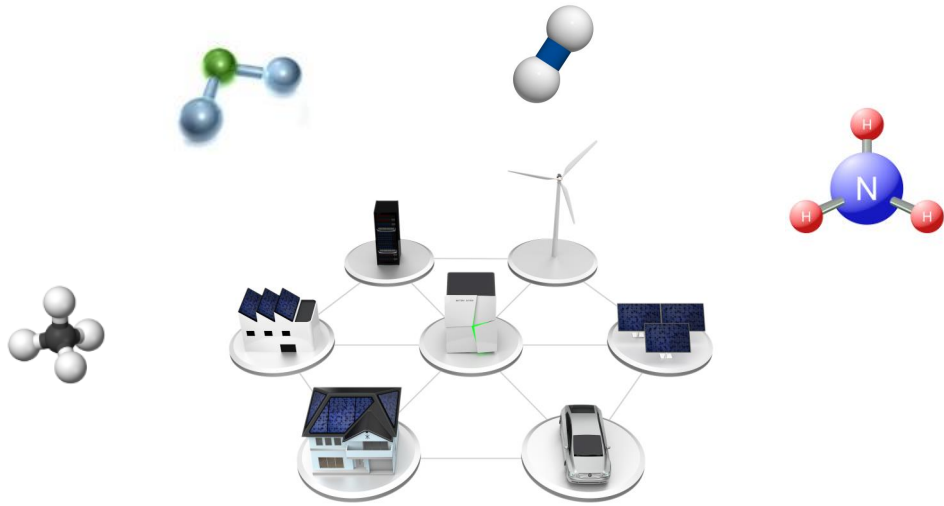
End



Transitions Ahead



Next Steps



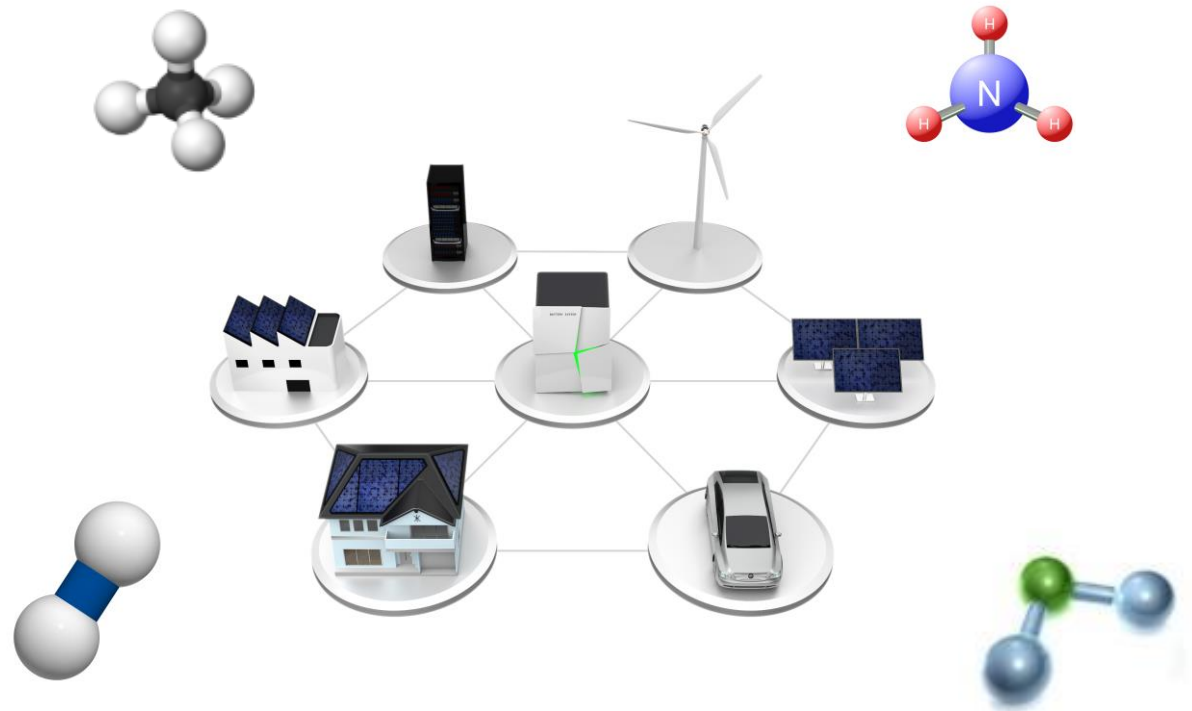
**Rethinking Role of Molecules:
Distributed Energy Resources
+ 'Electric' Vehicles**



**Blockchain
Hype vs Hope**

2020 – 2030

Rethinking the Role of Molecules



Partial Story of Biggest Electrification Headlines

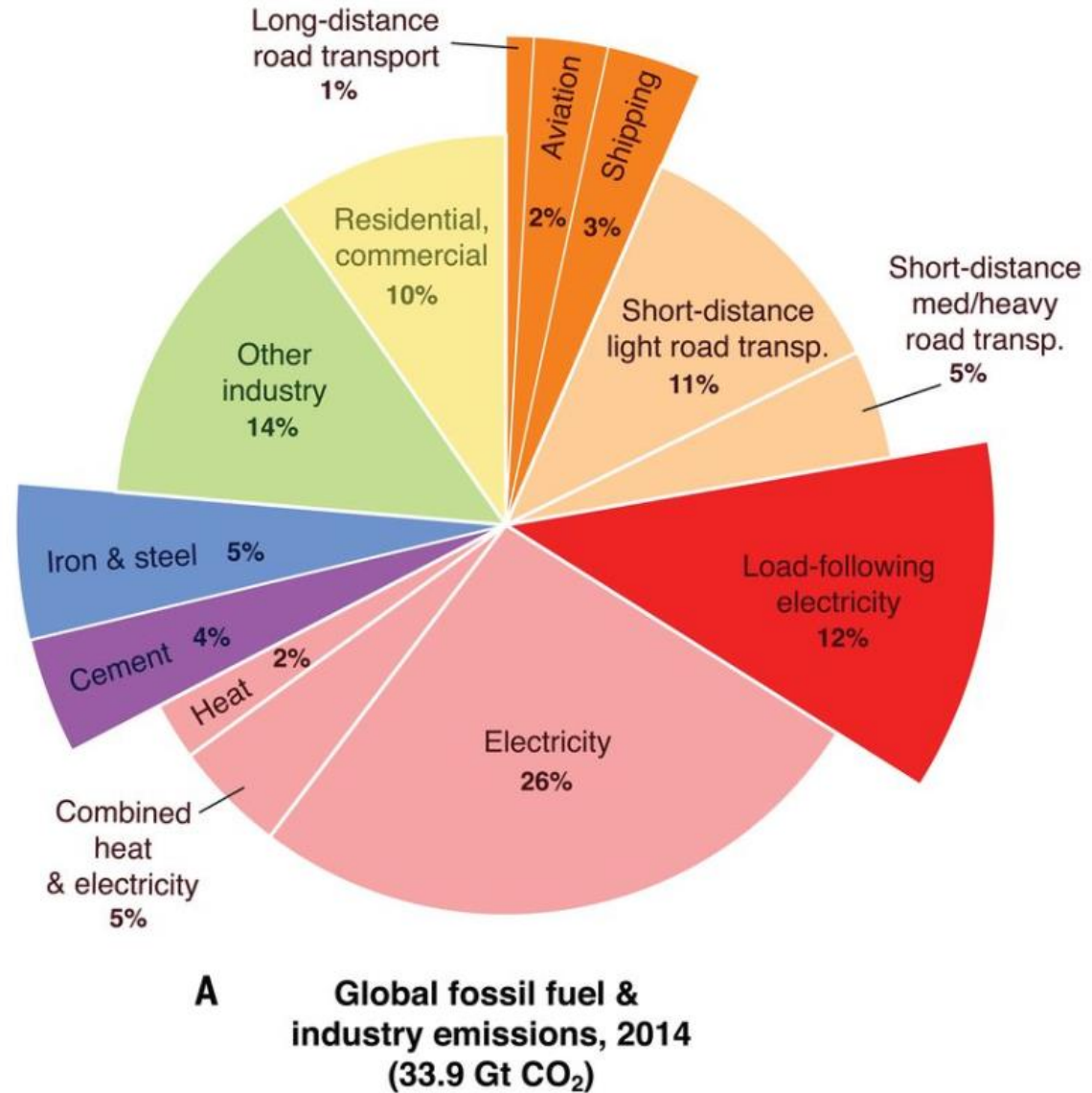


Solar on Rise



**Energy Storage
Battery Revolution**

Emerging Policies: Decarbonization (Power Sector & Industry)

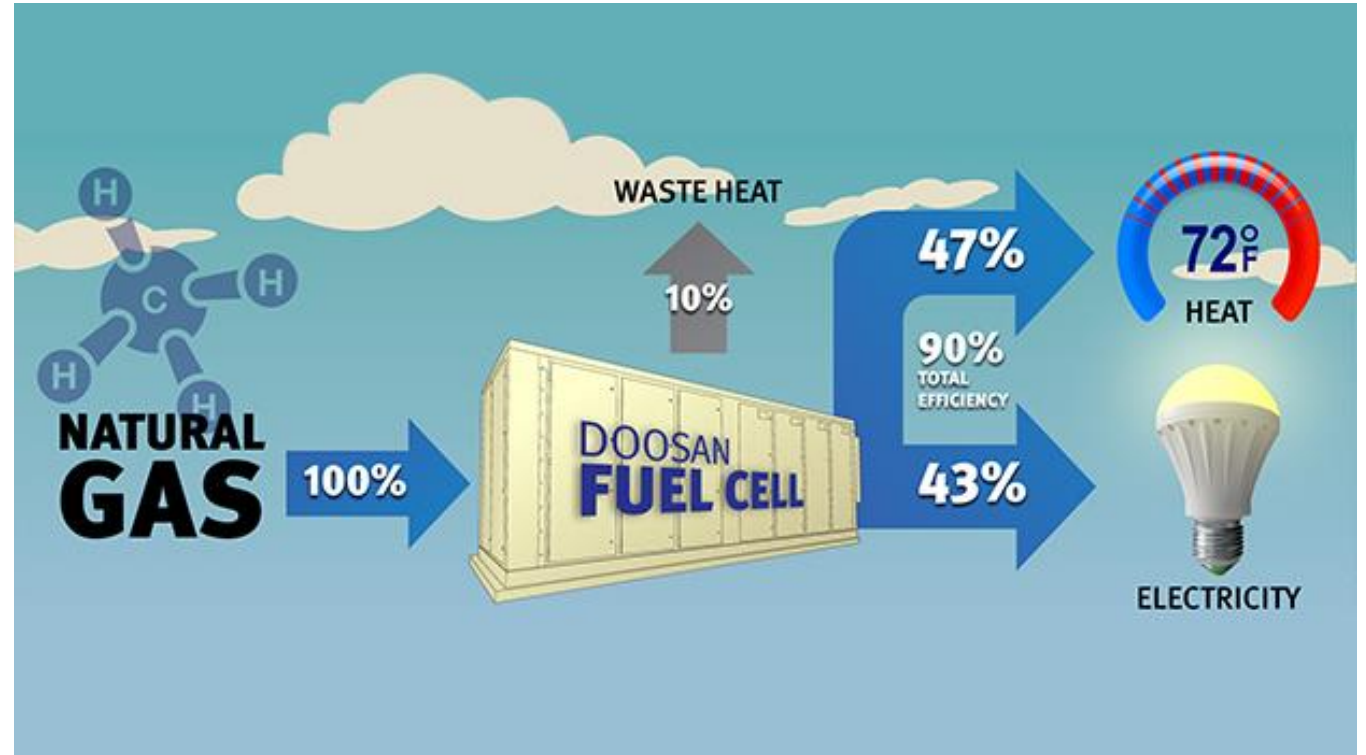


Lingering Scars vs Strengthening Signals

DER Scenario: Natgas + Fuel Cells as Foundation for Transformation



Bloomenergy



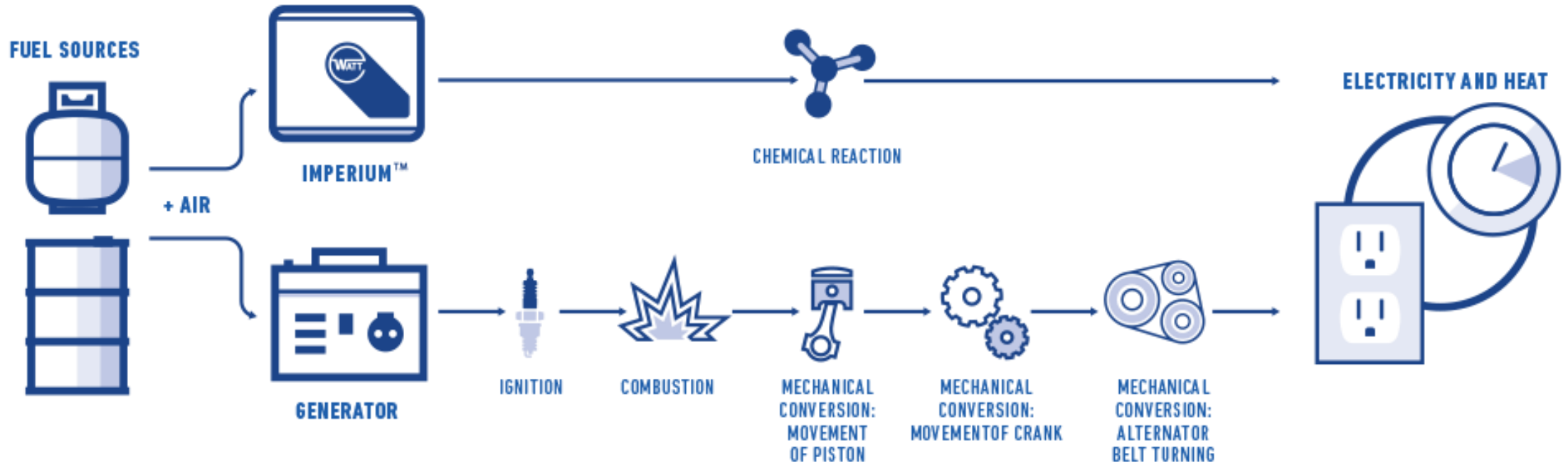
Utilities exploring range of Distributed Energy Resources
and Energy Infrastructure-as-Service Models

The Simplicity of Electrochemical Conversion

21st Century

20th Century

NatGas + (Solid Oxide) Fuel Cells = Oil + Combustion Engine



20 LB PROpane = 55 GAL* DIESEL FUEL = 87 80Ah* BATTERIES

*BASED ON A 3 CYL AND 40A ALTERNATOR

*ASSUMING 50% DISCHARGE



Story of New Energy Appliances: SOFCs (Solid Oxide) & PEM Fuel Cells



100-home pilot program

BlueGEN



EU Passes 1,000 Installs;
US Dealerships
Factory Investments (20K/yr)

PEM Fuel Cell



Construction Site Diesel
Generator Alternatives

Utility Scale Solutions

Utility Debate:

Gas vs Power

Gas + Power



Power Parks
63 MW Beacon Falls

fuelcellenergy

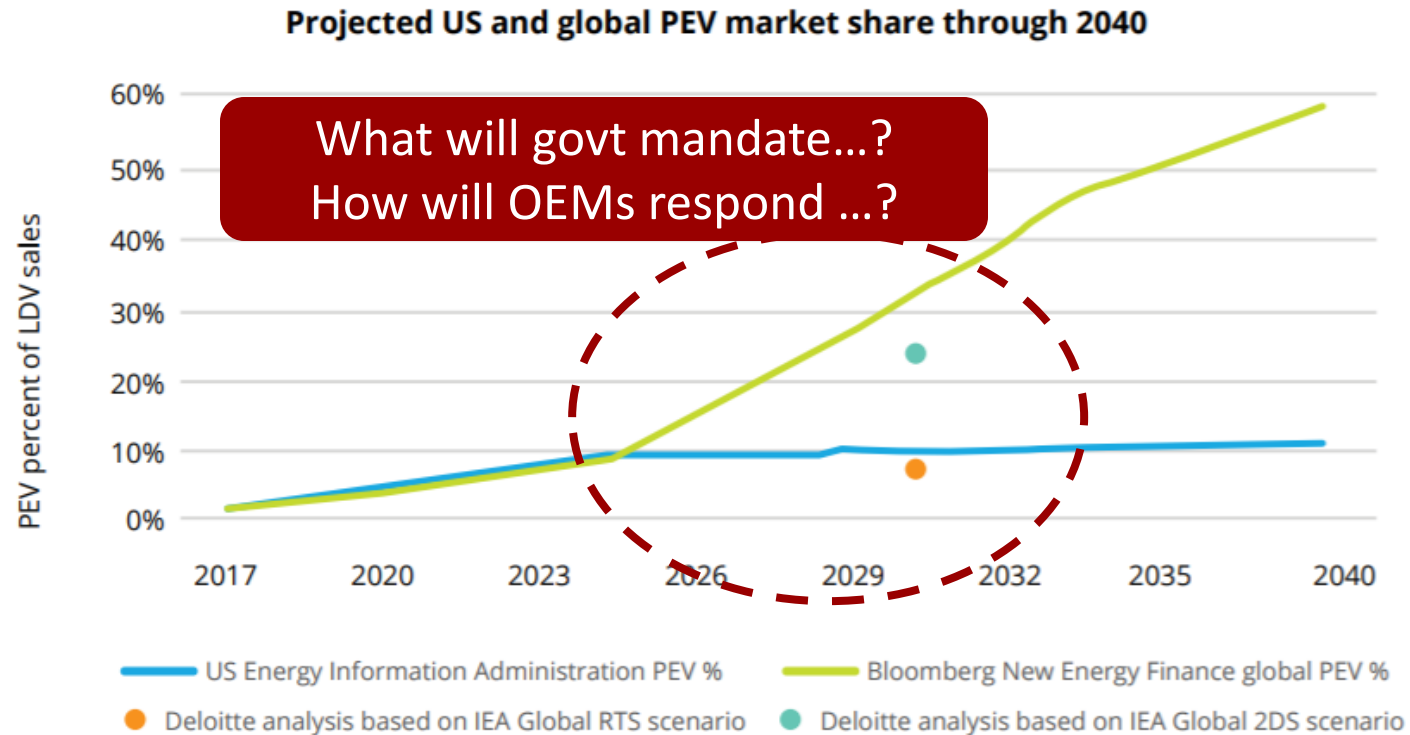
Role of Molecules

Pathways to 'Electrification'



Electrification of Vehicle Fleet

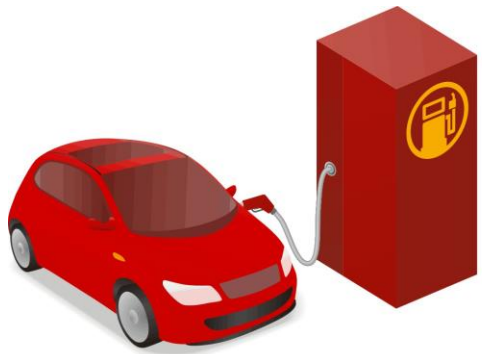
Figure 2. Projected PEV share of total light-duty vehicle sales



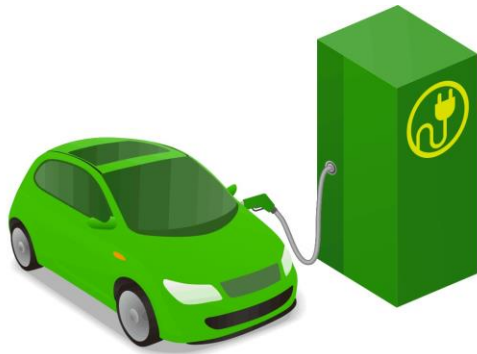
The IEA's Reference Technology Scenario (RTS), projecting 56 million electric cars in circulation by 2030, reflects projections that respond to policies on energy efficiency, energy diversification, air quality, and de-carbonization that have been announced or are under consideration. The IEA's 2DS scenario, projecting 160 million EVs in circulation by 2030, occurs in a context consistent with a 50% probability to limit the expected global average temperature increase to 2°C. We estimated annual sales required to meet IEA's EV stock projections for 2030 and then calculated the EV share of sales as a percent of total light-duty vehicle sales projected by Bloomberg New Energy Finance for 2030.

Source: Deloitte analysis.

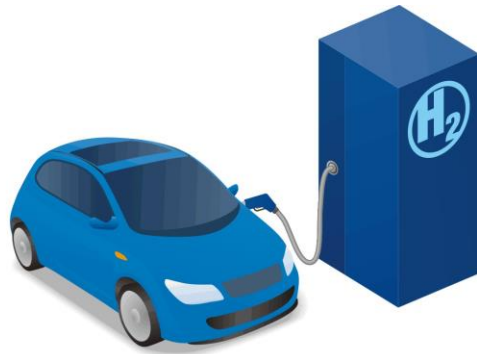
Pathways to 'Electrification' include Electrons + Fuels



Hybrid ICEs



Plug-in EVs



Fuel-based EVs

**Thinking Beyond
Passenger Vehicles:**

Rail
Marine
Trucking
Aviation/UAVs

Autonomous
Last Mile / Micro
Transit
Robotics

Marathon, Not a Sprint



***... Elon Says Game-Over
Batteries have Won!***



More than three-quarters of executives (77% global; 85% U.S.) say fuel-cell electric mobility will be the real break-through for electric mobility.

***... but Industry betting on
integration & fuel-based EVs***

BEVs 'Have Won' vs Limitations of All Electric Pathway

Battery pack = 400 miles
Daily Need = 40 miles



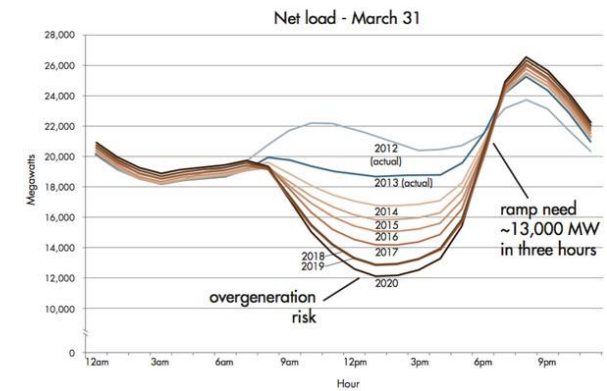
OEM Cost-to-X
vs Daily Use Demand



Uptime for Fleets &
Recharging in Urban Markets

'Duck Curve' to 'Dragon Curve'

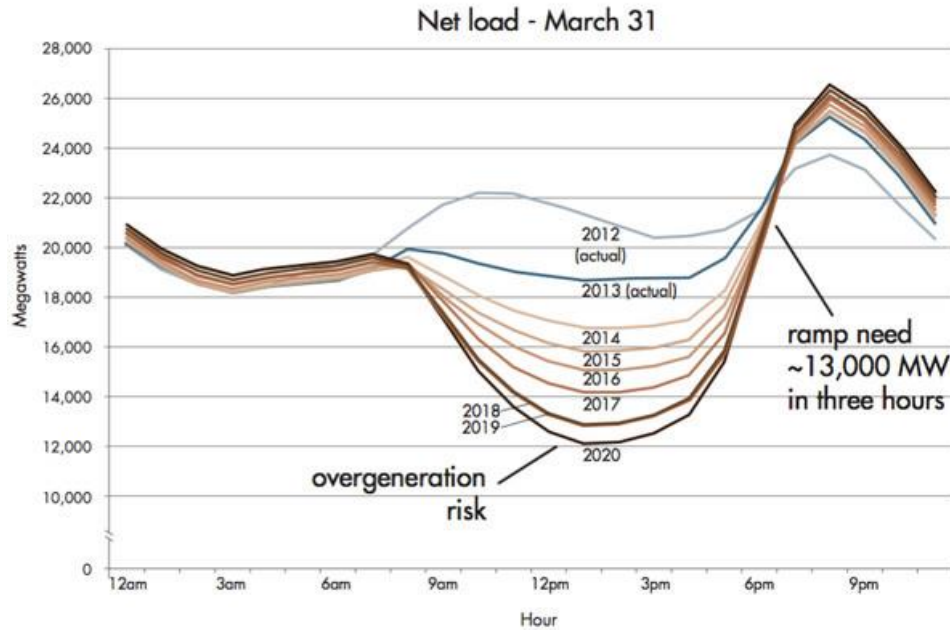
Figure 2: The duck curve shows steep ramping needs and overgeneration risk



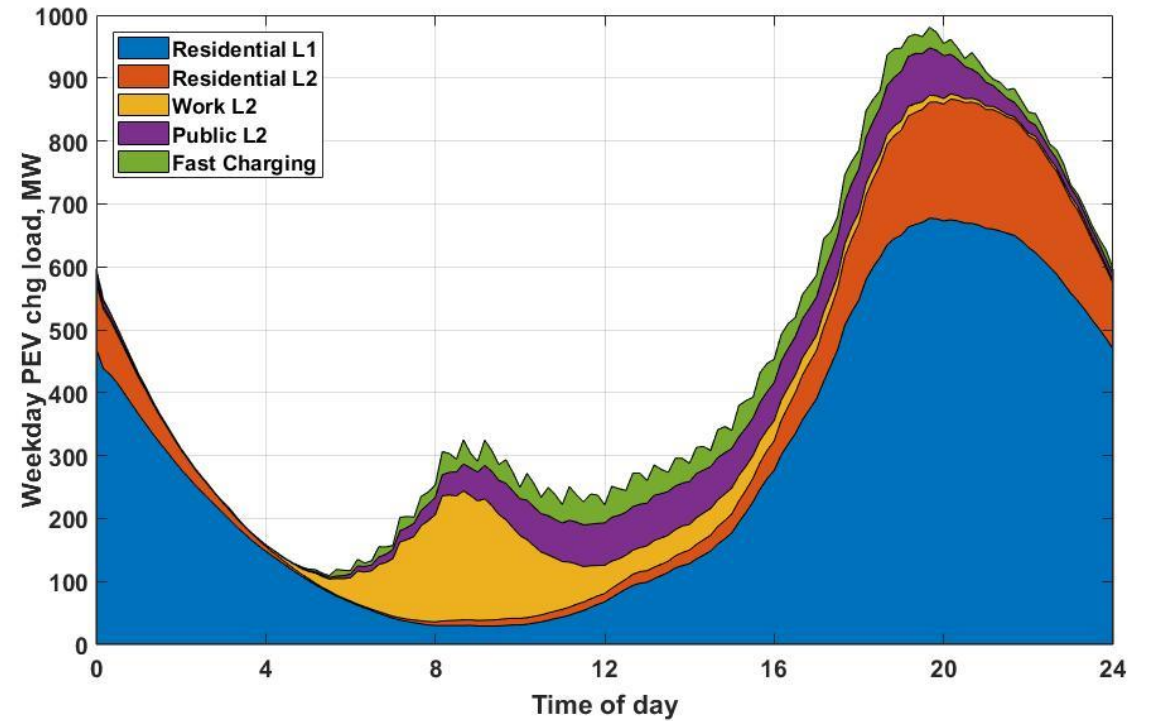
Full Costs of
Grid Management

Total Grid Management Costs 'Duck Curve' to 'Dragon Curve'

Figure 2: The duck curve shows steep ramping needs and overgeneration risk

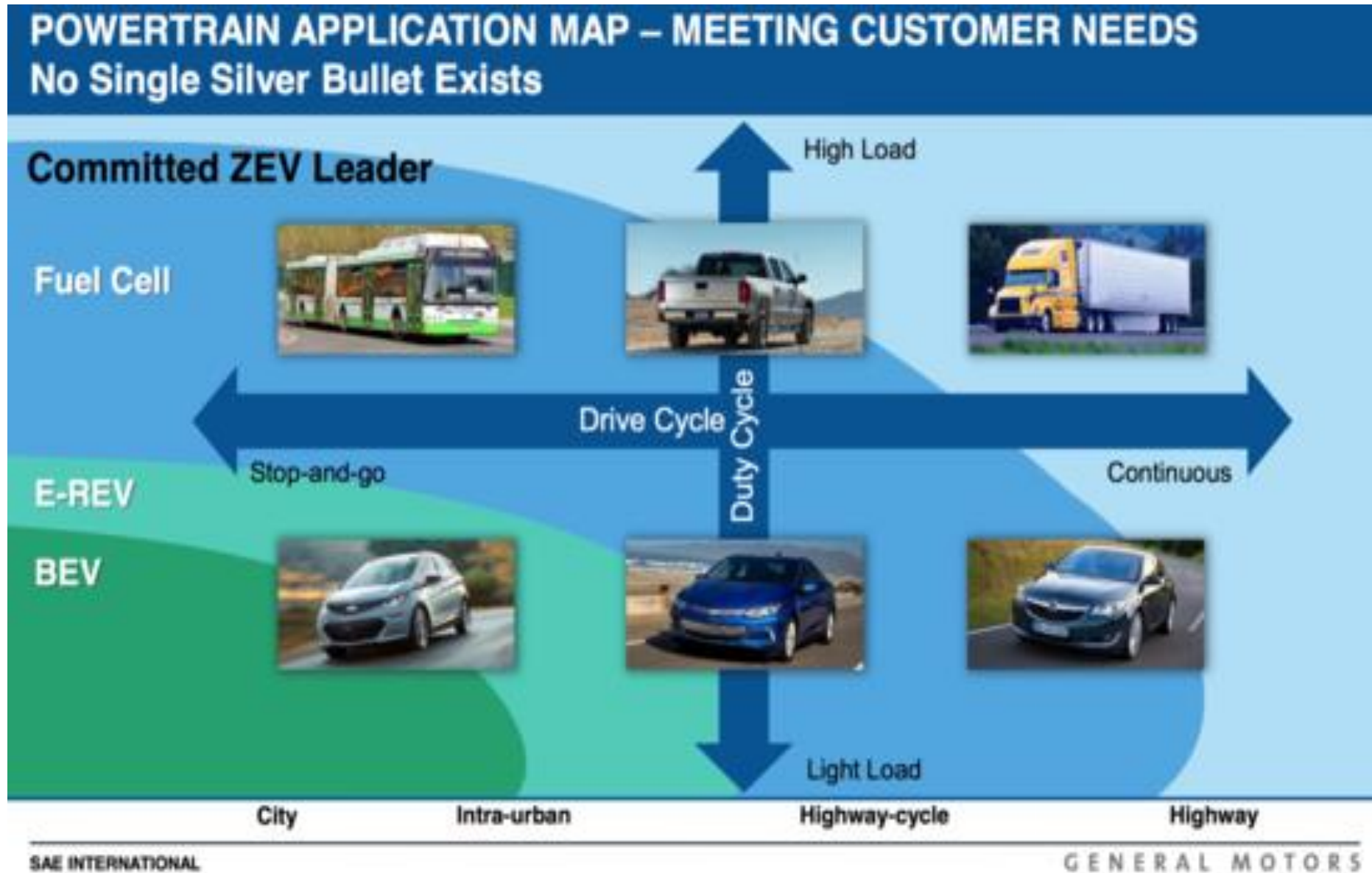


'Duck Curve'



'Dragon Curve'

The Shared Strategy for Integration & Fuel-based EV Fleet



The Shared Strategy for Integration & Fuel-based EV Fleet



NIKOLA ONE™



POWERCELL
BOSCH

Trucking



Royal Caribbean INTERNATIONAL VIKING YANMAR ABB

Maritime



Hydrail

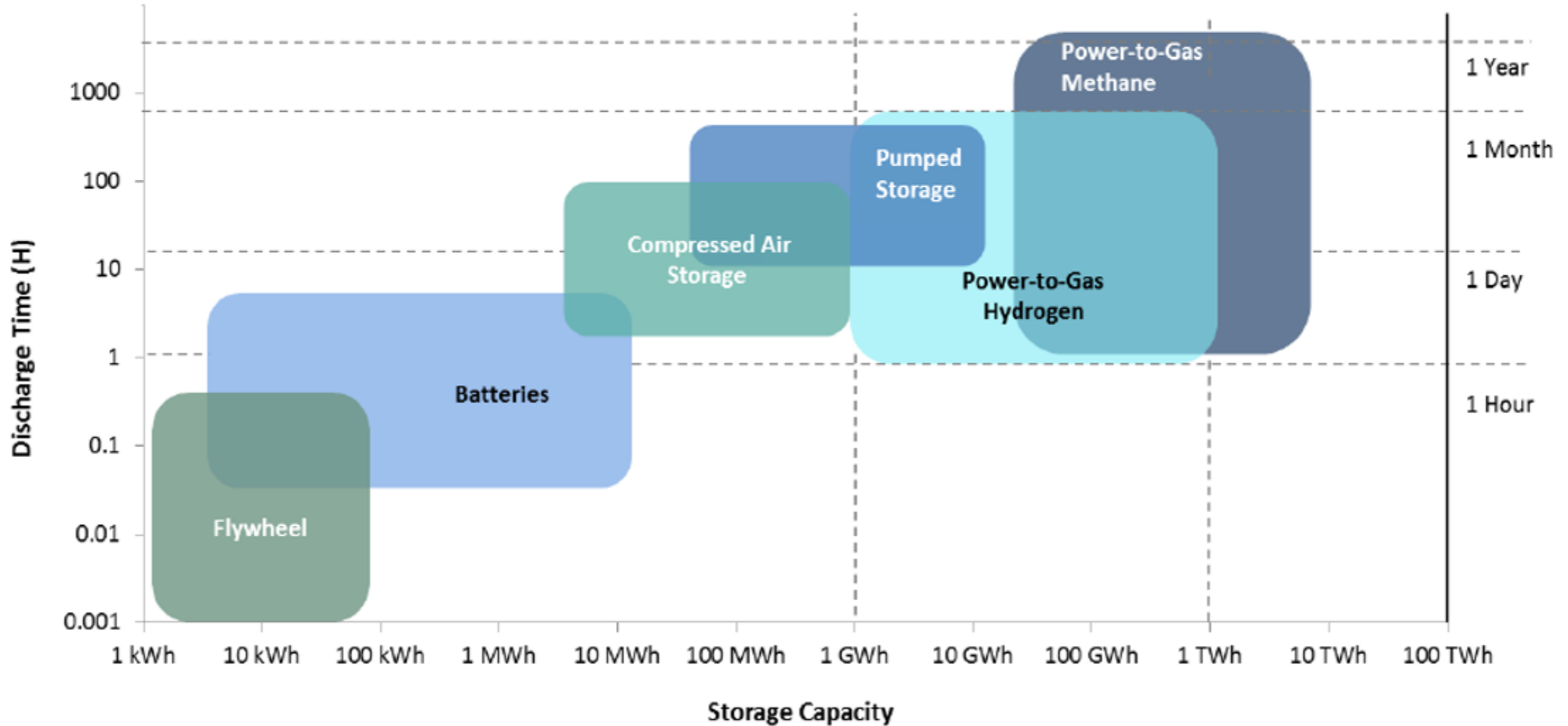


Ultra Electronics USSI Protonex® a Ballard® company flyH2 AEROSPACE

Aviation / UAVs

Energy Storage – Beyond Batteries & Pumped Hydro

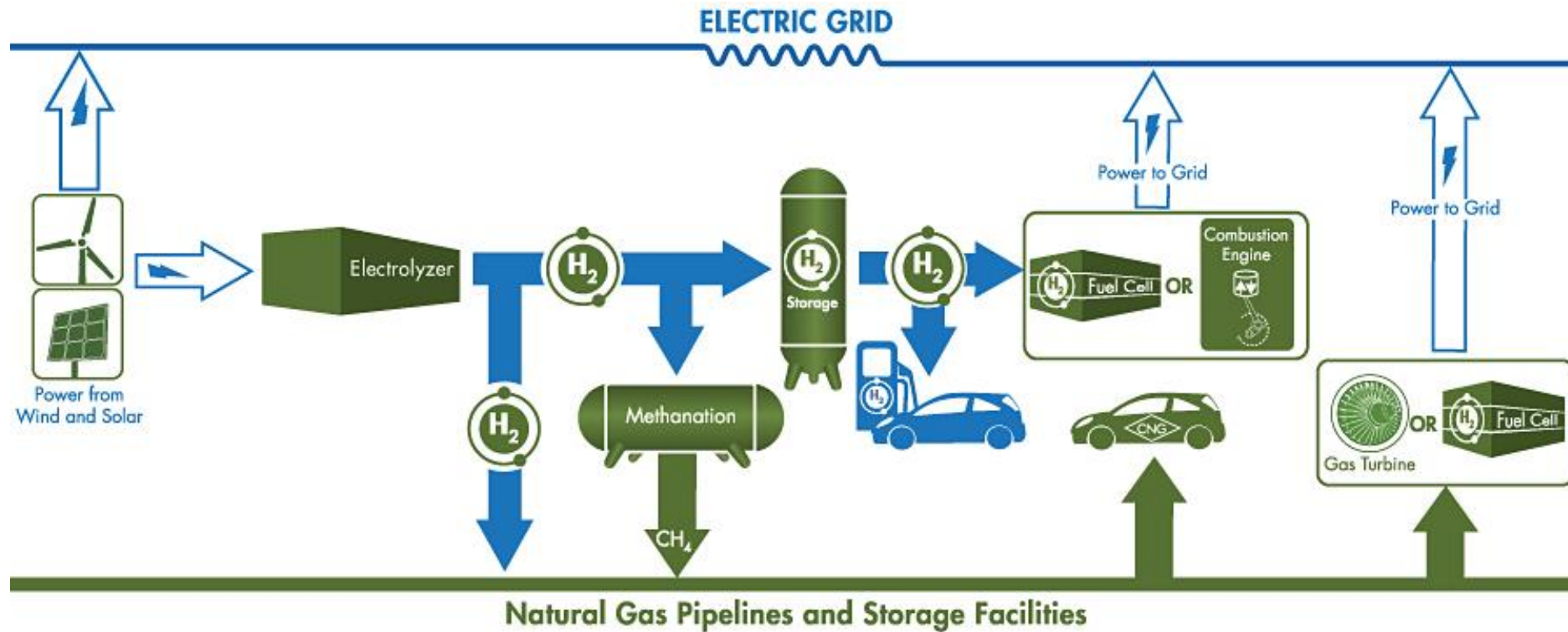
The Case for Power to Gas: Hydrogen is Not Dead



After Fraunhofer ISE, 2015

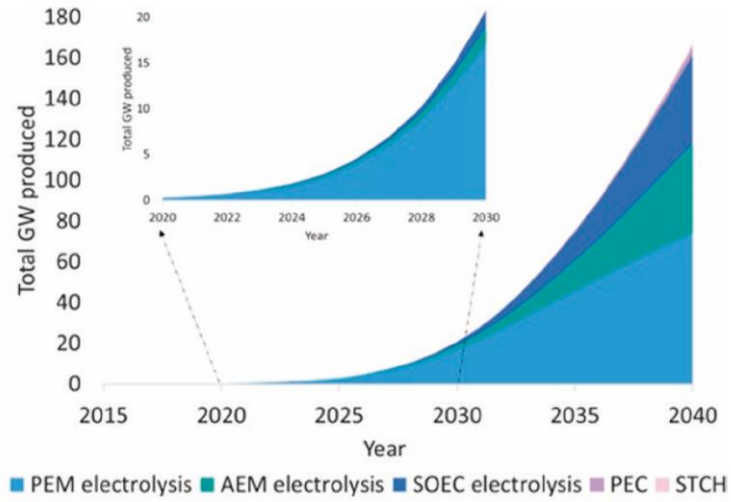
Decarbonization Policy 2020s

Power to Gas (PtG) Delivers Scale & Versatility



Innovation & Cost Curve

PtG by Incumbents Who Do System Level Scaling



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

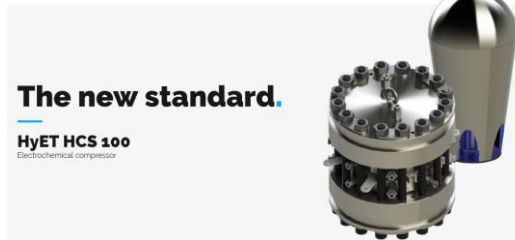
PEM = proton exchange membrane; AEM = anion exchange membrane; SOEC = solid oxide electrolysis cell; PEC = photoelectrochemical; STCH = solar thermochemical.

Katherine Ayers

© Materials Research Society, 2017

Production

HyET Hydrogen Efficient purification & compression



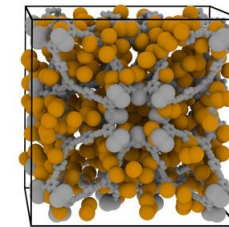
The new standard.

HyET HCS 100
Electrochemical compressor

Compression



Gas



Solid



Liquid

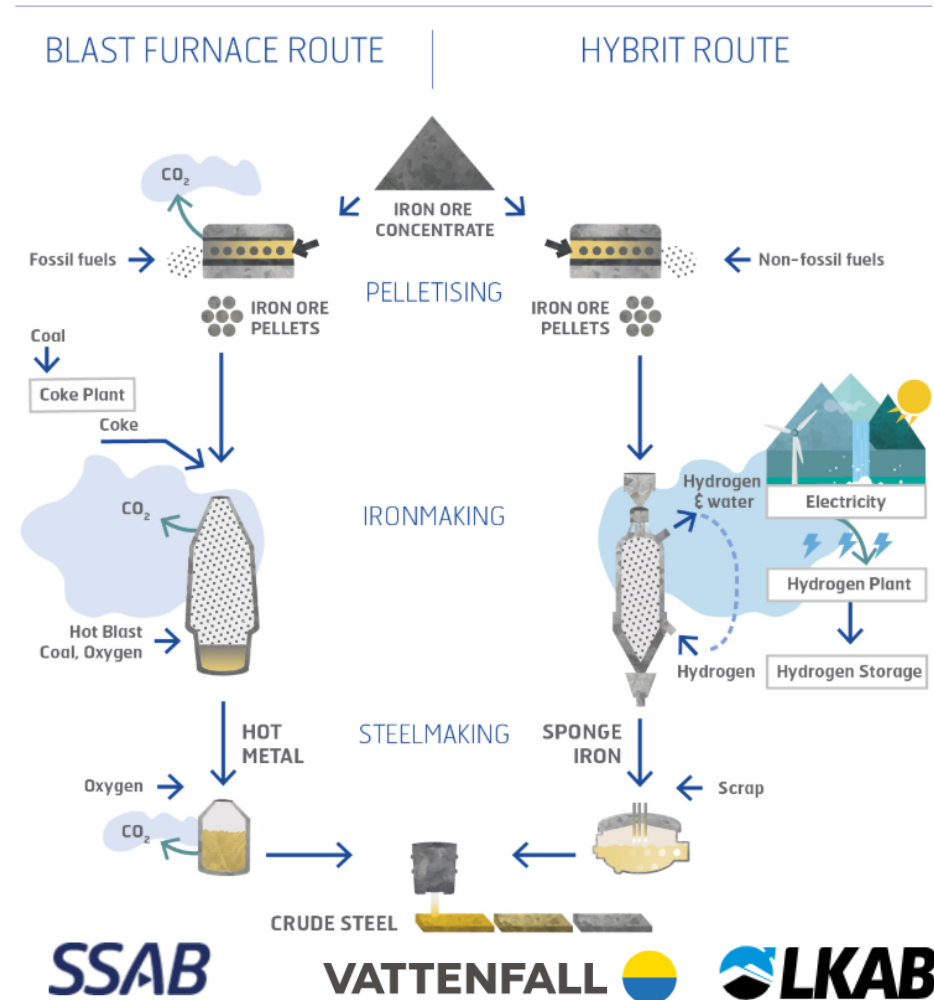
Storage

Utilities & Decarbonization of Heavy Industry

Decarbonization for Steel Making

Cut CO₂ by 25% by 2025
Remaining CO₂ emissions by 2045

HYBRIT (Hydrogen Breakthrough Iron Technology)



2020 – 2030

Utilities Explore Fuel-based EVs & Integration of PtG



- Grid Mgmt + Balancing
- Scaling Renewables**
(Duck Curves; Seasonal Storage; Curtailment)
- Storage (Volume/Duration)
- Value Model for Industry Solutions**
- Reg Support to Integrate Gas + Grid
- Decarbonize Heat & Industries**
- Fuel-based Solution for FCEVs

Blockchain Hype vs Hope



Implications of the blockchain cannot be understood... yet



1994: "Today Show": "What is the Internet, Anyway?"

Evolution of the Web-based Capabilities & Solutions



***Access to
Digital Files***



***Access to
Social Networks***



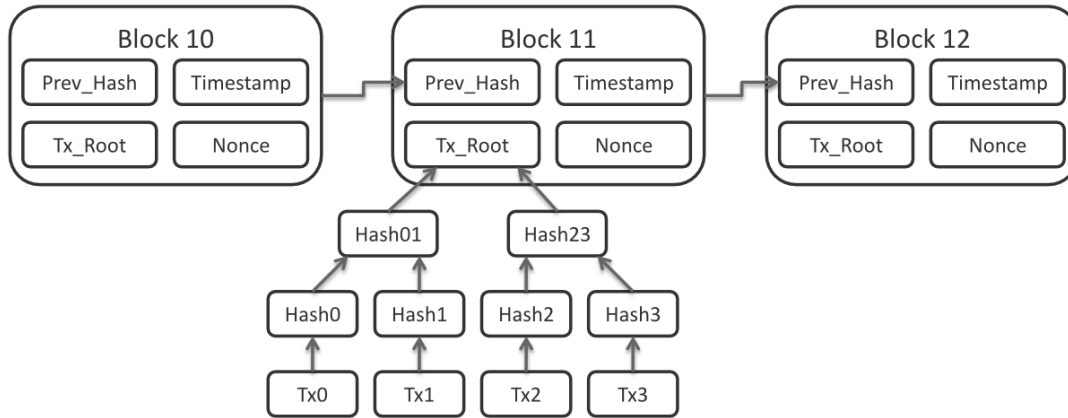
***Access to
Trusted Transactions***

It's just Decentralized Databases + Process Automation!

**Assets enter ledger
and generate keys**



**Network Consensus
on who did what...**



**'Assets' = Energy Usage Data, Bills, Appoints,
Crew Field Notes, Identity, Payment Information,
Equipment Repairs...**

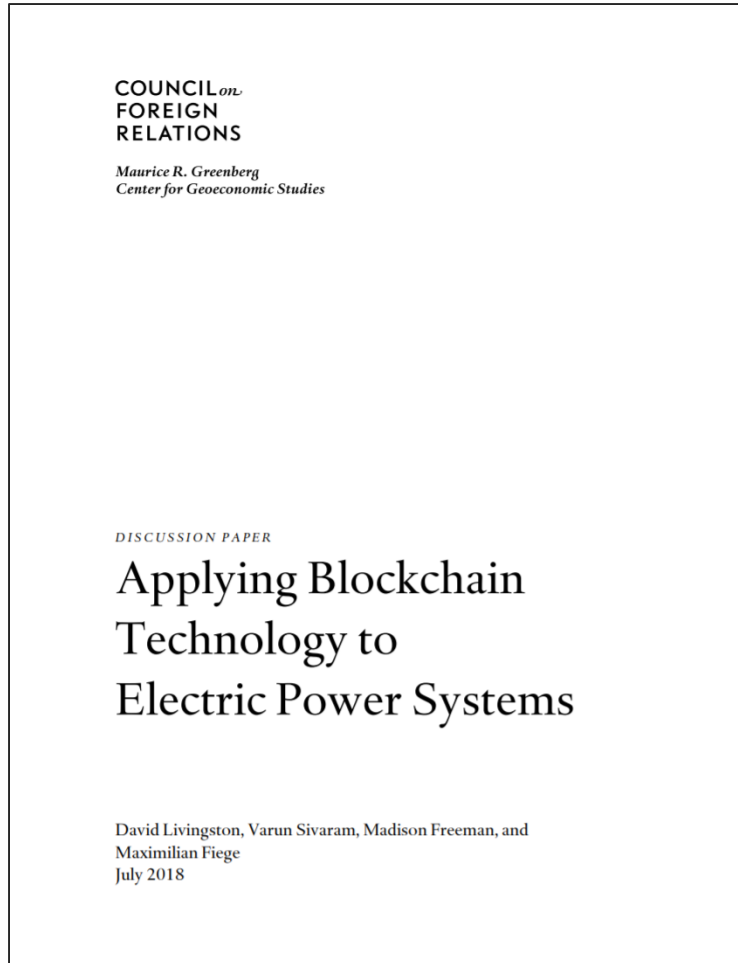
**Smart Contracts execute legal
agreements + business processes**

A sample of EtherScript

```
note: ***An Ethereum smart contract to sell website for "5000 by March"
note: First, store buyer's ethereum address:
put: 6af267736363738ghgs7726337373737 in storage slot BUYER
note: Then, store seller's ethereum address:
put: 6af267736363738ghgs7726337373737 in storage slot SELLER
note: April 1, 2014 is 13929839948 in "computer time"
put: 16365437465 in storage slot DEADLINE
note: If the agreed amount is received on time...
When: transaction value ≥ 50000 ether
and block timestamp ≤ storage slot DEADLINE
then
note: ... then designate the buyer as the new website admin and pay the seller
put storage slot BUYER in storage slot WEBSITE_ADMIN
Spend contract balance to storage slot SELLER
```



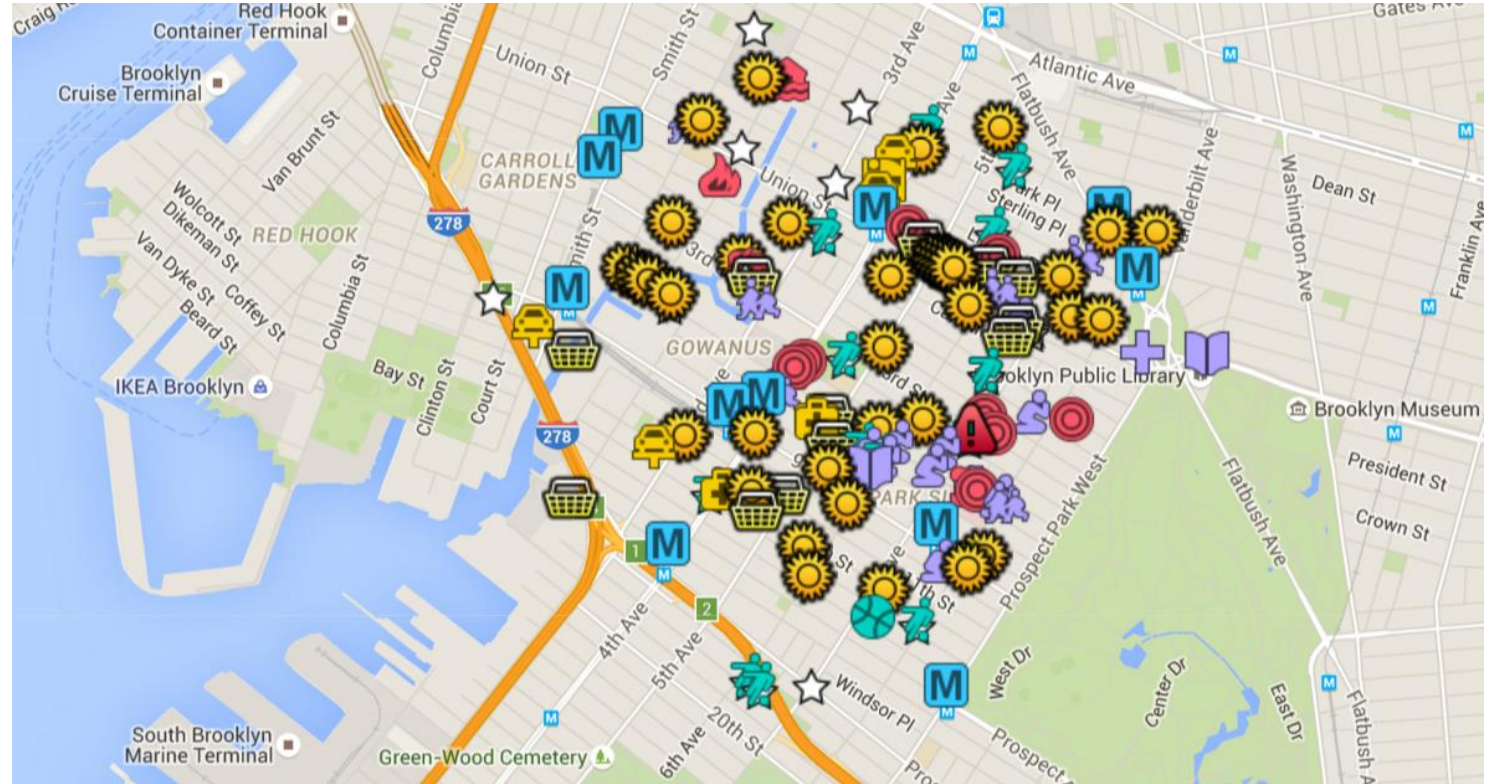
Grounded in Current Reality



Blockchain Initiative Categories:

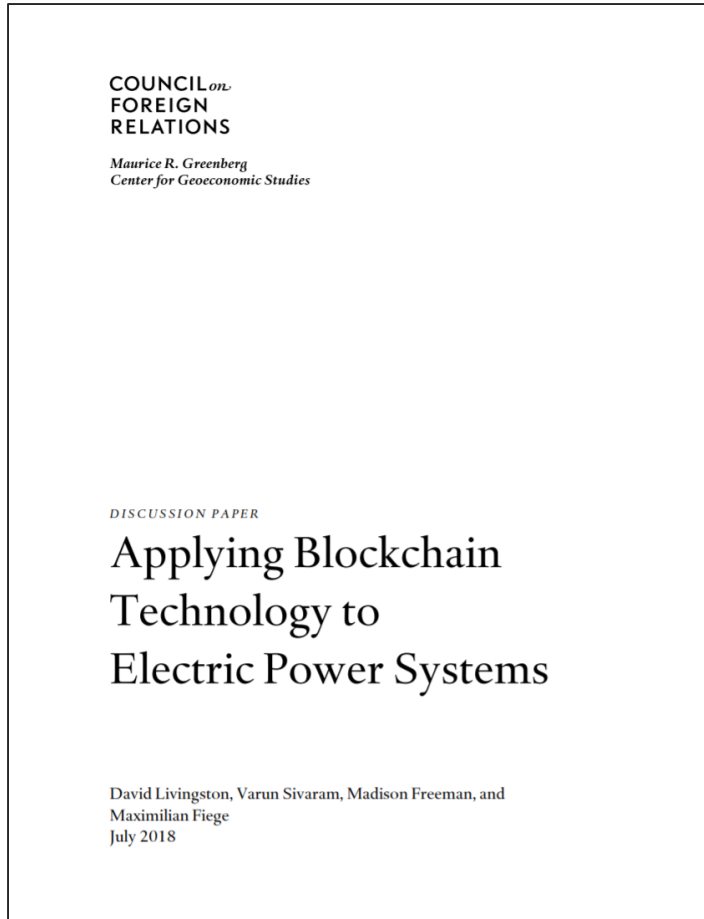
Peer to Peer Transactions

Blockchain: Capturing Headlines, But Disruptive?



Near-to-Nearby Energy Sales
Group-funding Community Energy Assets
Economics for Behavior Change (Negawatts)

Grounded in Current Reality



Blockchain Initiative Categories:

Peer to Peer Transactions

BEV Infrastructure

Shared Infrastructure for Recharging Stations

SHARE & CHARGE

Innogy Charges New Electric Car Fleet Using Ethereum Blockchain



EV-MARKET OF TOMORROW

- ▶ 200 million electric vehicles in 2030
- ▶ 11.9 billion kW peak capacity
- ▶ 98 billion US\$ of power consumption

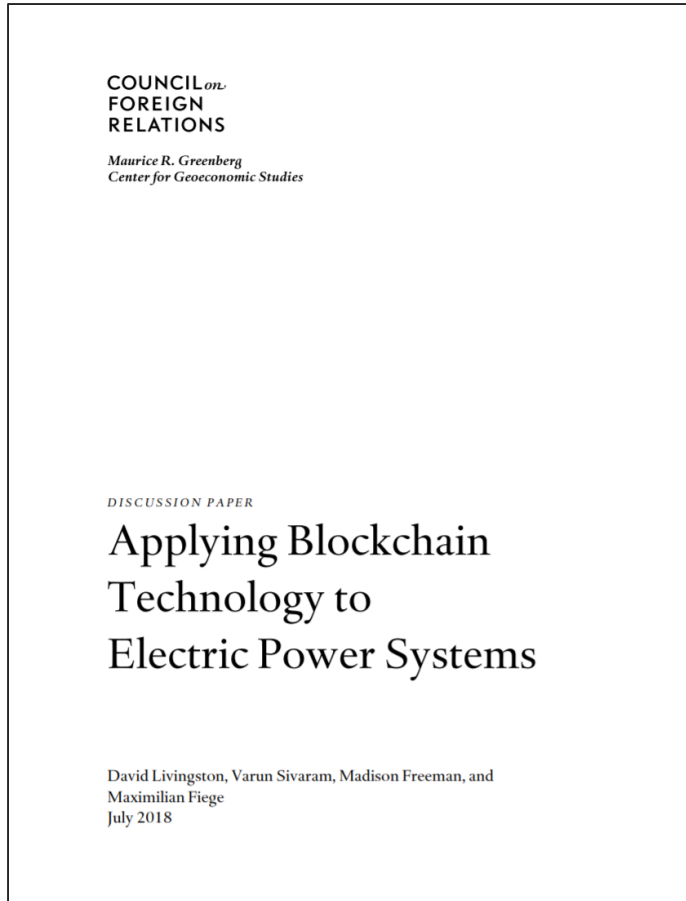


PROBLEMS OF EV-CHARGING

- ▶ Highly fragmented market
- ▶ Overload of power grids
- ▶ Complex settlement processes of electric vehicle companies

Innogy SE, a subsidiary of German energy conglomerate RWE, announced that it has launched hundreds of blockchain-powered charging stations for electric cars across Germany through its e-mobility startup venture **Share&Charge**.

Grounded in Current Reality



Blockchain Initiative Categories:

- Peer to Peer Transactions
- BEV Infrastructure
- Grid Transactions**
- Energy Financing**
- Sustainability Attribution (Credits)**

Sustainability Attribution Credits

Utilities Help Commercial Customers Maximize Credits

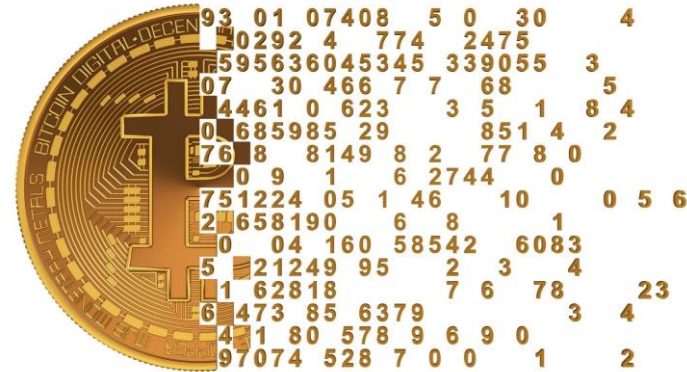
Unlocking Value



The Sustainable Sugar Project

**Tokenization: Supply Chains & Operations:
Buy, Sell Trade Attribution Credits**

Utilities Issue Negawatts



**Crypto Currencies + Smart Contracts automate
incentives for energy demand management**

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

- Cellist, Yo-Yo Ma

Thank You!!

PDF + Resources

garrygolden.com/October31

garrygolden@gmail.com

Two Rs

