

The Slow Pace of Fast Change

The Future of Energy Systems



SOUTHERN MINNESOTA
MUNICIPAL POWER AGENCY

Garry Golden
Forward Elements Inc

Start

End



In the News



Transitions Ahead



The *Slow Pace* of Fast Change



Alternative Futures

Baseline Future

Integrated (Gas + Grid)
Cyber Security

Transactive Grid

Distributed

Design for
Behavior Change

Maintenance,
Preservation
& Renewal

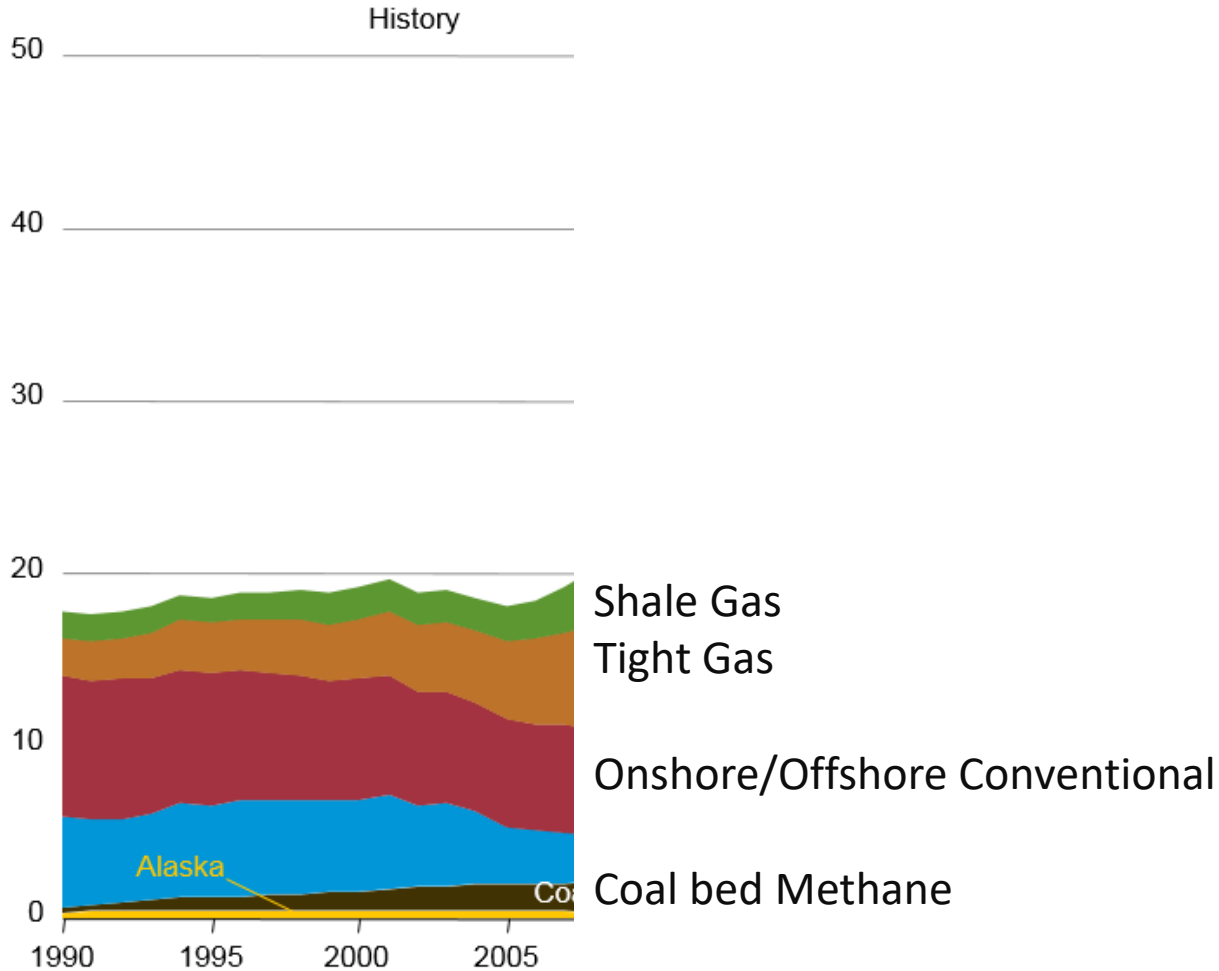
20th Century Dynamics

21st Century Dynamics

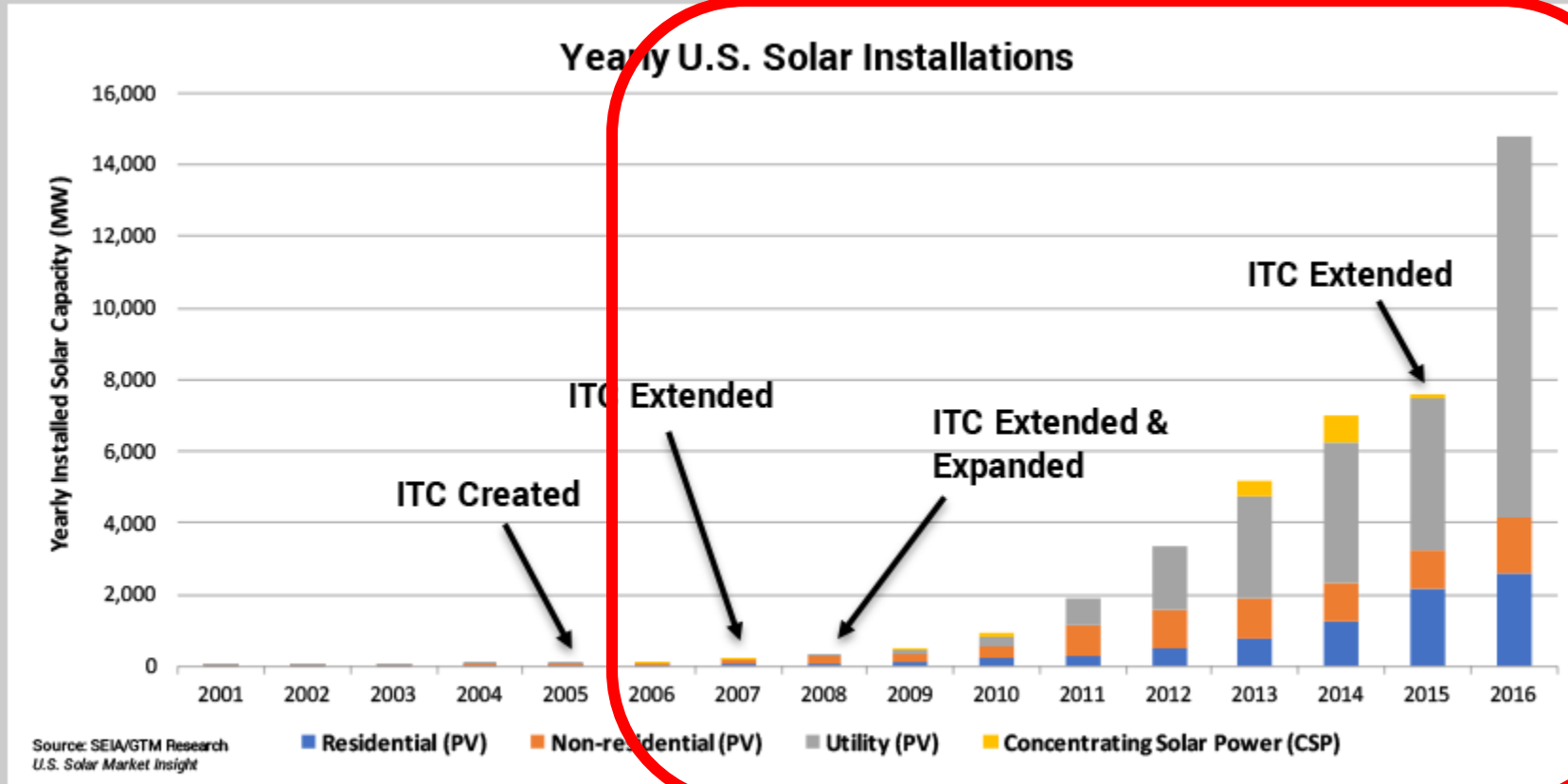
10 Years: Uncertainties in Fuel Dynamics

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

trillion cubic feet



10 Years: Uncertainties in Policy



10 Years: Uncertainties in 'Players' & Business Models

TESLA



Alphabet

amazon

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?

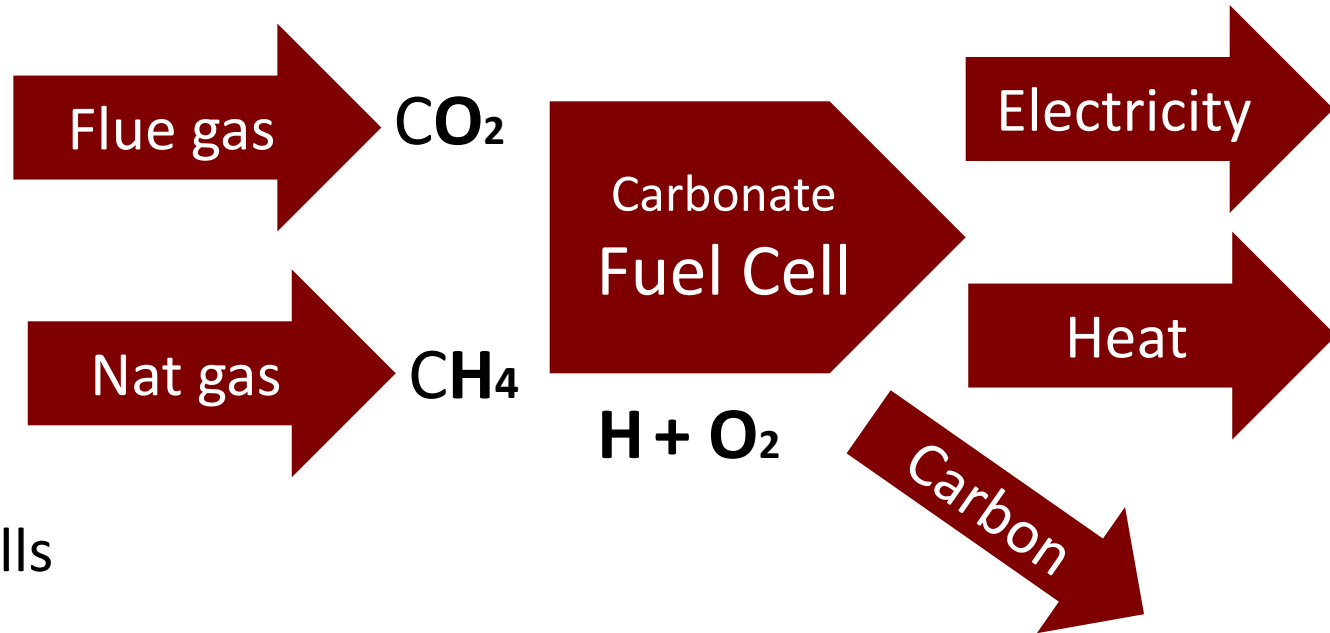
Transforming Generation Asset Utilization & Longevity?

ExxonMobil

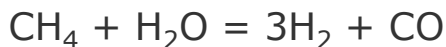
 FuelCell Energy

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% CO2 capture with fuel cell	522 MW	.06 (\$/kWh)

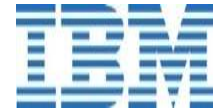
(Source: Fuelcell Energy & ExxonMobil)



Carbonate Fuel Cells



Four Futures Thinking



**Continued
Growth**

**Disciplined
Constrained**

Transformed

**Decline
Collapse**

Describing the Four Futures for SMMPA and Your Utility...



**Continued
Growth**



**Disciplined
Constrained**



Transformed



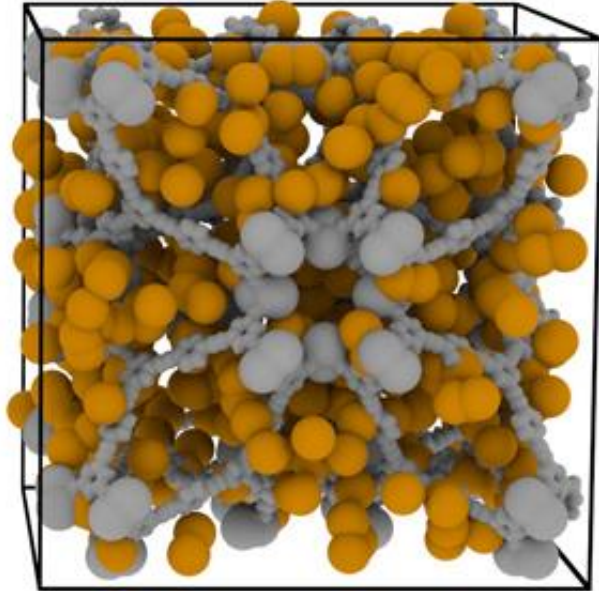
**Decline
Collapse**



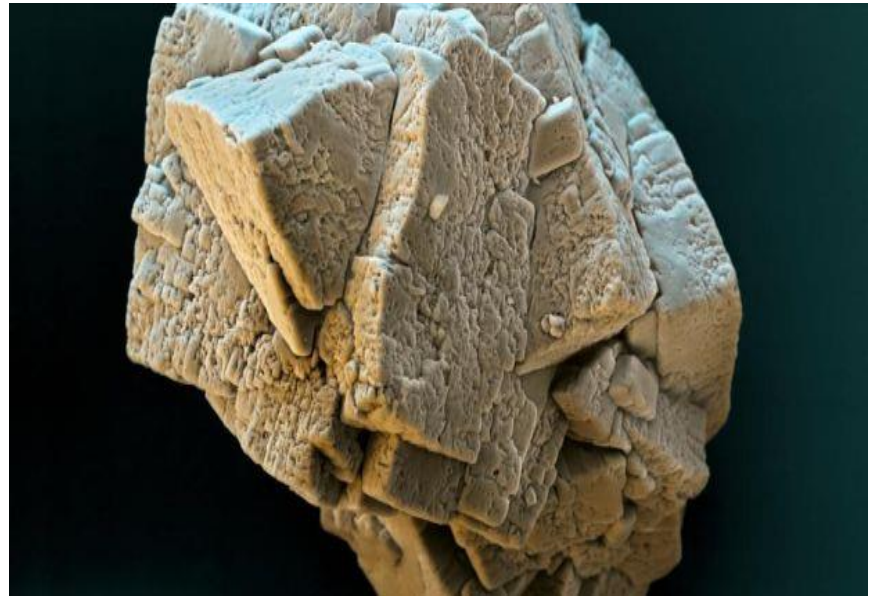
In the News

High Surface Area Crystal Sponges

MOFs – Metal Organic Frameworks



Northwestern
Image by Christopher Wilmer/NuMat Technologies)



Science Journal



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



True

False

Dubai Testing Retail based Fuel Distribution for EV Scooters

STOR·H

by AAQIUS



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

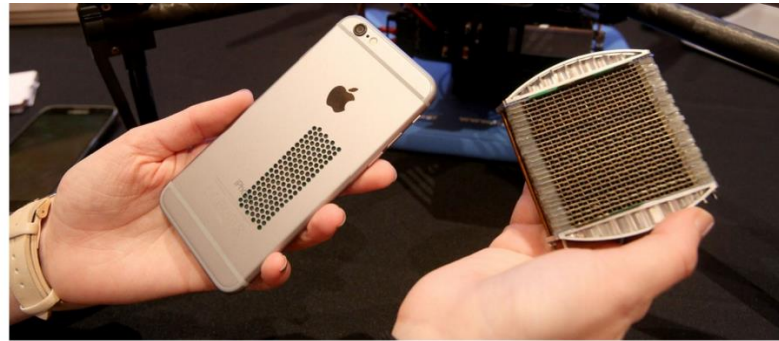


\$49 (12 cartridges)
11 phone charges per cartridge

Disruptive Idea: Embedded Fuel cell Power Systems

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.



Faster Recharging vs Refueling

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



MyFC initiates feasibility study with leading Chinese smartphone manufacturer

“Since we launched the world’s smallest fuel cell LAMINA in early 2017, our intention has been to pursue the integration of our fuel cell technology in smartphones. This R&D project marks the start of that initiative, which we refer to as job #3,” says Björn Westerholm, CEO of myFC.

What could happen in 12 years...?



Industrial Policy
Beyond Battery

2023



Acquisitions in
Portable Power

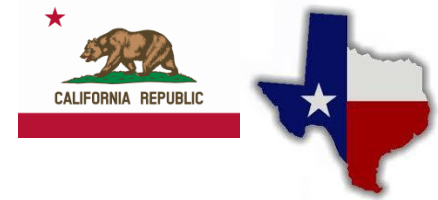
2025



Unplugging at
Burning Man



2028



Houses without
Electrical Sockets

amazon
Walmart
Vision: #1
Fuel Distributors

2033

What if fuel-based innovations capture the head, heart & wallets of the our communities?

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

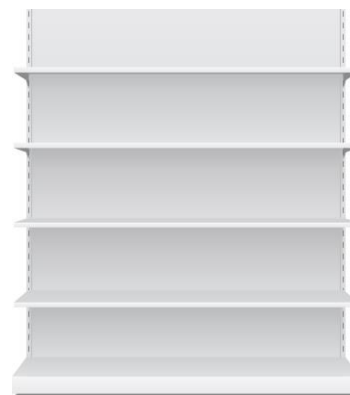
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An Apple iPhone and a quadcopter, both retrofitted with hydrogen fuel cell batteries, and a hydrogen fuel cell are displayed by Intelligent Energy at ShowStoppers. Photo by Ann Singer.



**Consumerization
Adoption Curves**



**Retail Shelf
Simplicity**



SAMSUNG

**Expanding
Partnerships**

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

End

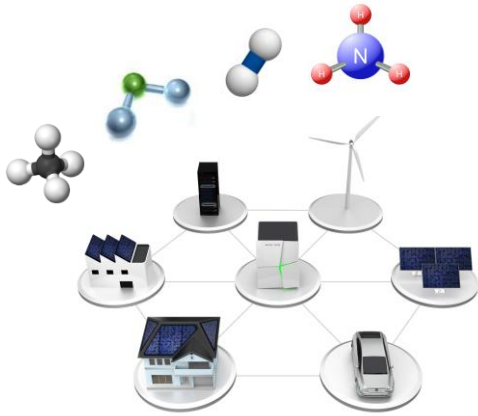


Transitions Ahead



Next Steps

Anticipating Transitions & Shifting Expectations



**DER Scenario
Gas + Grid**



**Pathways to
Electrification**



**Blockchain
Hype vs Hope**



2018 – 2030

**Rethinking Role of Molecules:
Distributed Energy Resources**



Policy Hinting at Favorites: Community Solar & Batteries



Community Storage: Aggregated System level Solutions

"Community Storage" is an emerging term for programs that aggregate distributed energy storage resources that are located throughout a community, such as water heaters, electric vehicles, and interconnected storage batteries, to improve the operational efficiency of electric energy services to consumers.



The Community Storage Initiative

[Join Our Email List](#)

The co-founders of the community storage initiative ask for your support:

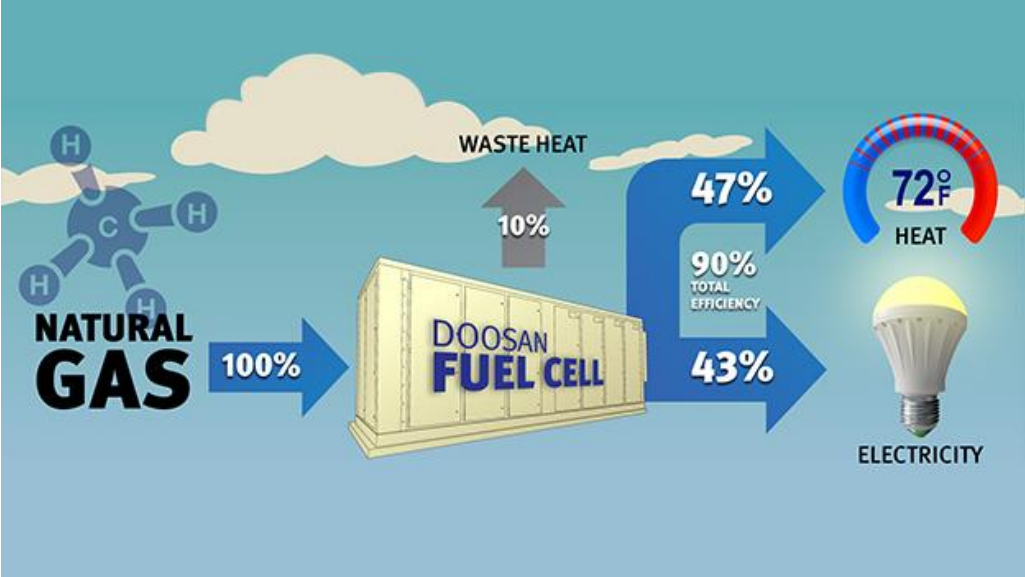
- Click on the link above to join the Initiative's email list to receive information about the Initiative and upcoming events
- Promote an "above the baseline" approach to electric water heating, electric vehicle charging, and residential battery use marketed as 'Community Storage'
- Share your business model and best practices around 'Community Storage'

We ask you to follow the Guiding Principles of The Community Storage Initiative:

1. Voluntary Participation (by the utility, home, business or individual)
2. Education & Training (information resources, program templates, quick-start guides, etc.)
3. Market Acceptance (locally, regionally and nationally)

Strengthening Signals but Lingering Scars

NatGas Friendly Vision: Fuel Cells as DER base of Micro Grids & CHP



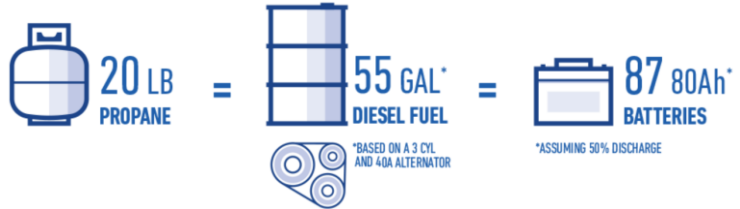
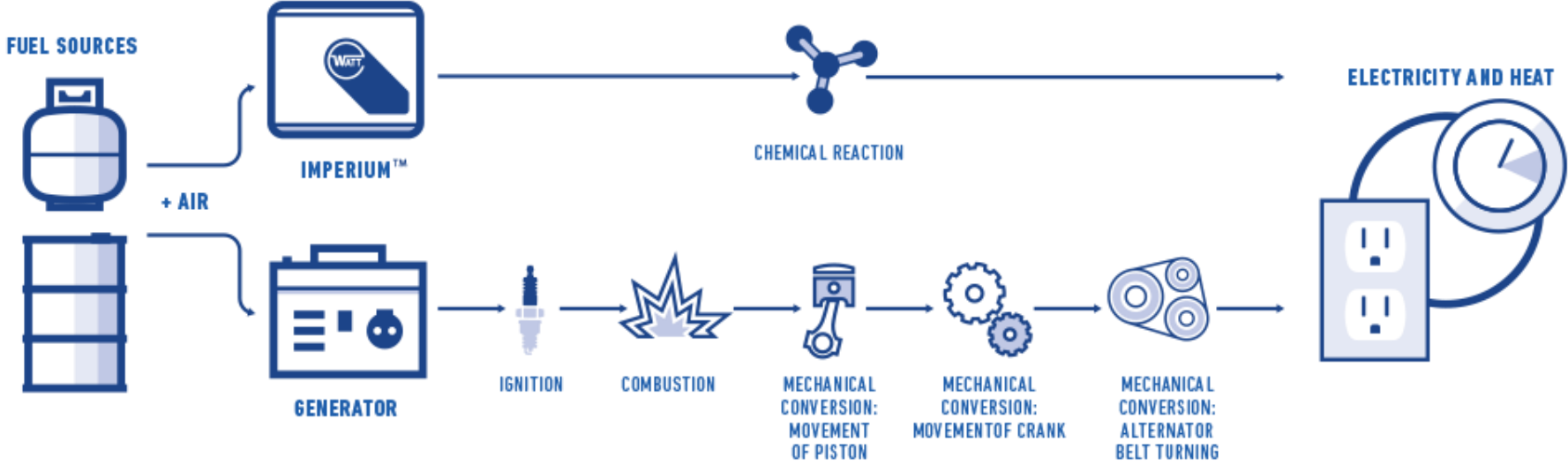
Strengthening Signals but Lingering Scars

DER Scenario: Natgas + Fuel Cells as Foundation for Transformation

21st Century

20th Century

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



Micro CHP via Solid Oxide Fuel Cells = 21st Century Energy Appliance



BlueGEN



100-home pilot program

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



Construction Site Diesel
Generator Alternatives

Public Debates:
Gas vs Power?
Gas + Power?

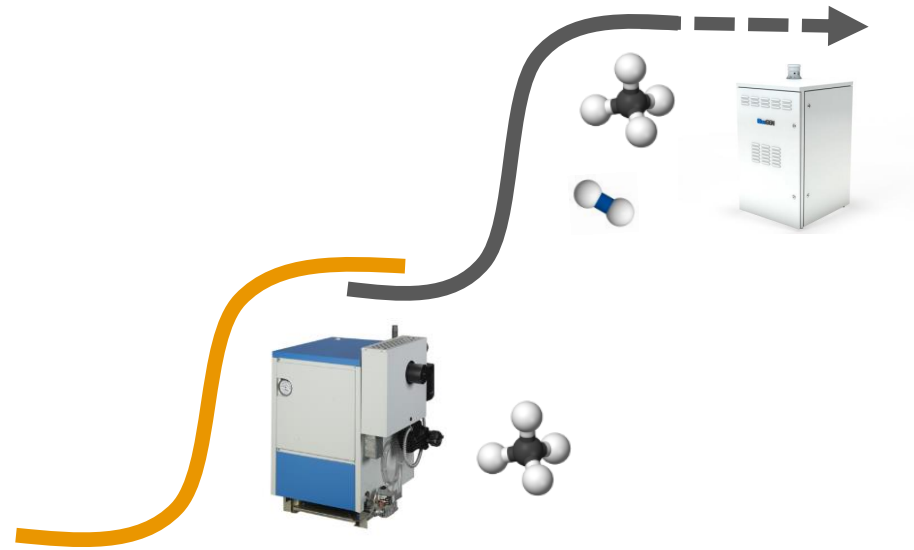


Power Parks
63 MW Beacon Falls



2020 - 2040

How might we navigate a DER Scenario that integrates public power + gas solutions for an era of energy appliances (MicroCHP) and utility-scale alternatives?

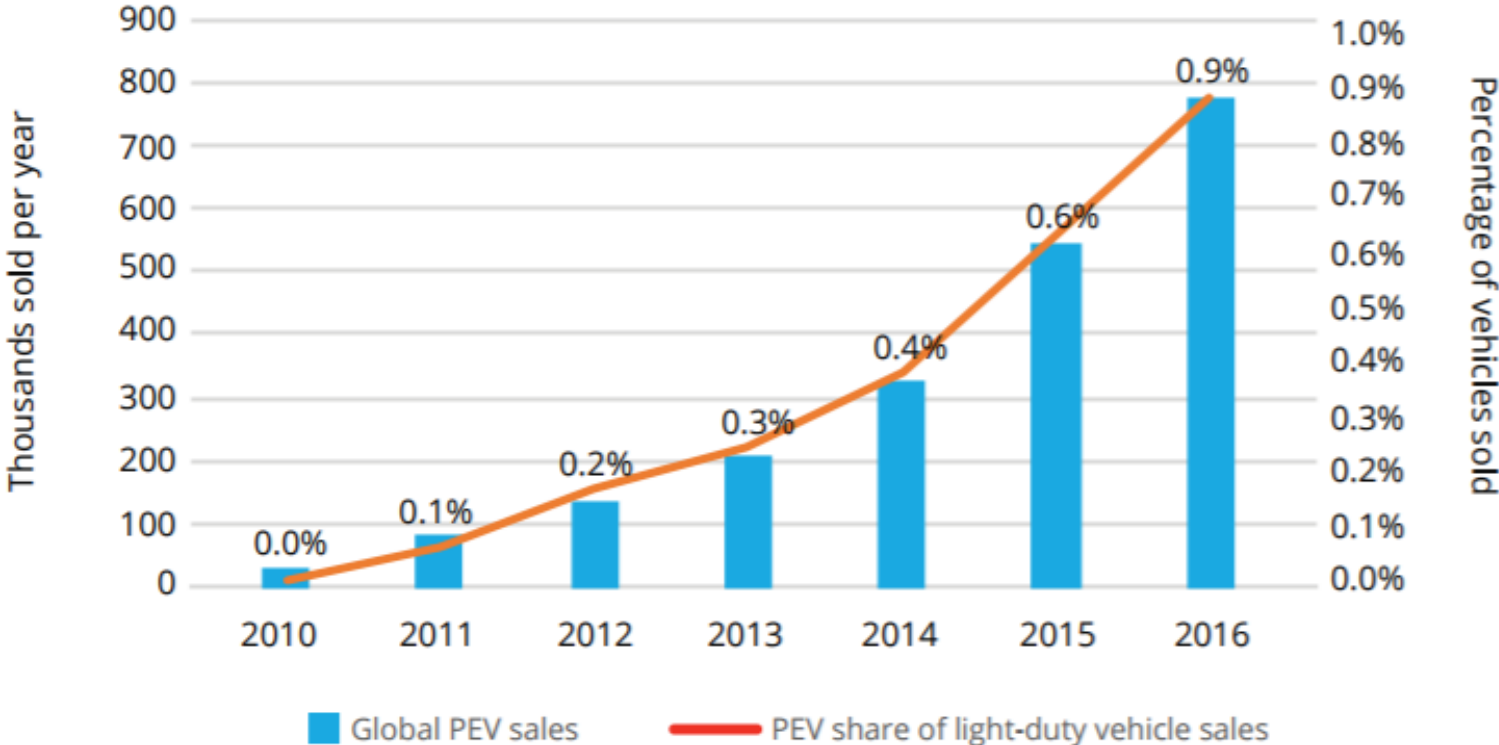


Pathways to 'Electrification'



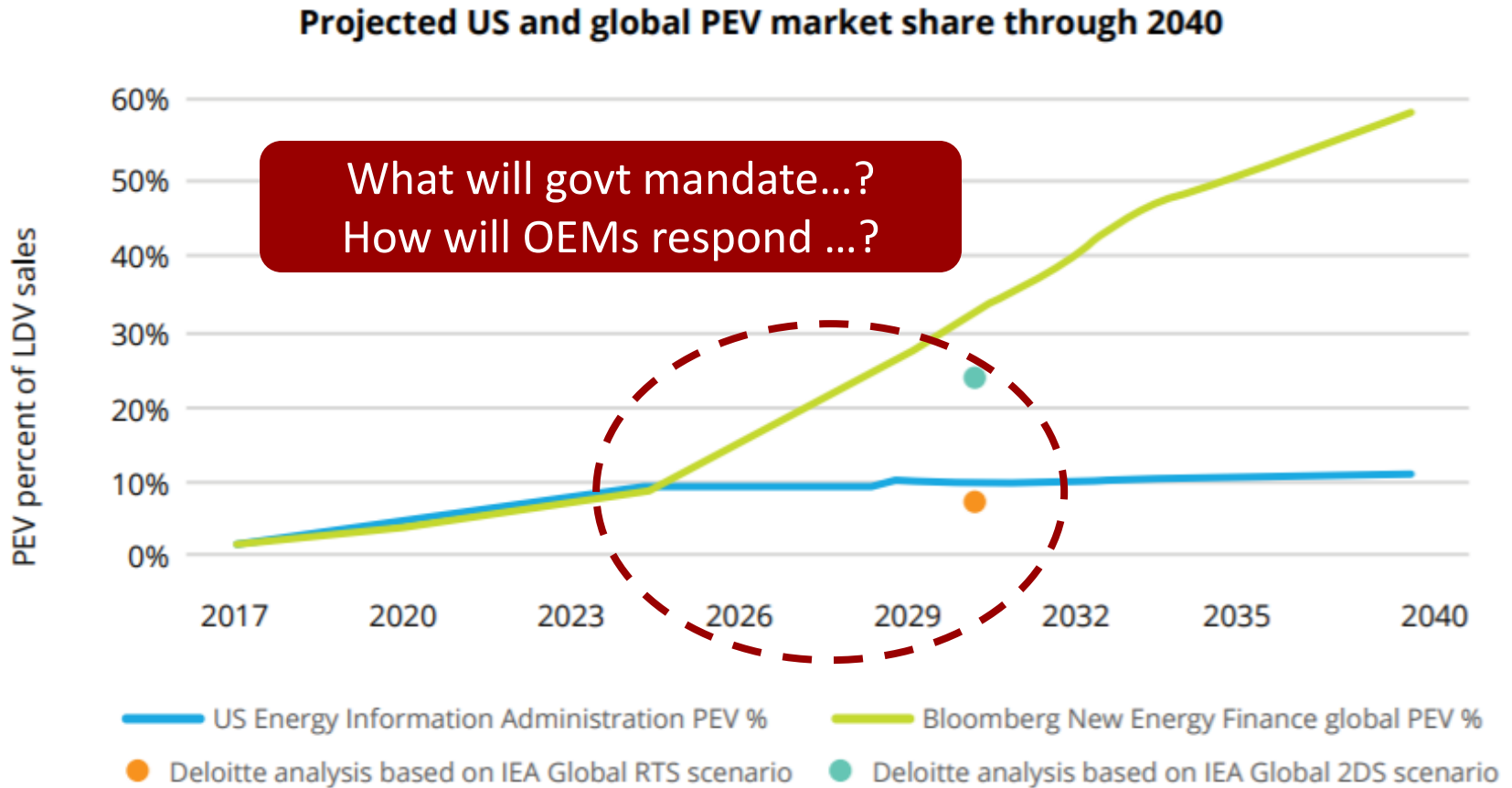
Electrification of Vehicle Fleet

Global PEV annual sales and market share, 2010 through 2016



Source: Electric Drive Transportation Association, "Electric drive sales dashboard," and Jeff Cobb, "Top ten plug-in vehicle adopting countries of 2016," HybridCars, January 17, 2017.

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.

'Electrification' of Vehicle Fleets – Electrons vs 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



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.

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

***... 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

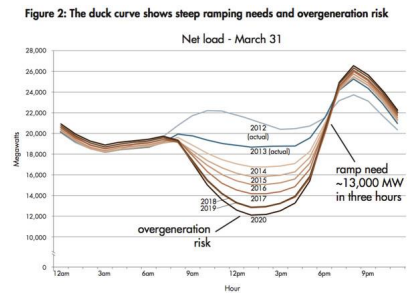


OEM Cost-to-X
vs Daily Use Demand



Uptime &
Recharging for
Urban Markets

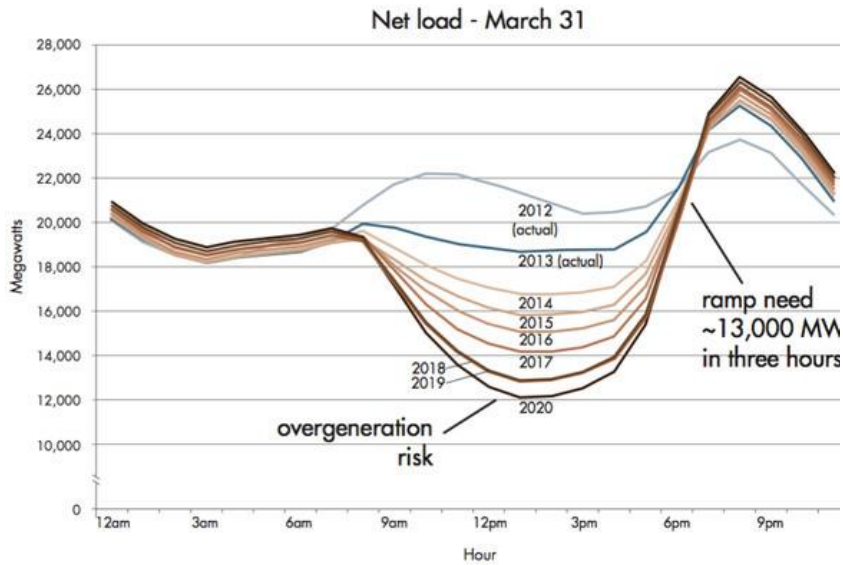
'Duck Curve' to 'Dragon Curve'



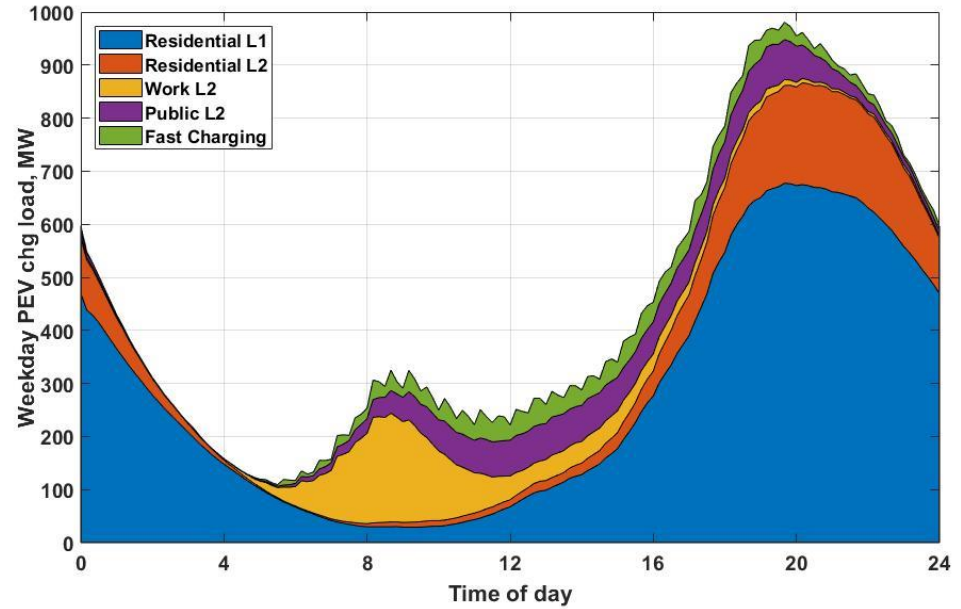
Full Costs of
Grid Management

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

POWERTRAIN APPLICATION MAP – MEETING CUSTOMER NEEDS No Single Silver Bullet Exists

Committed ZEV Leader

Fuel Cell



High Load

E-REV

Stop-and-go

Drive Cycle

Duty Cycle

Continuous

BEV



Light Load

City

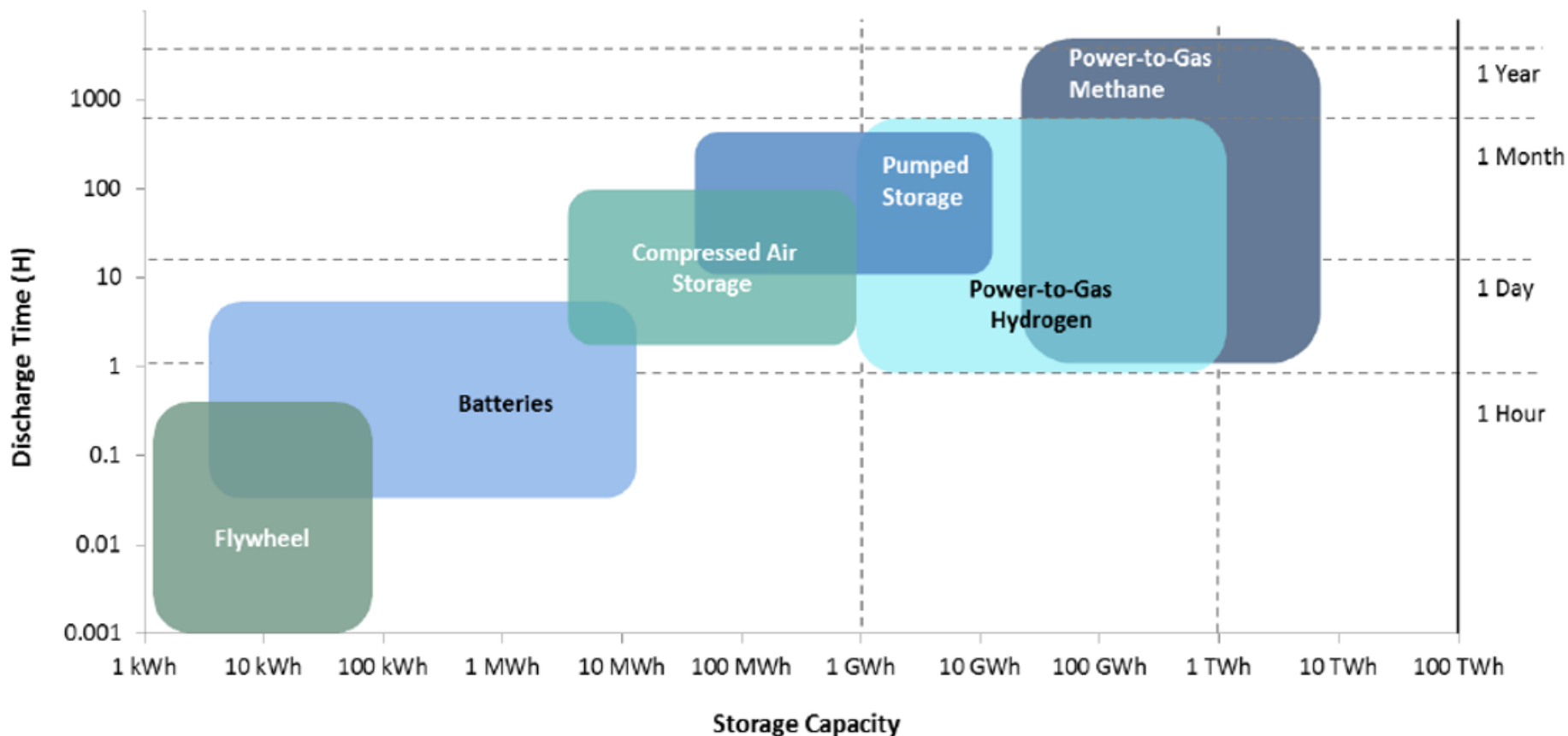
Intra-urban

Highway-cycle

Highway

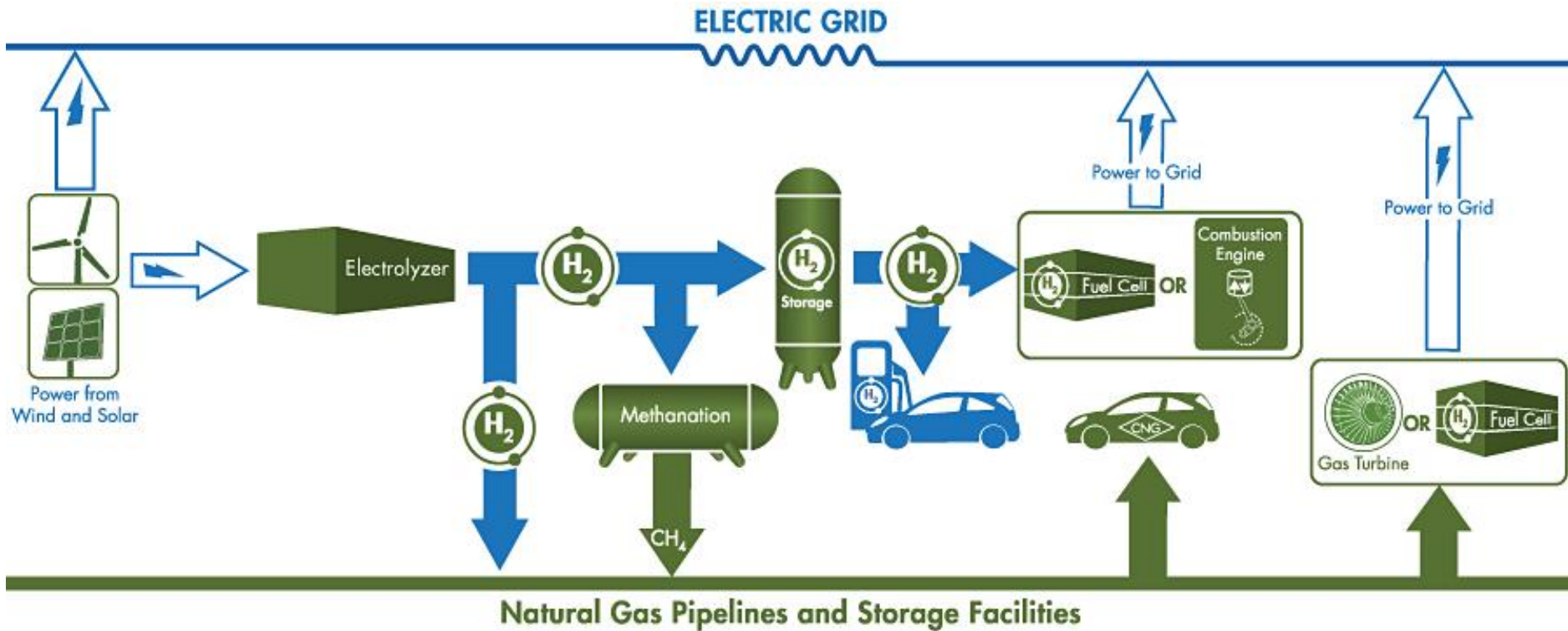
Energy Storage – Beyond Batteries & Pumped Hydro

The Case for PtG: Hydrogen and ‘Renewable Gas’



After Fraunhofer ISE, 2015

Power to Gas (PtG) Value Delivers Scale & Versatility

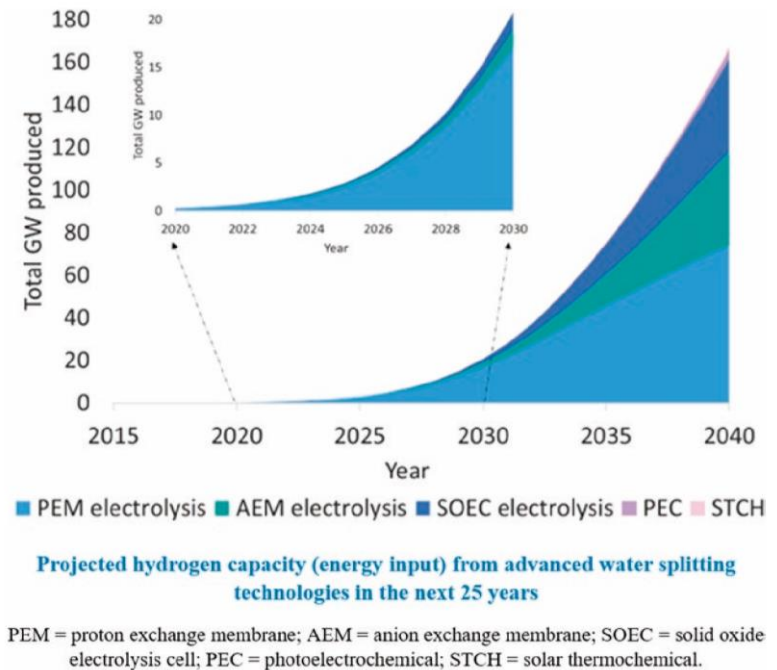


A Sempra Energy utility

The National Fuel Cell Research Center's Research and Development on "Power-to-Gas"

Public Power Debates Integration Upside of PtG

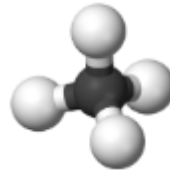
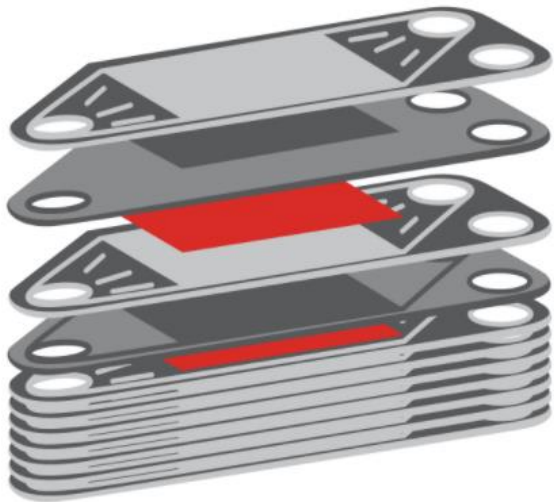
- ❑ Grid Mgmt + Balancing
- ❑ **Scaling Renewables**
(Duck Curves; Seasonal Storage; Curtailment)
- ❑ Storage (Volume/Duration)
- ❑ **Value Model for Industry Solutions**
- ❑ Integration of Gas + Grid
- ❑ **Decarbonize Heat & Industries**
- ❑ PR Strategy with *Big Gas*
Growth of 'Hydricity'



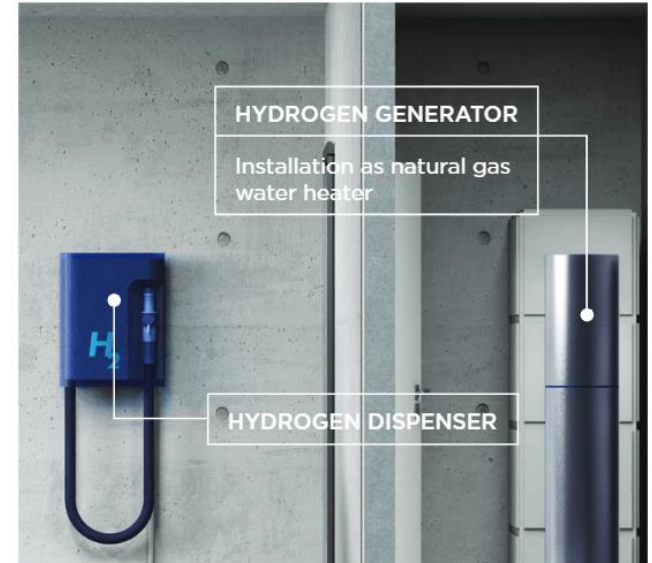
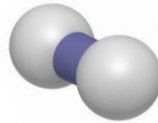
Scenario: Natural Gas Does Not Sit on FCEV Sidelines

COORSTEK.

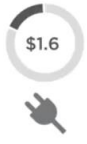
ACTIVE CERAMIC MEMBRANES



Near Zero Loss
Energy Conversion



Driving Cost
\$/100km





**Including
Fuel-based
Electrification
Investments**

Opportunities

- Broader Sector Solutions
- Managed Services for Fleets
- Transform Excess Electrons to Higher Value H2 Fuel

Challenges

- Regulated Mandate
- Elon's Twitter Account & Early Adopter Enthusiasm
- Business Model

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***



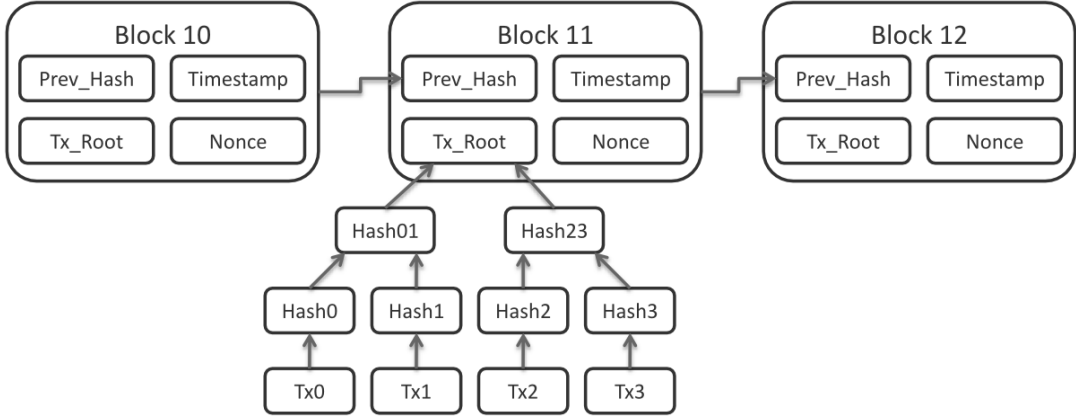
***Access to
Social Networks***



***Access to
Trusted Transactions***

It's just Decentralized Databases + Process Automation!

Assets get entered onto the ledger and generate keys + Network Consensus on who did what... 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 13929830948 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

```



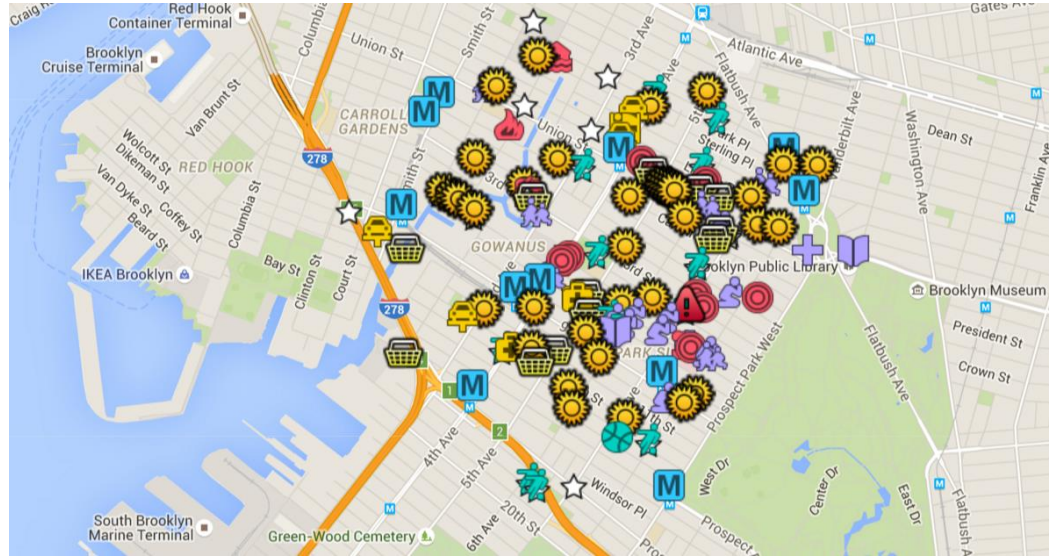
'Assets' = Energy Usage Data, Bills, Appoints, Crew Field Notes, Identity, Credit Card Information, Equipment Repairs...

Authorization for Data use; Revenue Cycle Management; Front-end Compliance Walls; IoT Cyber Security; Wholesale Trading

Blockchain as Backbone for Microgrid?



LO3 ENERGY



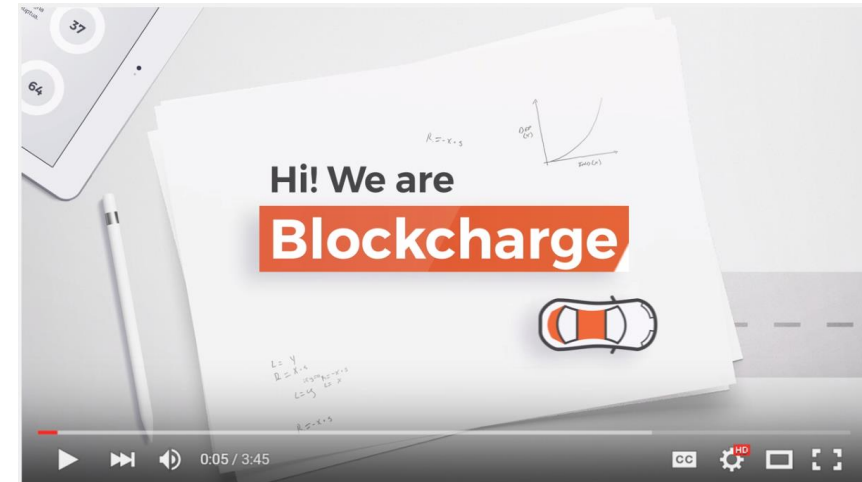
Neighbor-to-Nighbor Energy Sales
Crowd-funding Community Energy Assets
Economics for Behavior Change (Negawatts)

Innovative Proof of Concepts... Shared Infrastructure

Innogy Charges New Electric Car Fleet Using Ethereum Blockchain



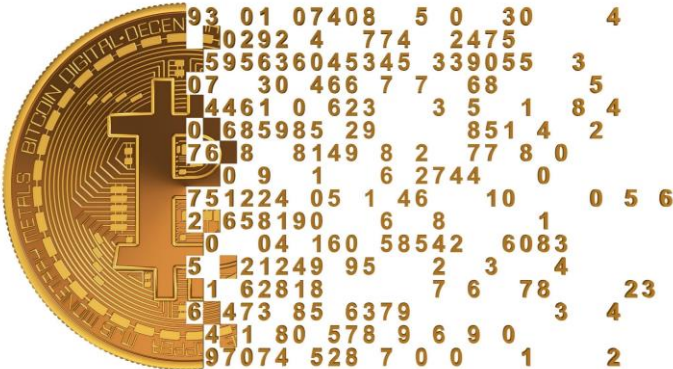
[Innogy SE](#), a subsidiary of German energy conglomerate RWE, announced that it has launched hundreds of blockchain-powered charging stations for electric cars across Germany through its e-mobility startup venture [Share&Charge](#).



[BlockCharge](#) - EV Charging via the Ethereum BlockChain (HQ)

Radical Idea: Crypto Currencies Tied to Behavior Change

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



Utilities Issue Negawatts

Thank You!!

PDF + Resources

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Two Rs

