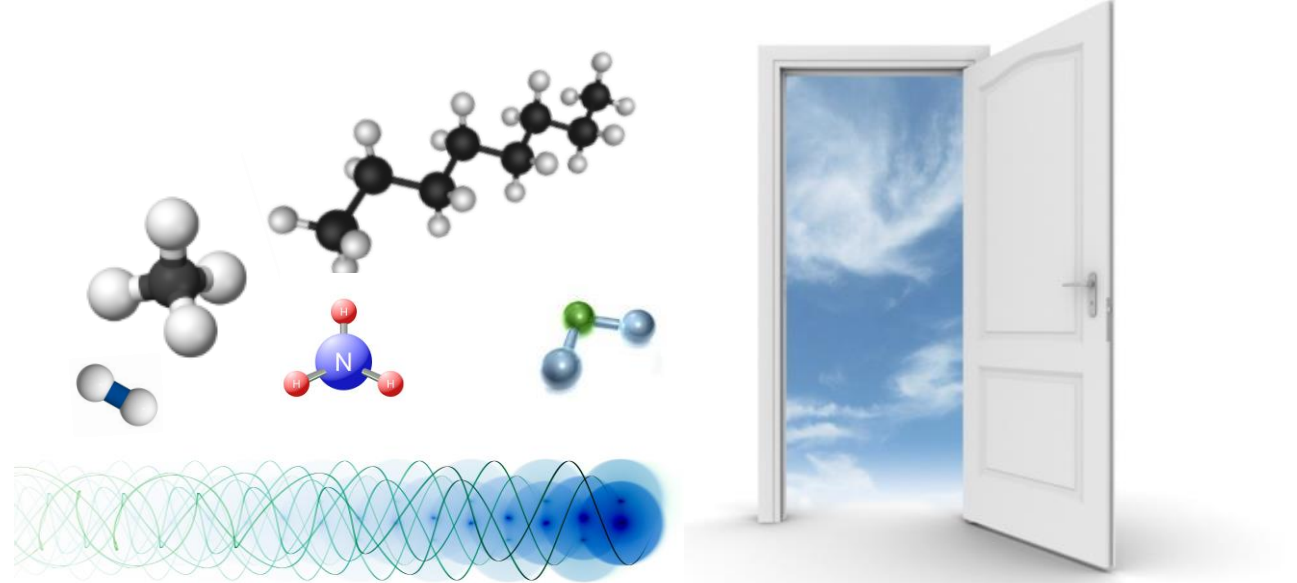


The Slow Pace of Big Change

# The Future of Energy Systems



Designed for



Designed by

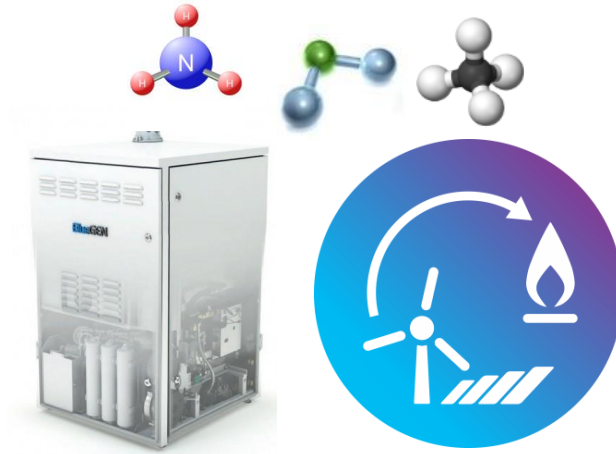
**Garry Golden**

**Start**

**End**



***Foresight 101***



**Emerging Solutions for  
Deep Decarbonization**



***Discussion***

# More or Less Change Ahead?

Last  
ten years



Next  
ten years



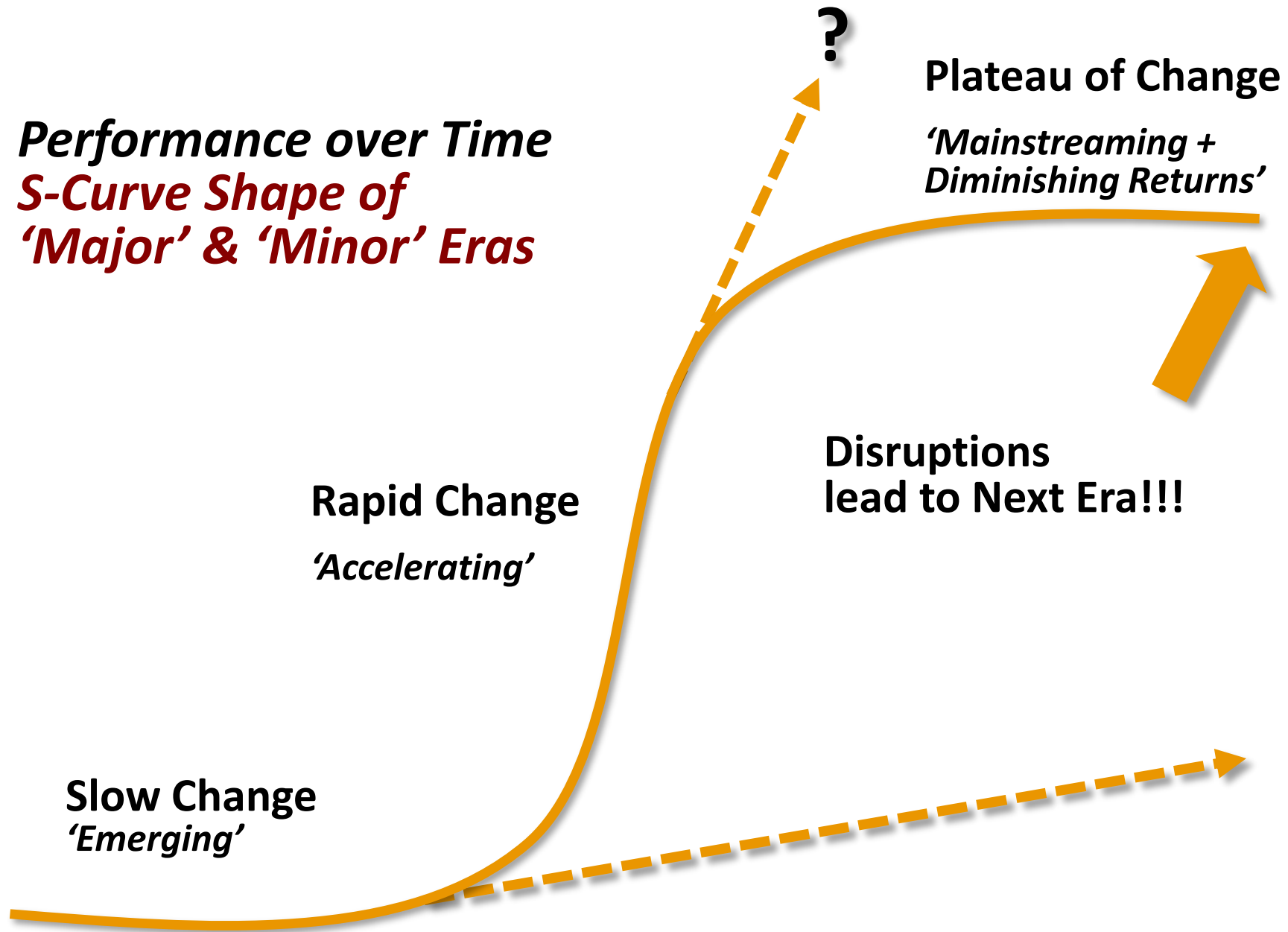
**Foresight *as the Front End...***  
**of Innovation + Strategy**

Foresight = Front end of Innovation

## Era-based Growth Strategies



**Performance over Time**  
***S-Curve Shape of***  
***'Major' & 'Minor' Eras***



**Plateau of Change**

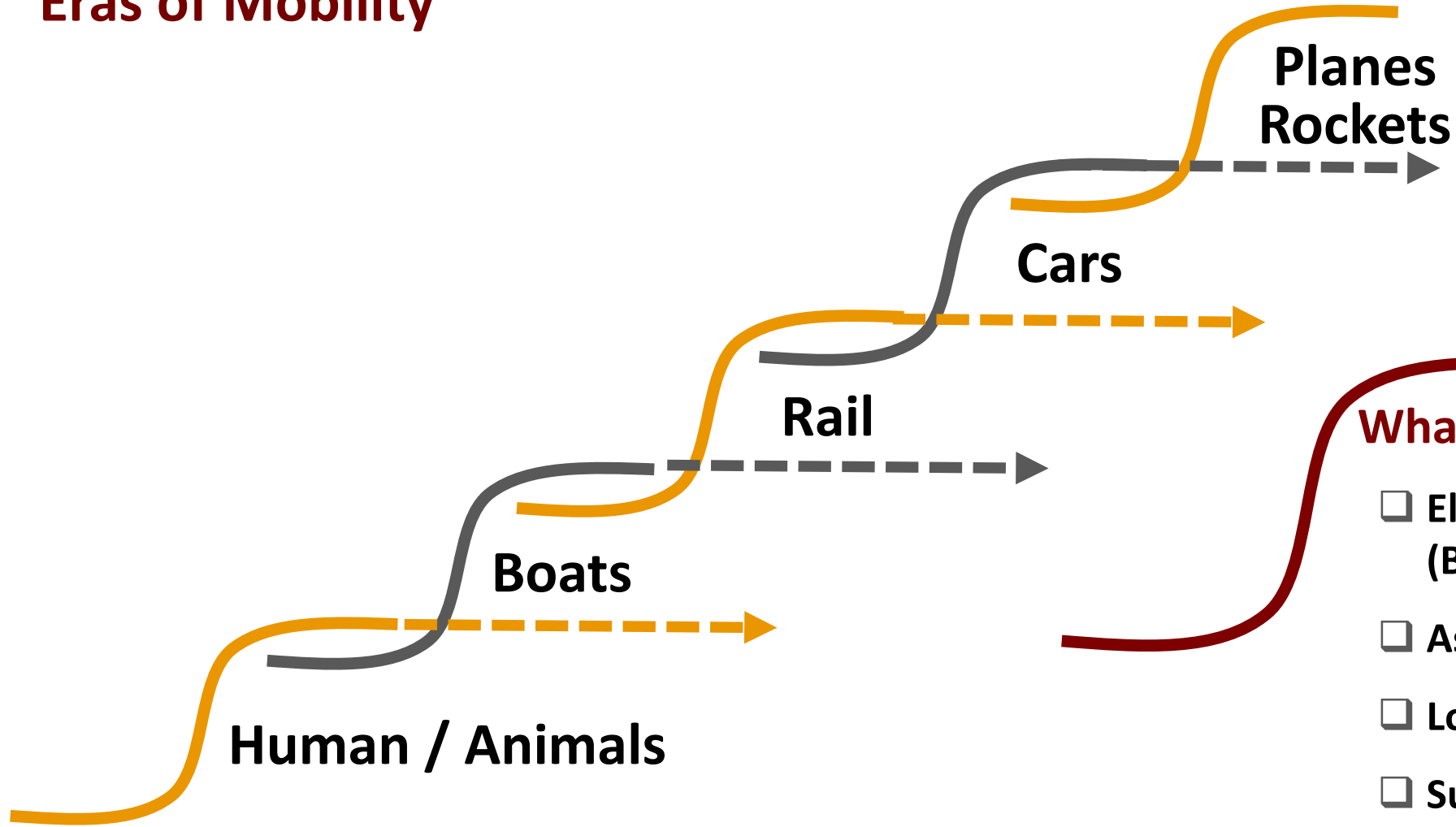
*'Mainstreaming +  
Diminishing Returns'*

**Rapid Change**  
*'Accelerating'*

**Disruptions  
lead to Next Era!!!**

**Slow Change**  
*'Emerging'*

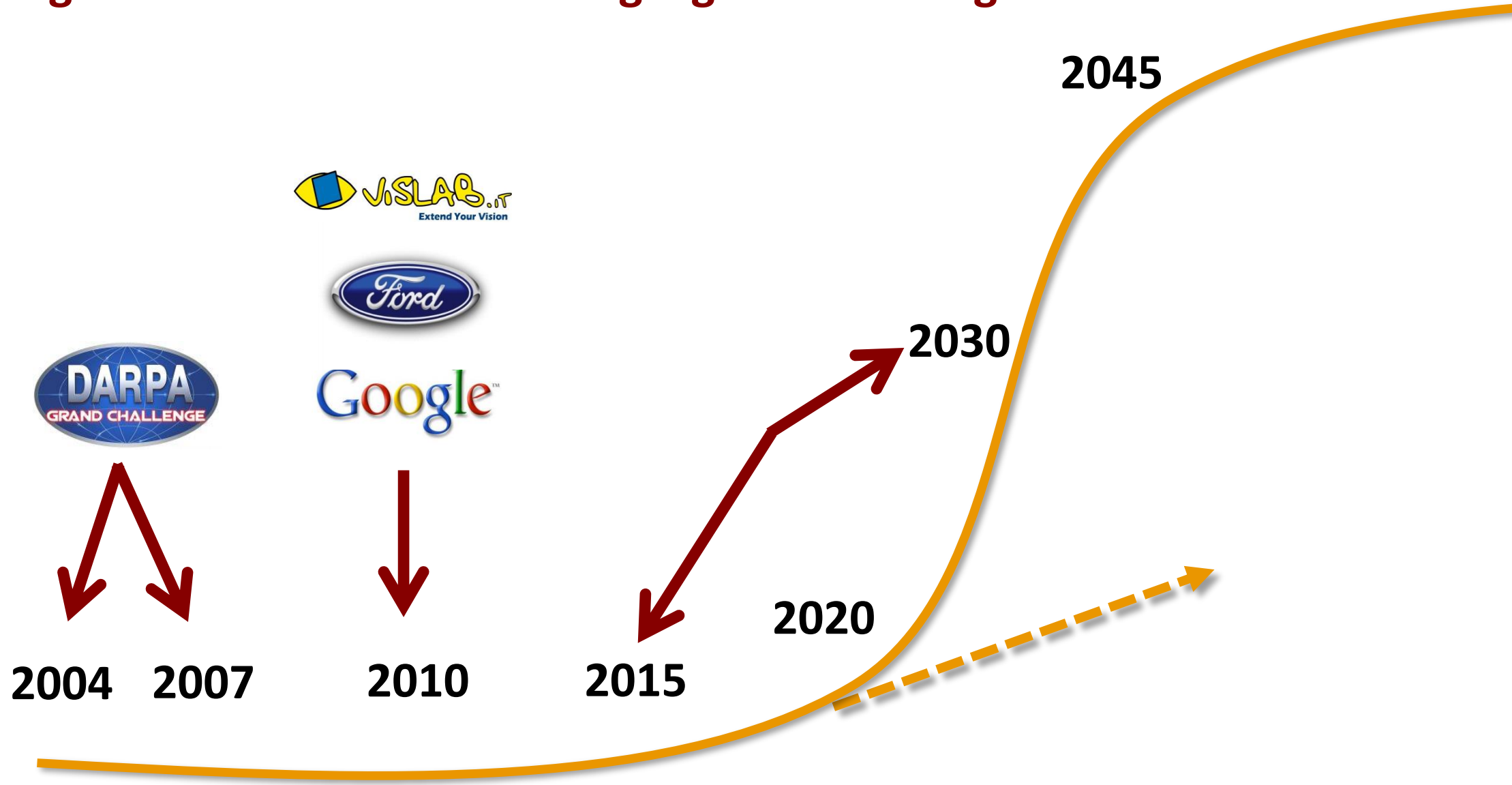
# Eras of Mobility



## What is next?

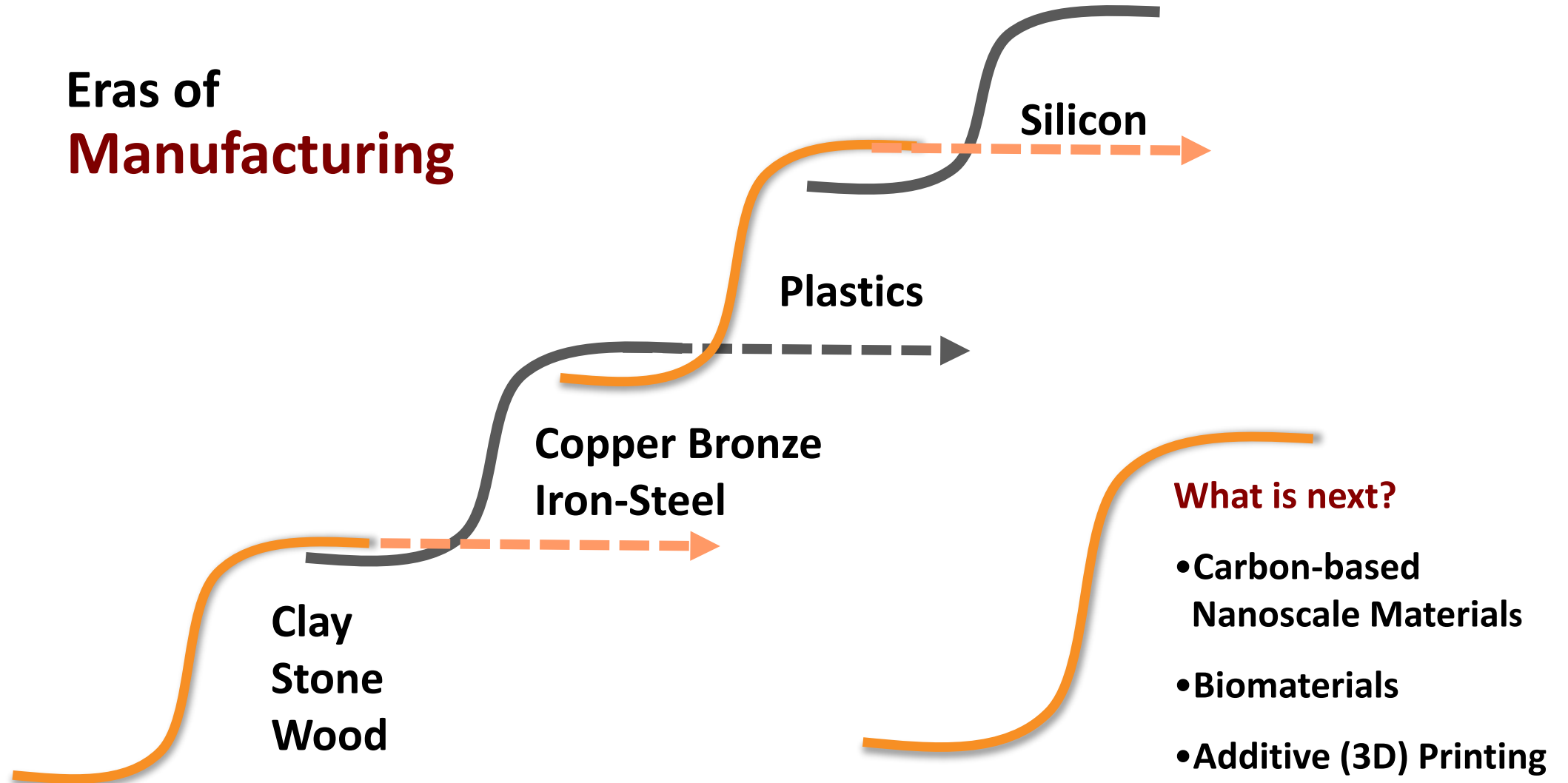
- Electric Vehicles  
(Battery + Fuel cell)
- Assistive + Autonomous
- Low-Volume Production
- Sub-orbital Space

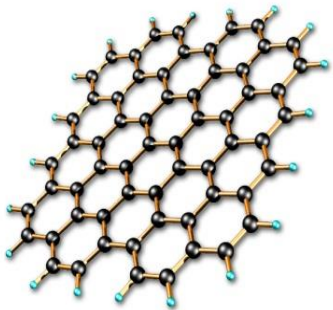
# Thinking Like a Futurist: Monitoring Signals of Change



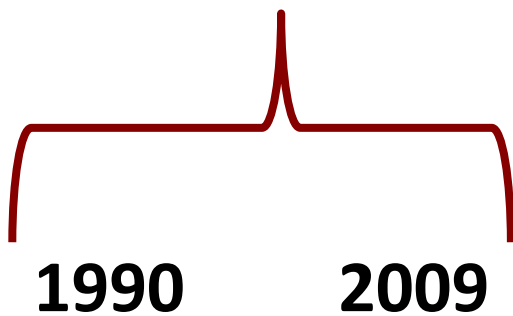


# Eras of Manufacturing

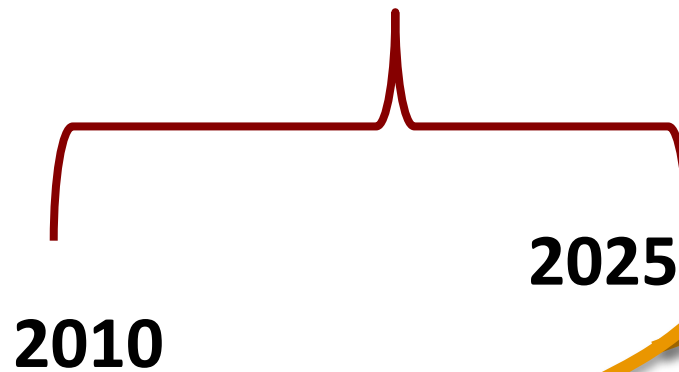




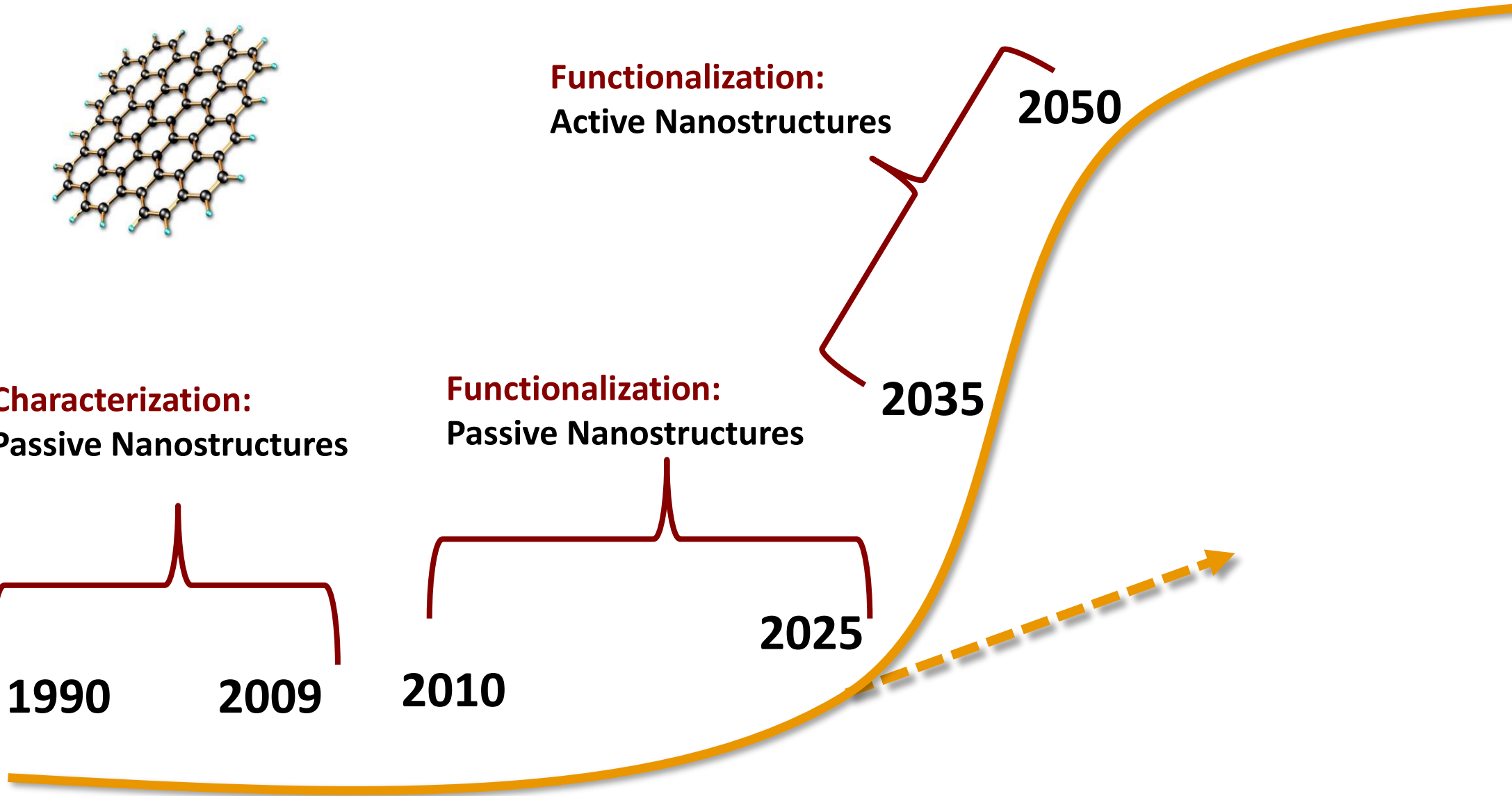
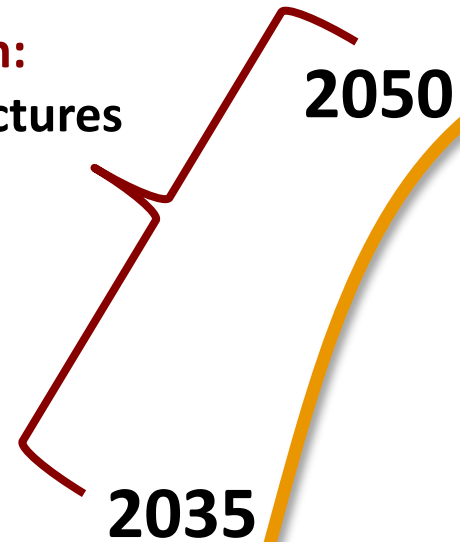
**Characterization:**  
Passive Nanostructures



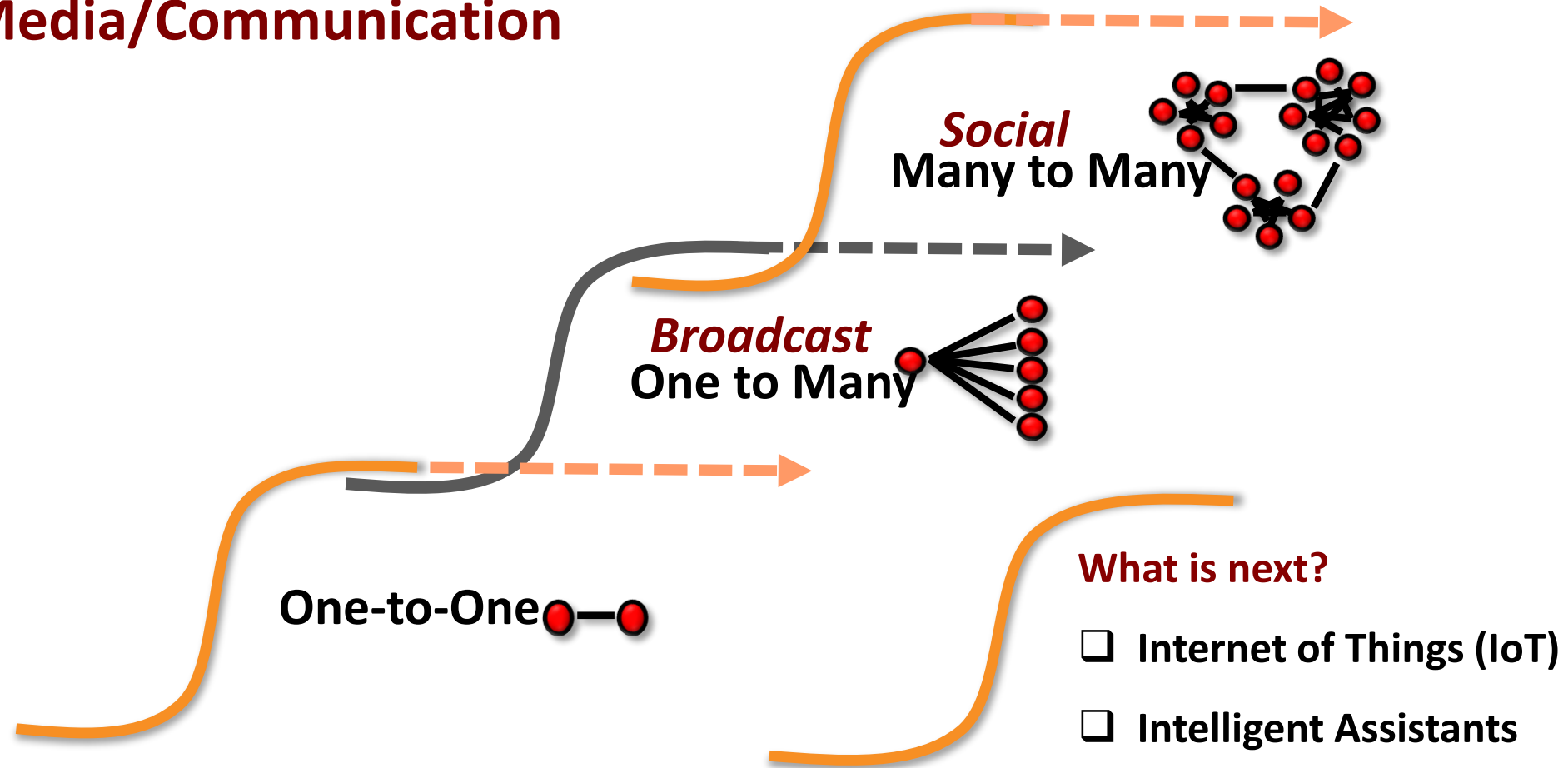
**Functionalization:**  
Passive Nanostructures



**Functionalization:**  
Active Nanostructures

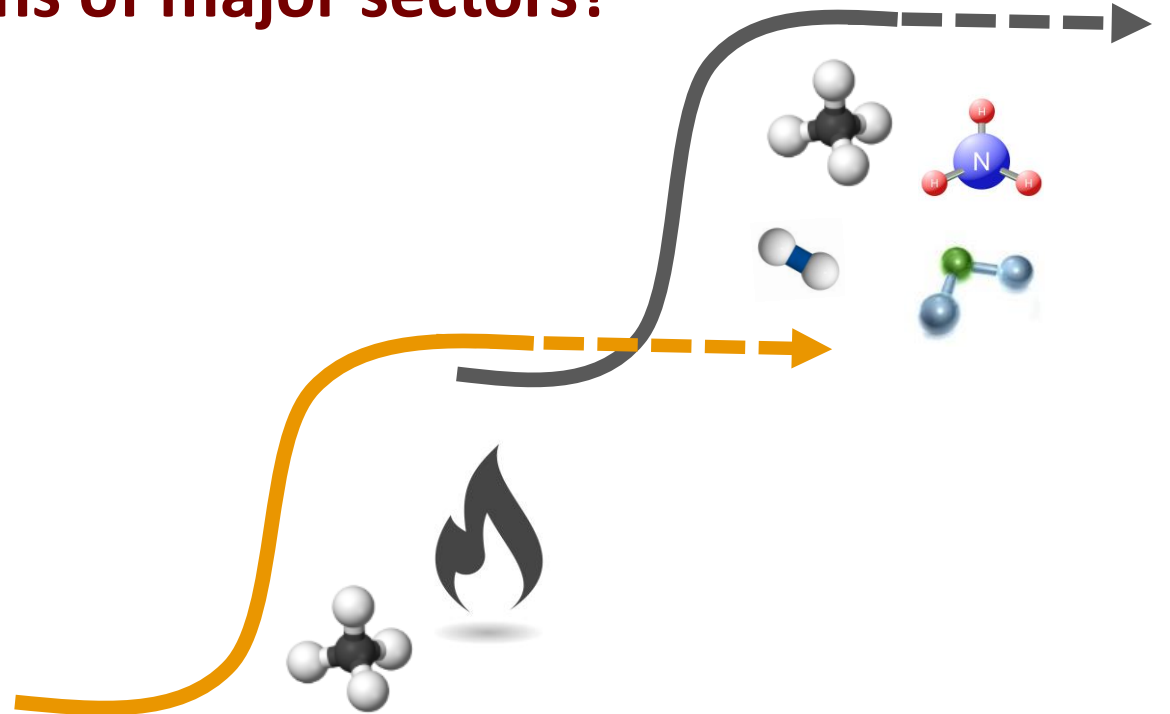


# Eras of Media/Communication



## How will societies navigate transitions of major sectors?

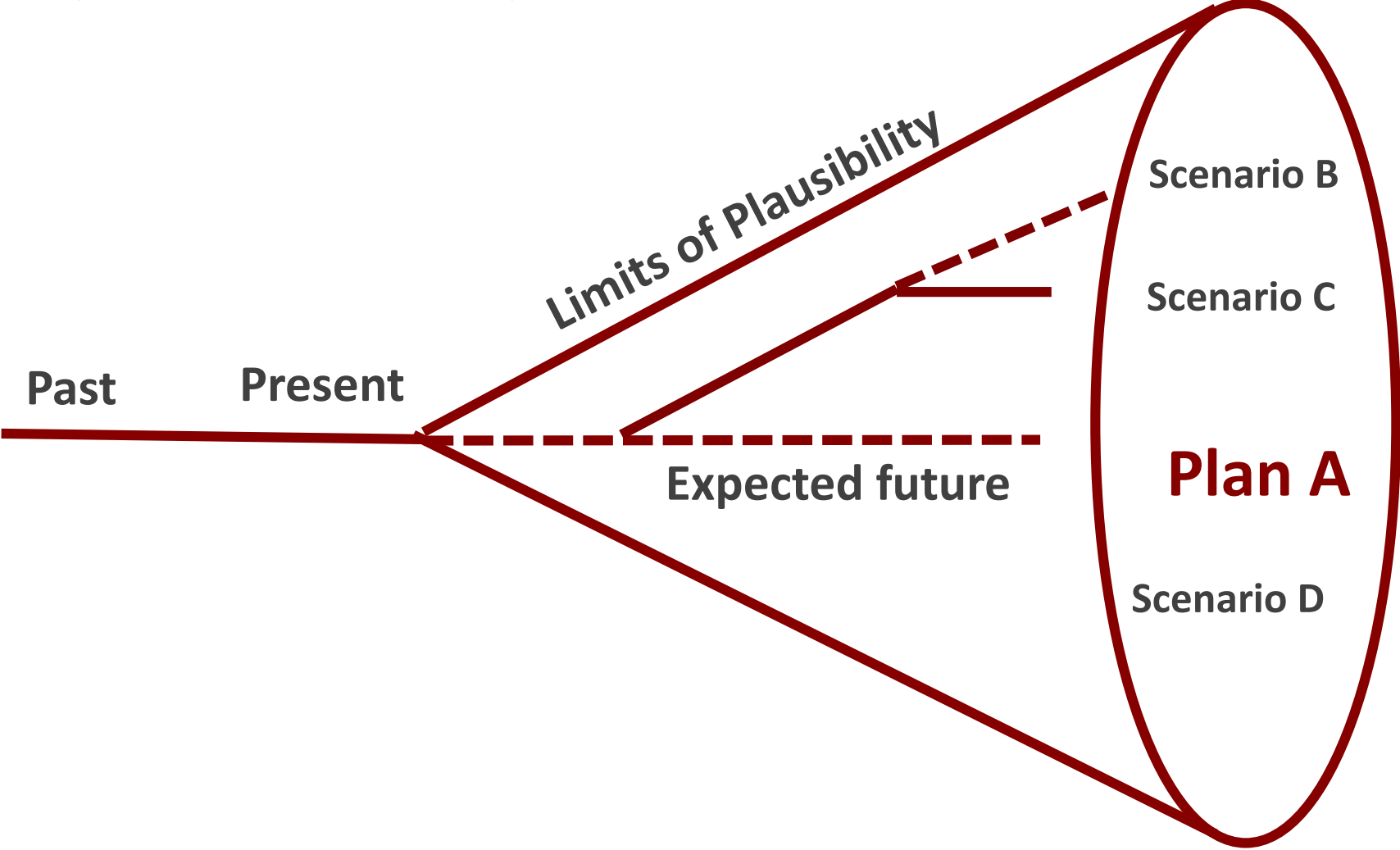
- Transportation/Mobility
- Healthcare / Wellness
- Agriculture / Farming / Food
- Retail
- Media / Communication
- Education / Learning



**Era-Step for  
Converting Molecules?**

# Foresight 101: Cone of Plausibility

Multiple Outcomes, Multiple Time Horizons

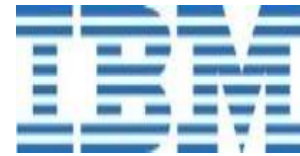


# Four Futures Thinking



Continued  
Growth

Disciplined  
Constrained



Transformed



Decline  
Collapse

# Ability to Tell Stories of Four Futures



Continued  
Growth



Disciplined  
Constrained



Transformed



Decline  
Collapse

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

**- Cellist, Yo-Yo Ma**

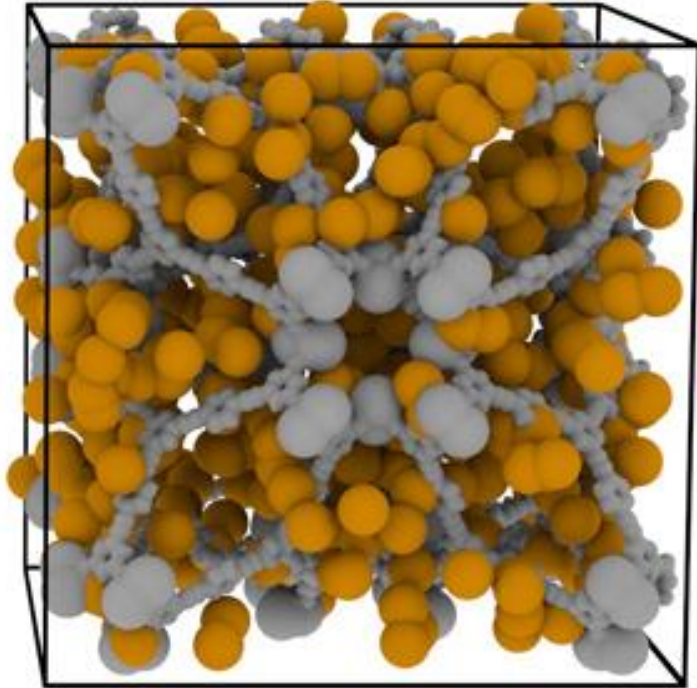




**In the News**

High Surface Area Crystal Sponges

# MOFs – Metal Organic Frameworks



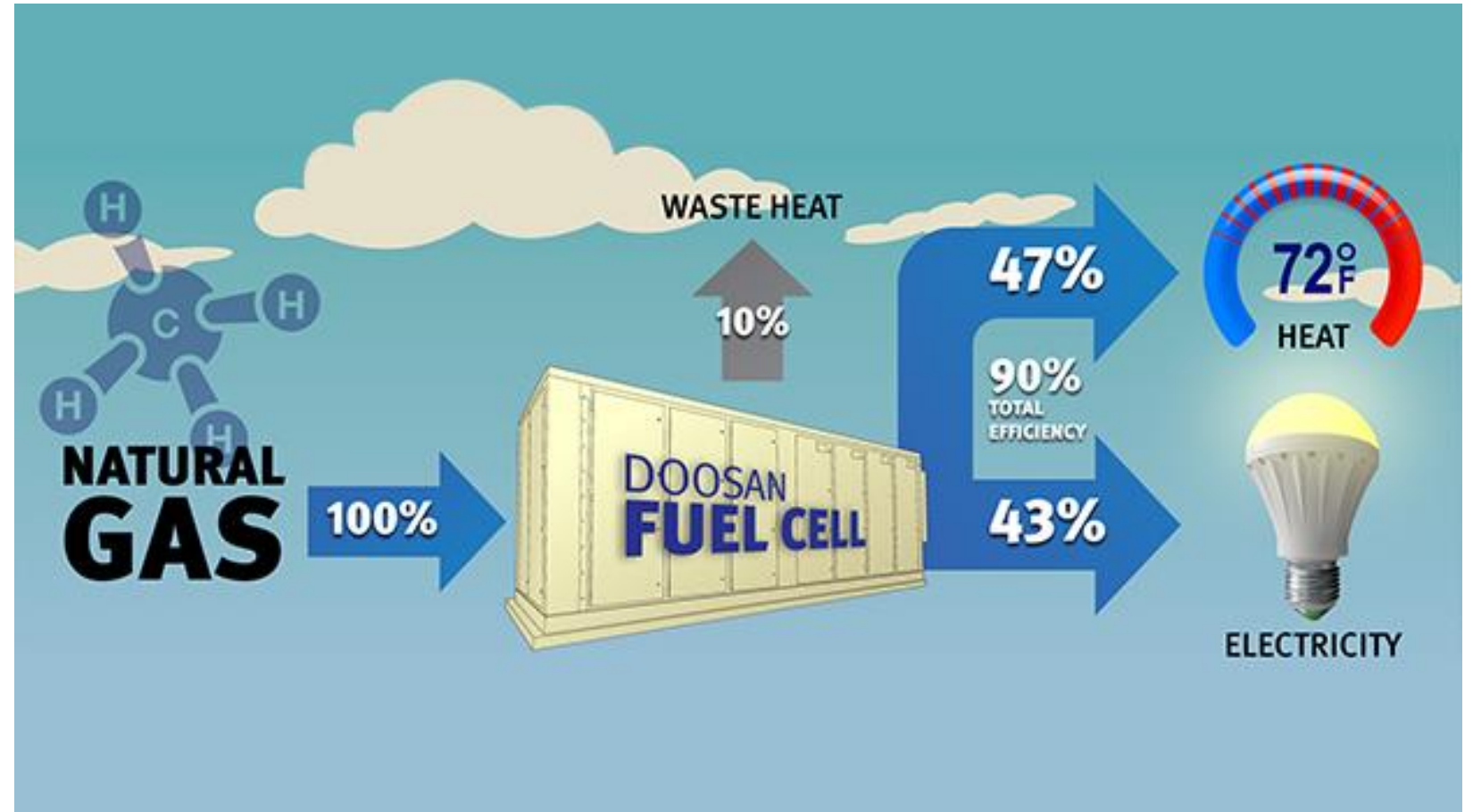
Northwestern  
Image by Christopher Wilmer/NuMat Technologies)



Science Journal



# Era of Fuel Cells = Single Step, Electrochemical Conversion



**SOFCs (Solid Oxide Fuel Cells) – Small to Large**



In mid-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

**STOR·H**  
by AAQIUS



**STOR·H**  
by AAQIUS



# 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

2023

2025

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**



**Pipelines vs Retail  
Shelf Simplicity**



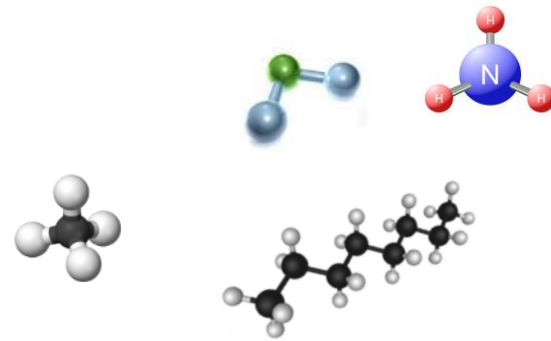
**SAMSUNG**

**Expanding  
Partnerships**





*In the News*



**Emerging Solutions for Deep Decarbonization**

**End**

# Decarbonization: Anticipating Transitions & Shifting Expectations

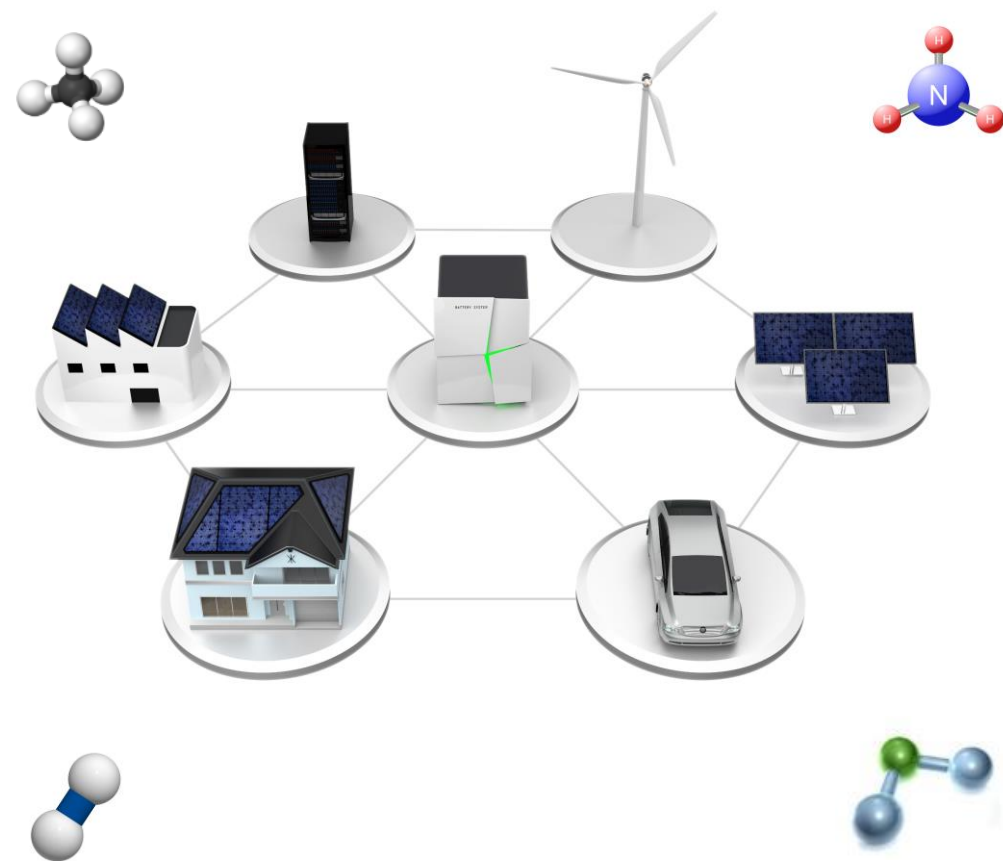


**Decarbonization:  
Rethinking the Role of Molecules**



*Future of Work*

# Rethinking the Role of Molecules





**Renewables vs Gas**  
**New Age of Energy Appliances**

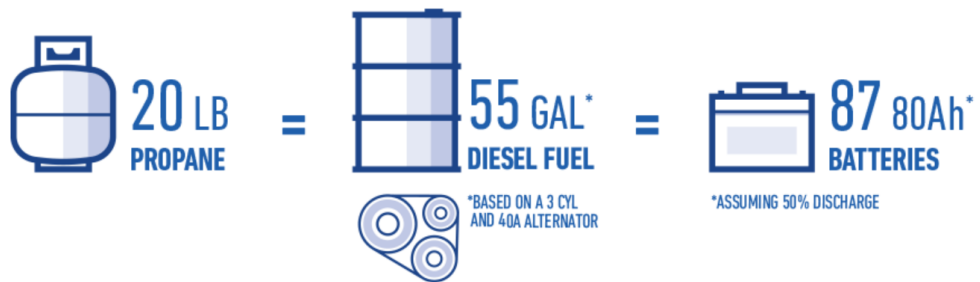
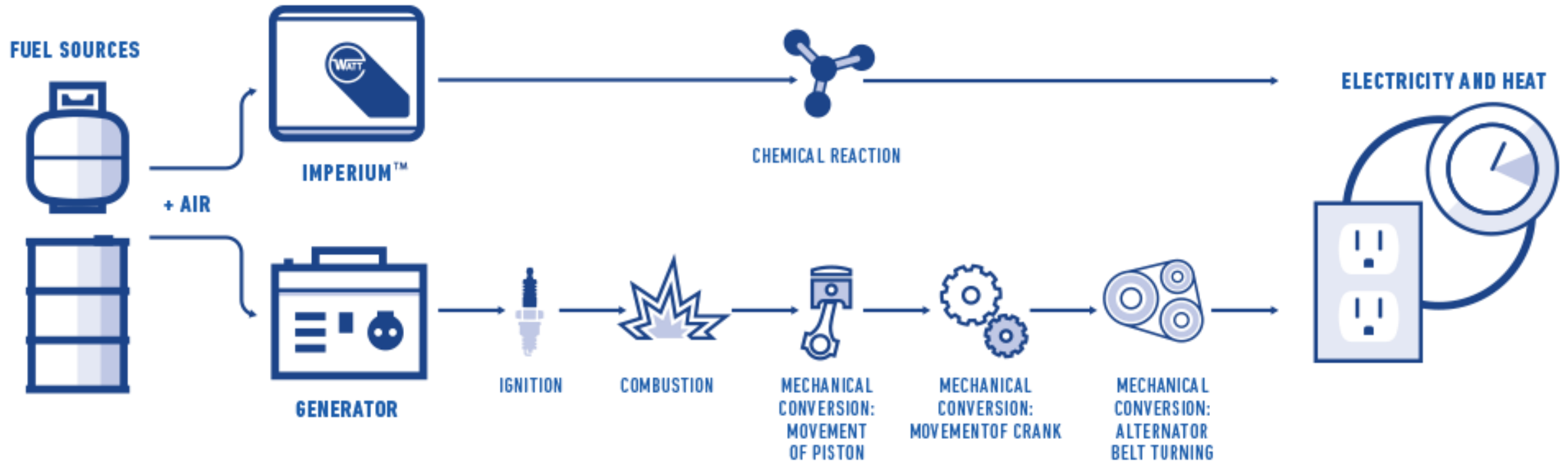


**Solar Plus Storage**

21<sup>st</sup> Century

20<sup>th</sup> Century

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



# Micro CHP via Solid Oxide Fuel Cells = 21<sup>st</sup> Century Energy Appliance



Peoples launches a 100-home pilot program



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

***Public Debates:  
Gas vs Power?  
Gas + Power?***



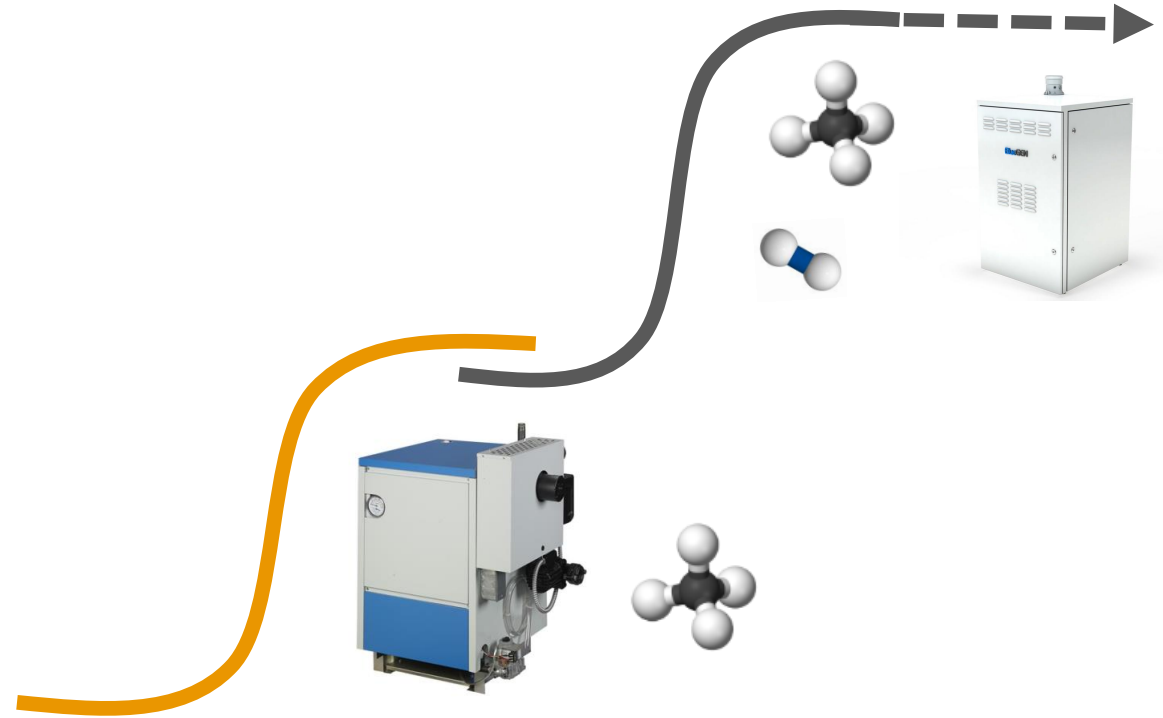
**Power Parks**  
63 MW Beacon Falls

**fuelcellenergy**



**2020 - 2040**

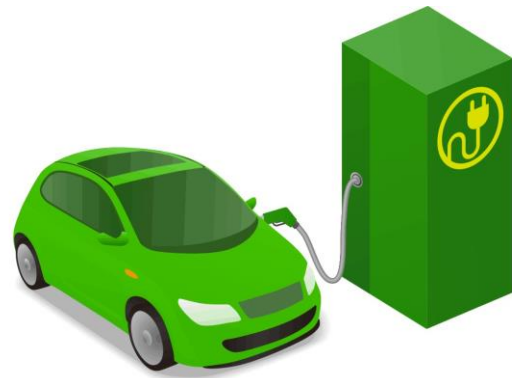
**How might we navigate a transition for public gas solutions in a new age of energy appliances (MicroCHP) and utility-scale alternatives?**



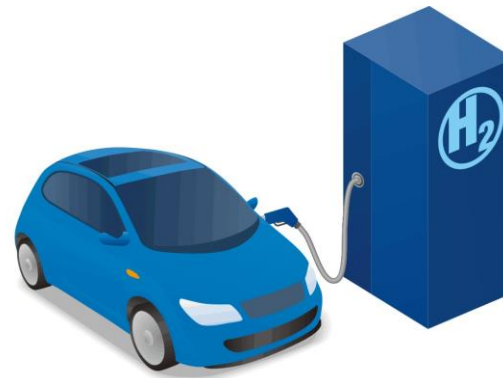
# 'Electrification' of Vehicle Fleets – Electrons vs Fuels?



*Hybrid ICEs*



*Plug-in EVs*



*Fuel-based EVs*

Thinking Beyond  
Passenger Vehicles:

Rail  
Marine  
Trucking  
Aviation/UAVs

Autonomous  
Last Mile / Micro  
Transit  
Indoor Robotics  
Outdoor Robotics

# BEVs 'Have Won' vs Limitations of All Electric Pathway

Battery pack = 400 miles  
Daily Need = 40 miles

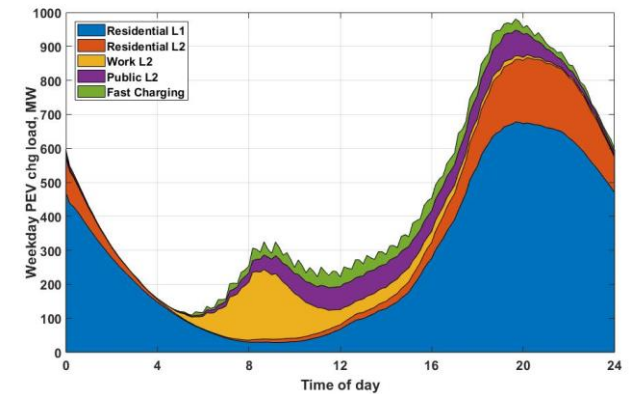


OEM Cost-to-X  
vs Daily Use Demand



Uptime &  
Recharging for  
Urban Markets

'Duck Curve' to 'Dragon Curve'



Full Costs of  
Grid Management

# The Shared Strategy for Integration & Fuel-based EV Fleet



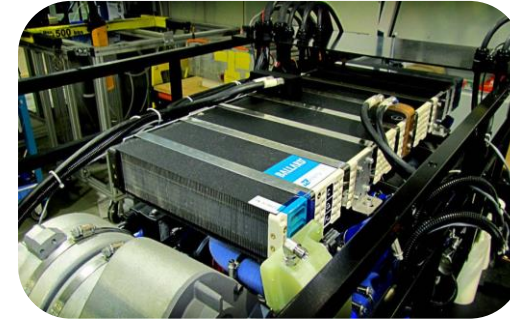
NIKOLA ONE™

Trucking



POWERCELL  
BOSCH

Royal Caribbean INTERNATIONAL VIKING YANMAR ABB



Maritime



ALSTOM

Hydrail



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

Aviation / UAVs



# Hydrail Coming to the Region

STATESVILLE  
**RECORD & LANDMARK**

By Kate Stevens news@statesville.com Sep 4, 2018

## N.C. plans shift to train powered by hydrogen fuel cells

The N.C. Department of Transportation plans to convert one of its Piedmont line trains to hydrogen fuel cells.



The N.C. Department of Transportation is in the early stages of a project to convert one of its Piedmont passenger trains, with daily service between Raleigh and Charlotte, from diesel fuel to hydrogen fuel cells.

The creation of a hydrogen fuel filling station could cost between \$1 million and \$2 million, but that's the cost equivalent of just 2,000 feet of catenary

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

HANNOVER MESSE

GRUPEXHIBIT

HYDROGEN

FUEL CELLS

BATTERIES

Jun 25, 2018

Weichai Power's Strategic Equity Investment in Ceres Power Receives Final Chinese Approval

SOFC range-extender for China bus market

Aug 29, 2018

Ballard Signs Historic Strategic Collaboration With Weichai Power, Advancing China Strategy

# China Will Drop Cost for Heavy Duty FCEVs and Hydrogen

2 JUL 2018

JD.com introduces fleet of hydrogen delivery trucks

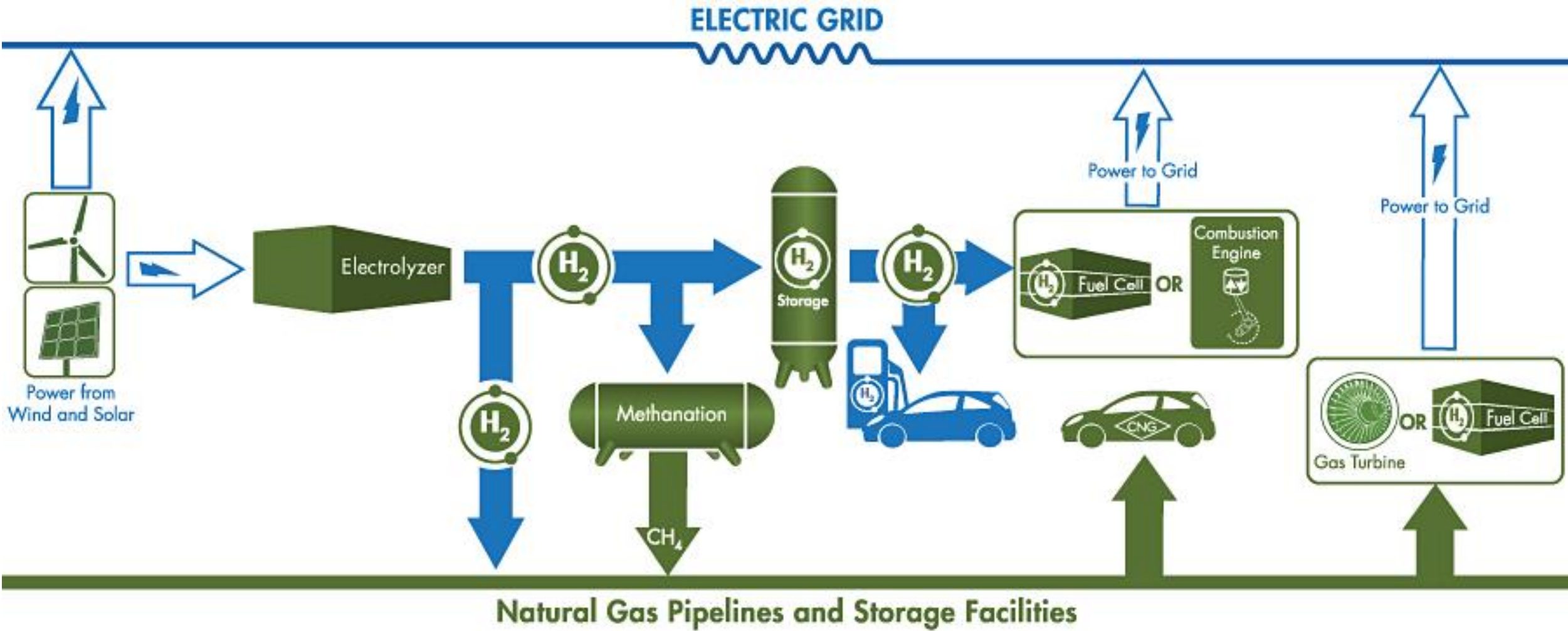
Bend, Oregon-based Element 1 Corp & China Aqueous Group Announce Joint Venture

US Hybrid Announces China Fuel Cell Joint Venture and Unveils Class 8 Fuel Cell Port Drayage Truck for San Pedro Ports

**UQM Technologies Announces New China and Europe Growth of Fuel Cell Compressor Business**

Added by FuelCellsWorks, May 09, 2018

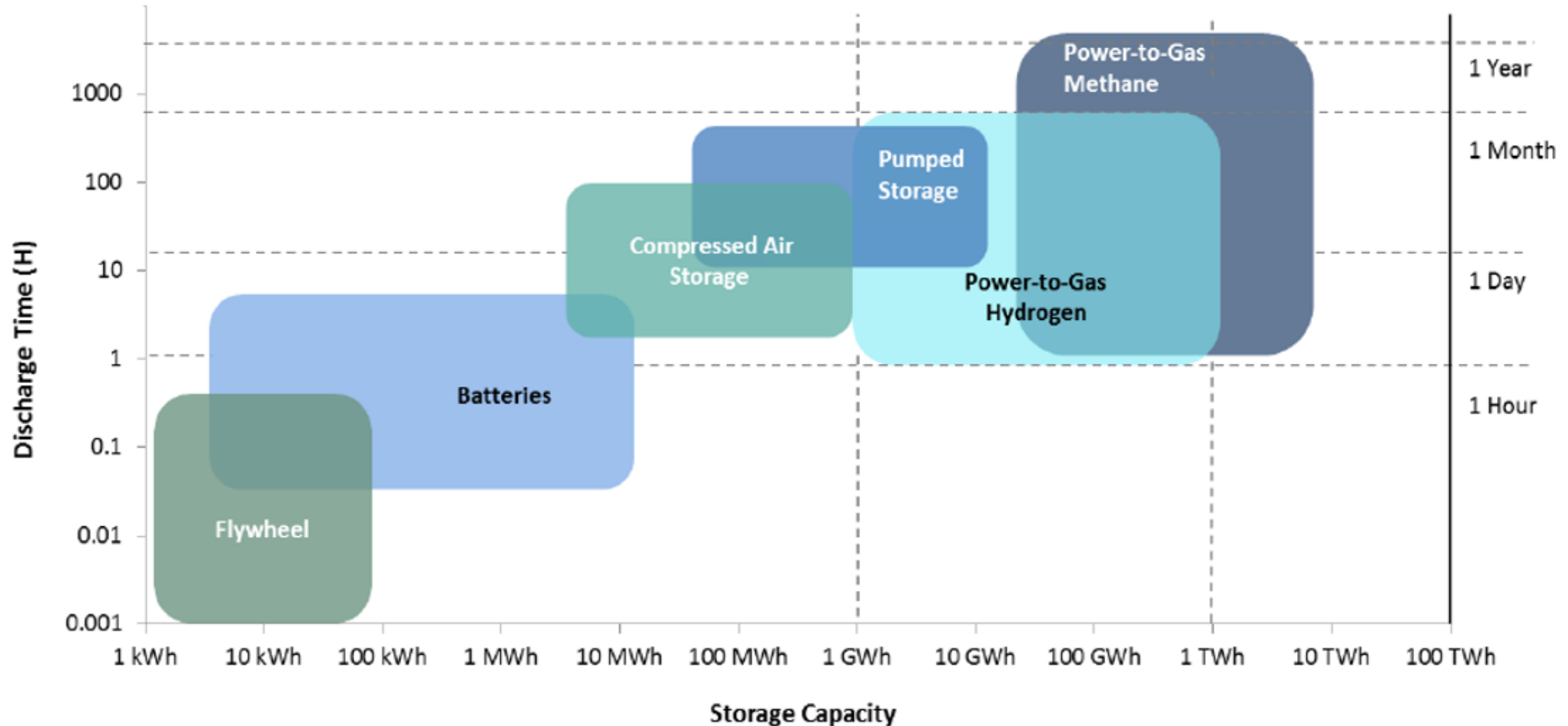
# Power to Gas Gains Momentum with Scale & Versatility





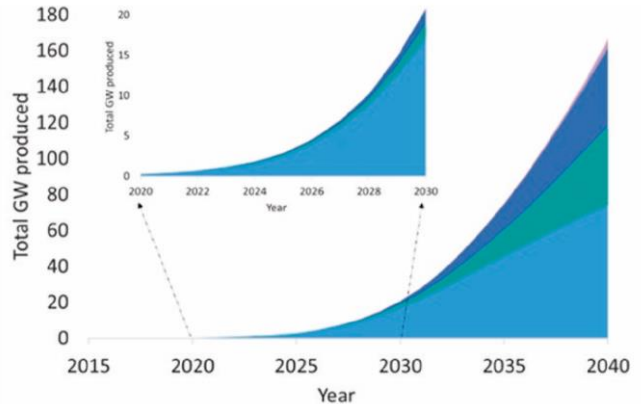
# Renewables ♥ PtG - Scale & Versatility of Hydrogen

## Will We Assume Role and Control of H<sub>2</sub>-rich Fuels & '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

**HyET Hydrogen** Efficient purification & compression

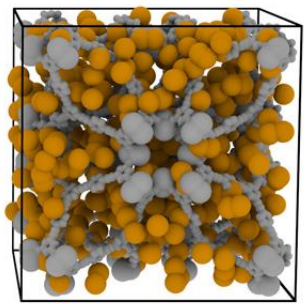
**The new standard.**

**HyET HCS 100**  
Electrochemical compressor

## Compression



Gas



Solid



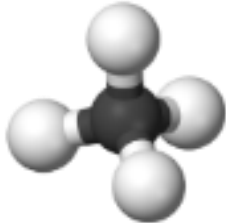
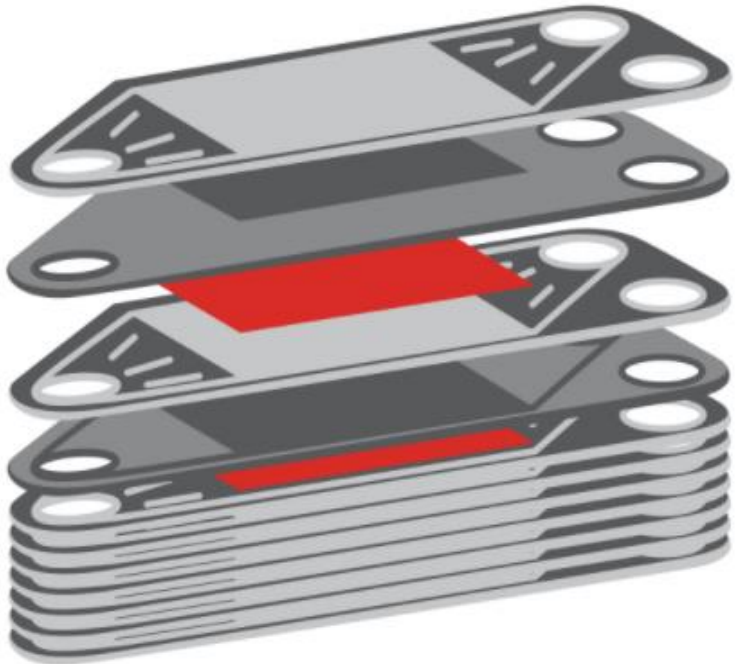
Liquid

## Storage

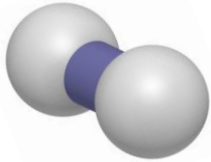
# Scenario: Natural Gas Expands into Hydrogen or *Green Gas*



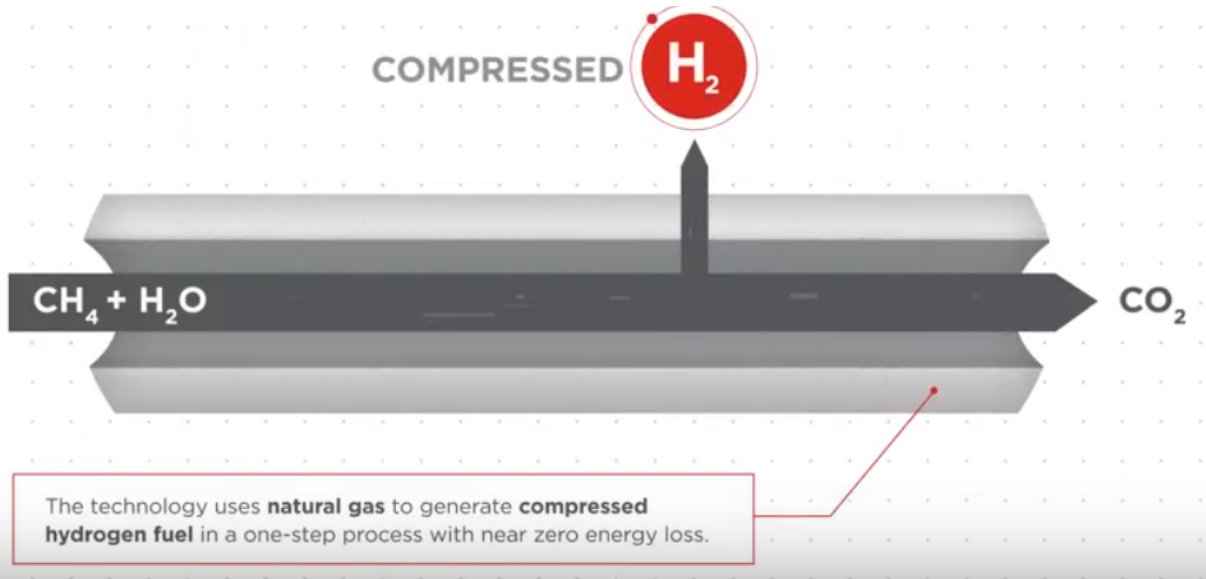
ACTIVE CERAMIC MEMBRANES



Near Zero Loss  
Energy Conversion



# Compact Hydrogen Generators via Natural Gas




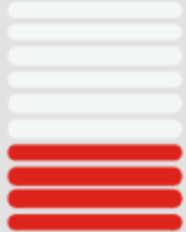



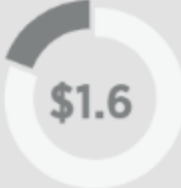



Driving Cost  
\$/100km



Source



# Hydrogen is **cheaper** and **cleaner** than electricity and petroleum

	CO <sub>2</sub> Emissions Well to wheel (g CO <sub>2</sub> /km)	Driving Cost \$/100 km
<b>H<sub>2</sub> Fuel Cell Electric Vehicle</b> Hydrogen by Membrane Reforming 	 <b>62</b>	 <b>\$1.2</b>
<b>Battery Electric Vehicle</b> 	 <b>78</b>	 <b>\$1.6</b>
<b>Internal Combustion Engine</b> 	 <b>180</b>	 <b>\$6.3</b>

PRICES • Natural Gas = \$0.25/Nm<sup>3</sup> • Electricity = \$0.1047/kW • Gasoline = \$1 (\$3.85/gal)

# Scenario: Your Teams Install NatGas to H2 Appliances in Service Area



**Compact Design**  
Enable H<sub>2</sub> at Home

**61%**  
of US single-family homes  
use Natural Gas heating

Source: U.S. Energy Information Administration, Office of Energy Consumption and Efficiency Statistics, Forms EIA-457A and EIA-457C of the 2015 Residential Energy Consumption Survey. Data: 49.5 million US single family homes (out of 80.9 million) use Natural gas as a heat source.

# Implications of These Disruptive Scenarios?

## Fuel Cells

### No Longer Fool Cells



How will our regulators, customers and public gas respond to option of power generation via SOFCs?

## Power to Gas

### Comes of Age



Will we enrich natural gas lines to help decarbonize our sector and help scale renewables storage and power grid balancing?

Will we get involved in fuel-based EV infrastructure?



# Decarbonization: Anticipating Transitions & Shifting Expectations



We did not get to this section –  
but enjoy the slides without  
context!

Decarbonization:  
Rethinking the Role of Molecules





**2020 – 2030**  
**Biggest Challenges & Opportunities**  
**The Future of Work**





**In the News**



Stanford Business School will pilot a program with Experience.ai to capture experience data from learning, project performance and decision processes within case study groups. Stanford's vision is for every student to retain rights to experience data and build a critical personal digital asset for the future.

True

False





Context of the *Creepy Line*

Google

Inevitability of Dealing with the *Creepy vs Compelling Line* in..

Future of Work

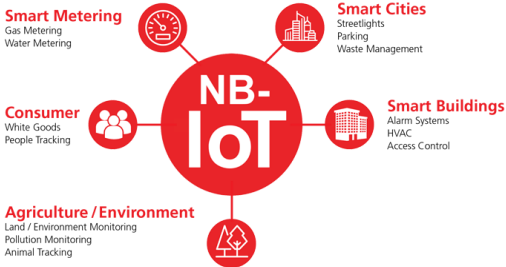
# Emergence of Data-driven World of Training & Work



**Social  
Data**



**Health  
Data**



**Device +  
Infrastructure**



"I did this..."

**Learning & *Doing*  
Experience Data**

# Signal of Change from the Learning & Development (L&D) Community

**Assumption: Experience Data Appears Inside School, Workplace & Beyond**



EXPERIENCE  
API

**Activity Streams**  
<Actor, Verb, Object>  
**“I did this”**

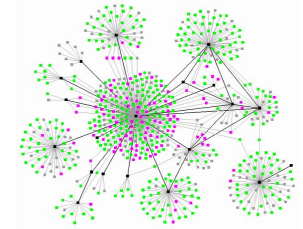


# Scenario: People Embrace Experience Capture Analytics



**"I did this..."**  
Statements

- Lucy **read** an article on virtual reality for aging populations
- Lucy **opened** an Evernote folder on ageing solutions
- Lucy **watched** a Youtube video on Social VR Experiences for Ageing Boomers
- Lucy **interviewed** the Director of MIT's Age Lab
- Lucy **attended** an MIT workshop on VR simulations
- Lucy **wore** an 'ageing suit' at MIT Age Lab
- Lucy **mentored** with the Head of Innovation at AARP
- Lucy **designed** a new VR social space using Facebook Oculus dev kit
- Lucy **demonstrated** her VR experience for Aging populations at a NYC Meetup
- Lucy **won** an Webbie award for Social VR platform
- Lucy **taught** a Coursera MOOC on Universal Design and VR experiences
- Lucy **was hired** as head of Social VR for Aging Populations at Facebook



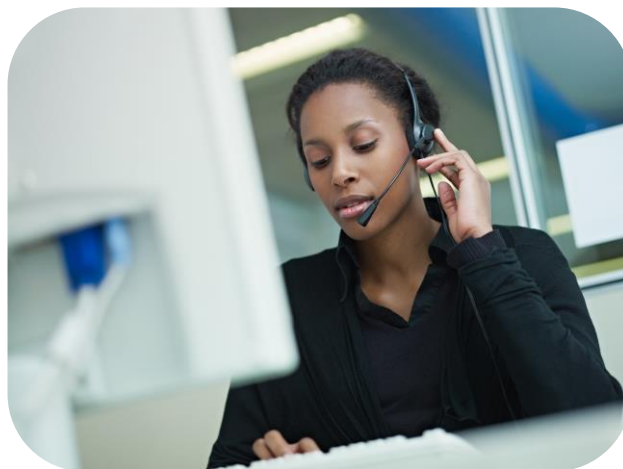


<Actor, Verb, Object>

“I did this”

Task + Experience Data

From People & Connected Equipment





# Case Study: Caterpillar



**Understanding  
LMS/CMS Activity**

**Expanding  
Video-based Analytics**



**ExperienceAPI (xAPI) L&D integration with focus on training for Service, Sales, Leadership & Marketing.**

When trying to help someone learn, the team considers these three vital questions:

- 1. Where does the learner want to go?**
- 2. What does the learner know?**
- 3. How can we develop the individual?**

Courses Passed	5.61	Track-Type Tractor Family	31334	MORE
----------------	------	---------------------------	-------	------

MORE	MORE	MORE
------	------	------

# Signal: Virtual Reality + ExperienceAPI

CenarioVR + EXPERIENCE API

amazon

float®



**“I did this...”**

# Signal: Computer Vision + ExperienceAPI

## Computer Vision on Jobsite



### The world's first deep learning enabled video camera for developers

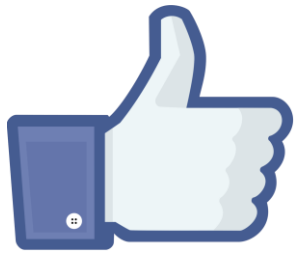
AWS DeepLens helps put deep learning in the hands of developers, literally, with a fully programmable video camera, tutorials, code, and pre-trained models designed to expand deep learning skills.

Buy Now

Register your DeepLens



# Scenario for 2020s: Early Adopters Embrace Experience Analytics



EXPERIENCE  
API

Assumption to Explore

**By 2025, Experience Data Will Become  
Our Most Valuable Digital Asset**

  
and Controversial

**If we capture experience data...**



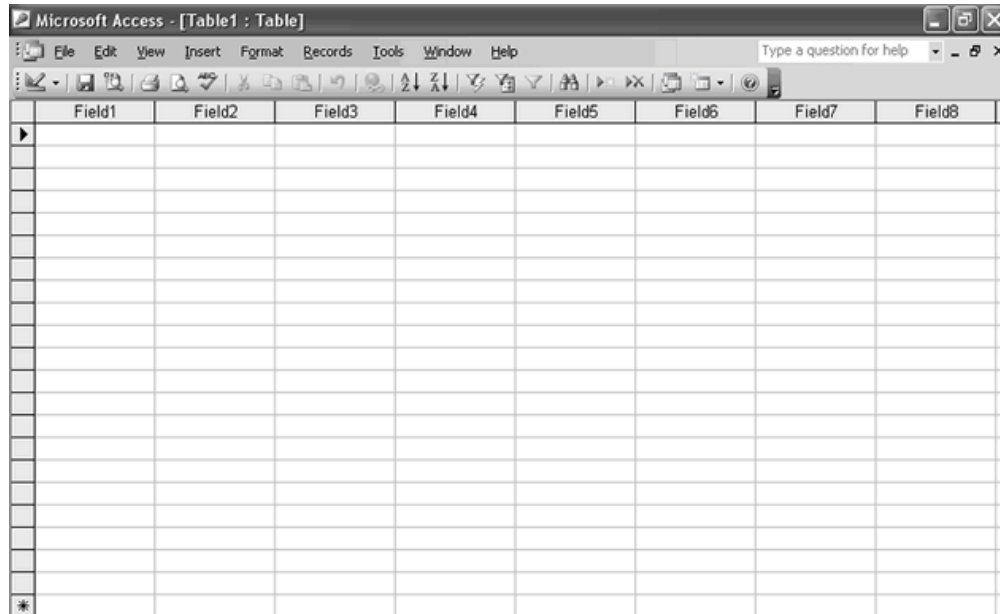
**“I did this...”**  
Statements

**How do we approach regulations?**

**How do we avoid the creepy line?**

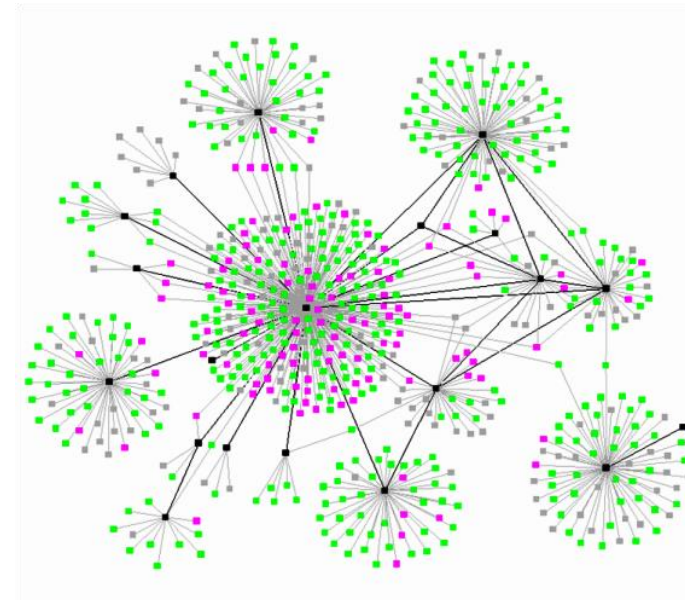
**How do we make sense of it?**

# Building a Connected Data Foundation for Innovation



A screenshot of the Microsoft Access application window. The title bar reads "Microsoft Access - [Table1 : Table]". The menu bar includes "File", "Edit", "View", "Insert", "Format", "Records", "Tools", "Window", and "Help". Below the menu bar is a search bar with the text "Type a question for help". The main area displays a table with 8 columns labeled "Field1" through "Field8" and approximately 20 rows. The table is currently empty.

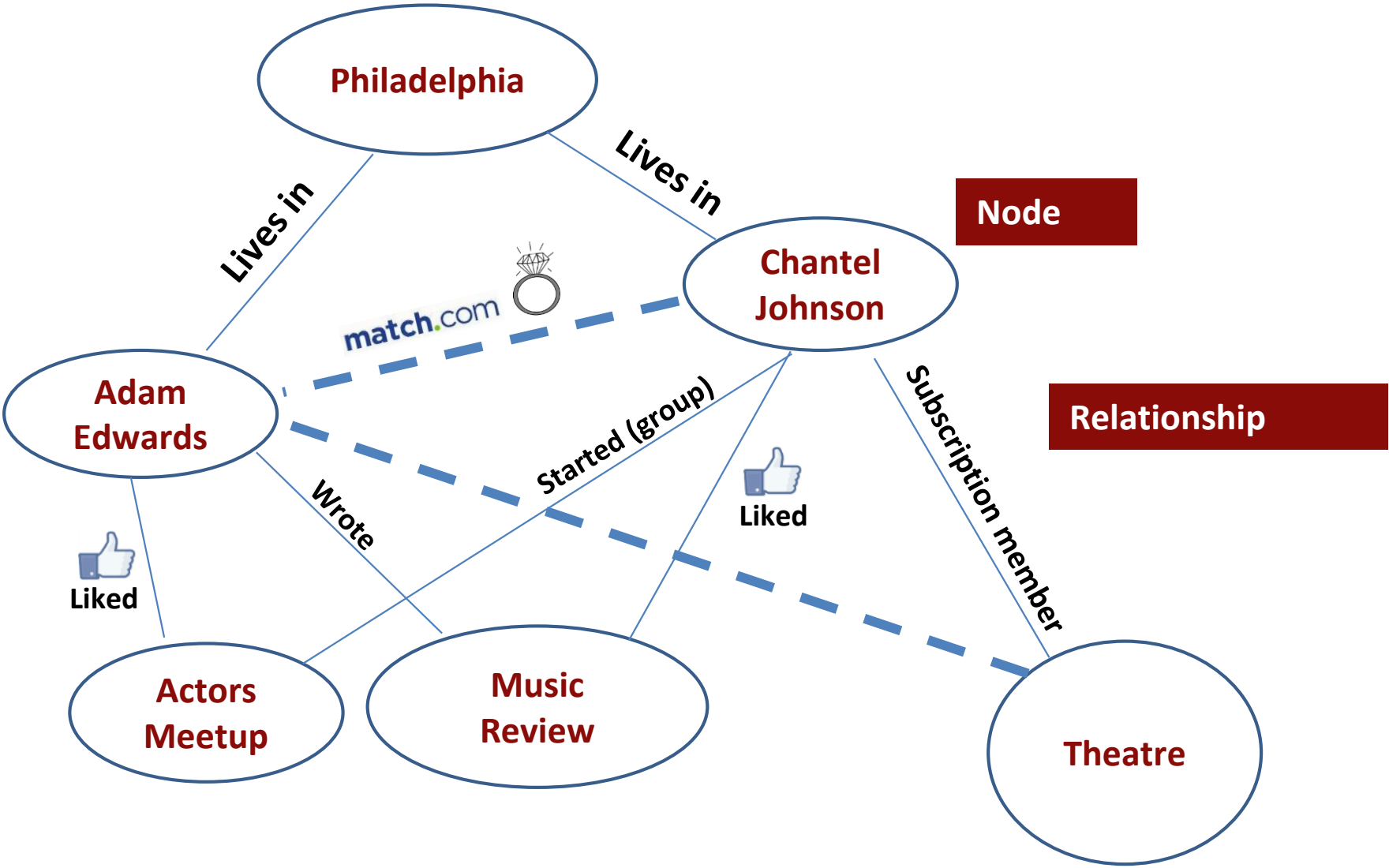
**Tables = Past**



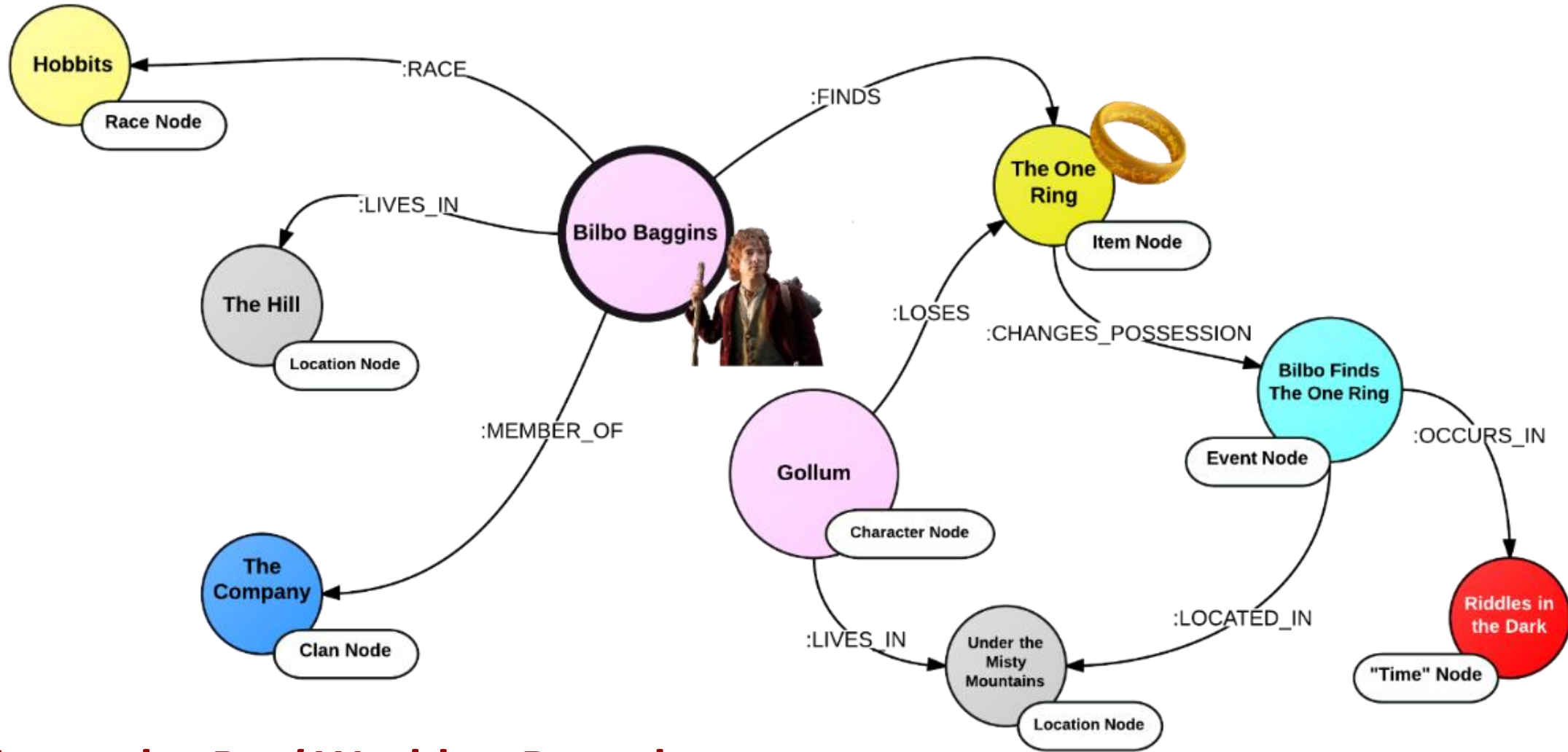
***Graph Thinking = Future***



# Graph Database = Understanding Relationships + Connections



# Graph Solutions for Understanding the Journey vs Work Outcomes

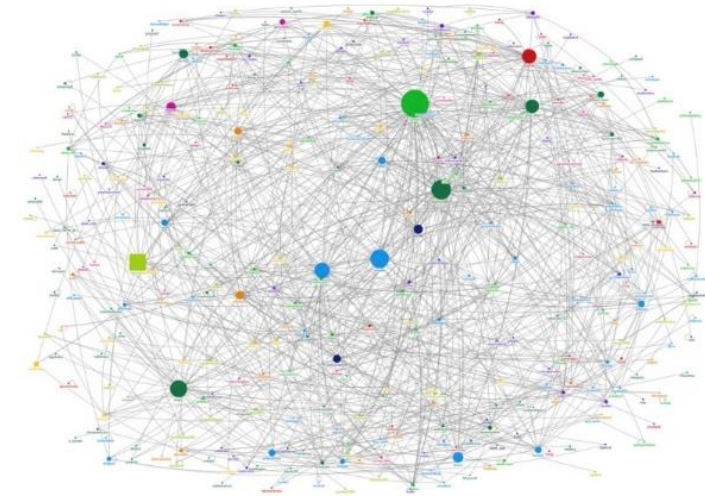
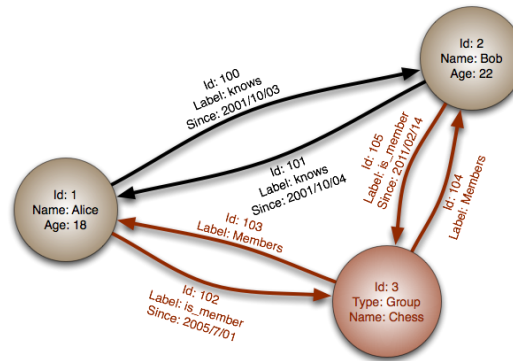


Mirrors the *Real World* to Reveal  
Influencer Profiles, Decision Pathways and Recommendations





## Era of Social Graph



## Era of Experience Graph

# Real World Product = Enterprise Knowledge Graphs

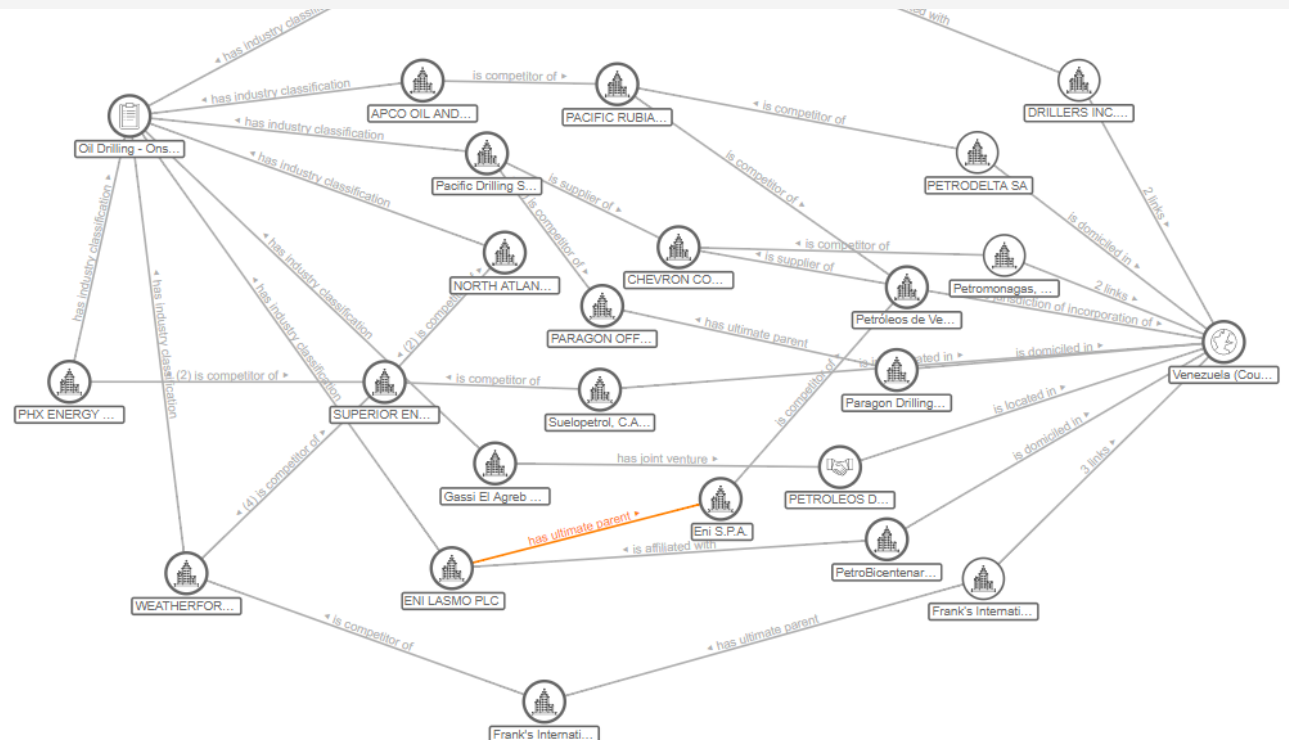
OCTOBER 23, 2017

Thomson Reuters Launches first of its kind Knowledge Graph Feed allowing Financial Services customers to accelerate their AI and Digital Strategies

Graph network of 2 billion relationships brings to life a comprehensive view of the financial ecosystem so that users can uncover new, unexpected or difficult to find insights from connected data.



A linked data feed of Thomson Reuters financial content sets with a pre-identified set of relationships, helping you to uncover previously undetected connections within and across data sets.



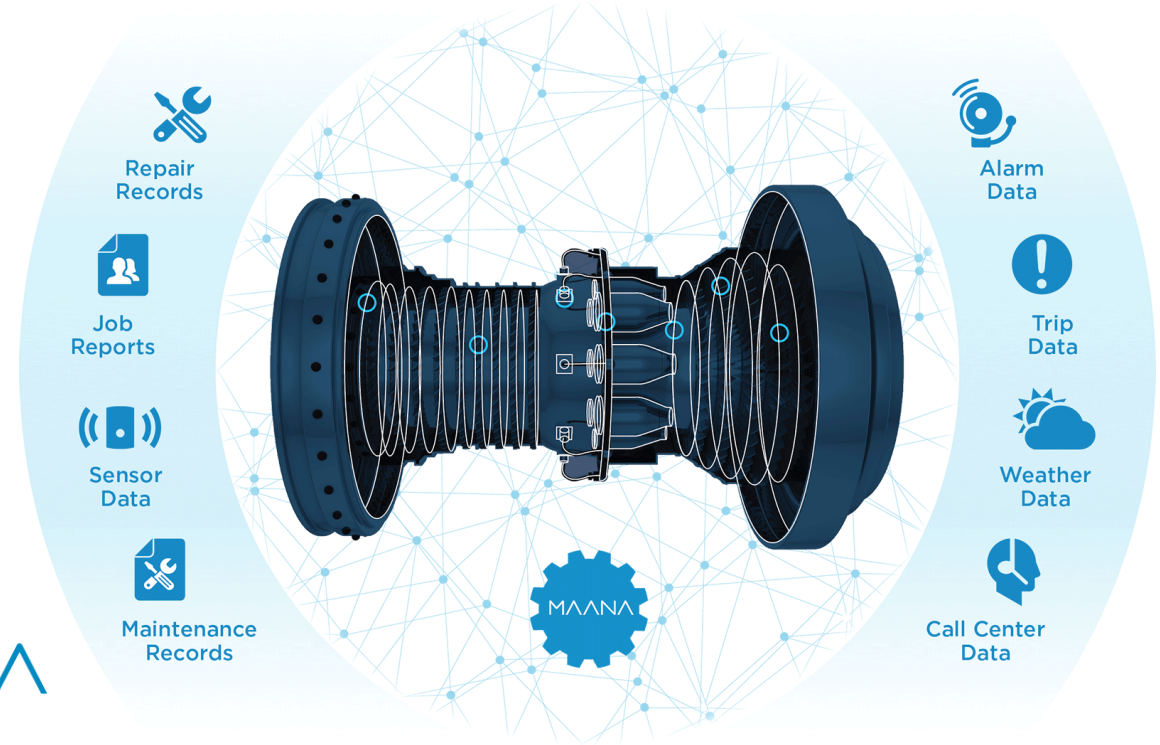
# Rise of Enterprise Knowledge Graph Vendors

## Knowledge Graph Applications

- ❑ Discovery & Dissemination
- ❑ IoT for Supply Chains;  
Predictive Maintenance
- ❑ Natural Language Processing  
(Voice to Report Generation)
- ❑ Q&A Datasets

MAANA

## Maana Knowledge Graph

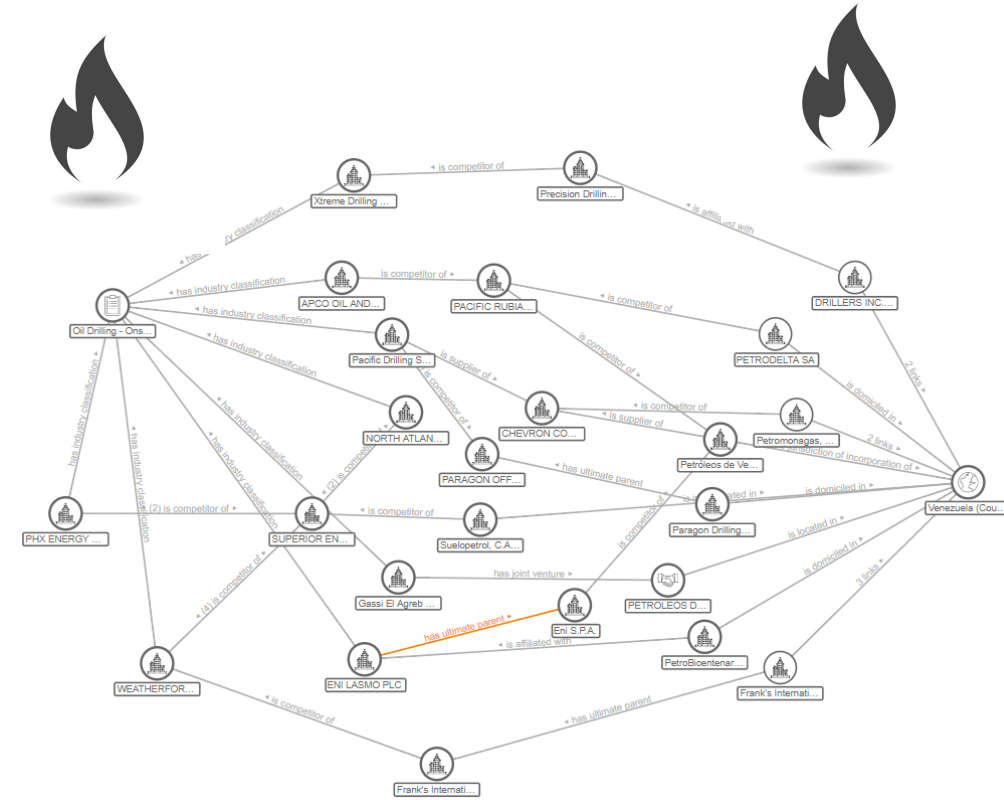


# Real World Product = The Economic Graph



Members – Companies – Jobs – Skills – Schools – Knowledge

How might a 'Connected Data' and Graph Strategy Transform the Nature of Work within the Natural Gas Industry?



# Learning Curve

 Yet Analytics

Watershed<sup>LRS</sup>  xapiapps

**Experience Analytics**  
**Learning Record Stores**

 neo4j

 JanusGraph

  
 GraphDB

 OrientDB<sup>®</sup>

**Graph Analytics**

# Future of Work & Experience Graph – 2020s – 2030s

## *Key Questions & Implications*

- Becoming a Data-driven Culture (More Transparency & Accountability)*
- Privacy: Ownership vs Access Spectrum of Experience Data*
- Future Value of Experience Datasets in Training A.I. (ML/DL)*
- Deciding on Pilot Cases vs Vision of Organization-wide Roll Out*

## *Uncertainties*

- xAPI Evolution alongside Semantic/RDF & Knowledge Graphs*
- xAPI Integration by Enterprise Software Providers*
- Adoption of Experience Graph by Niche Job Functions vs General Positions*
- Techno-solutionist Over-Engineering?*

Thank you!



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