



Hydrogen and fuel cell technical advisory committee meeting

May 9, 2012

Presented by: Prabhu Rao, VP Commercial Operations

Nuvera Fuel Cells
129 Concord Rd. Bldg 1
Billerica, MA 01821

Agenda

- The Journey

 - Lessons Learned

- Current Focus

- Challenges and Opportunities

Company Introduction

- Nuvera Fuel Cells is a global leader in the development and advancement of multi-fuel processing and fuel cell technology
- Operations in US and EU
 - R&D
 - Low Volume Manufacturing
 - Sales & Service
- Total 120,000 sq. ft.
- 132 employees (127 in US)
 - >100 high skilled engineers (88 in US)
- Wholly owned by Hess



Billerica, MA (USA)

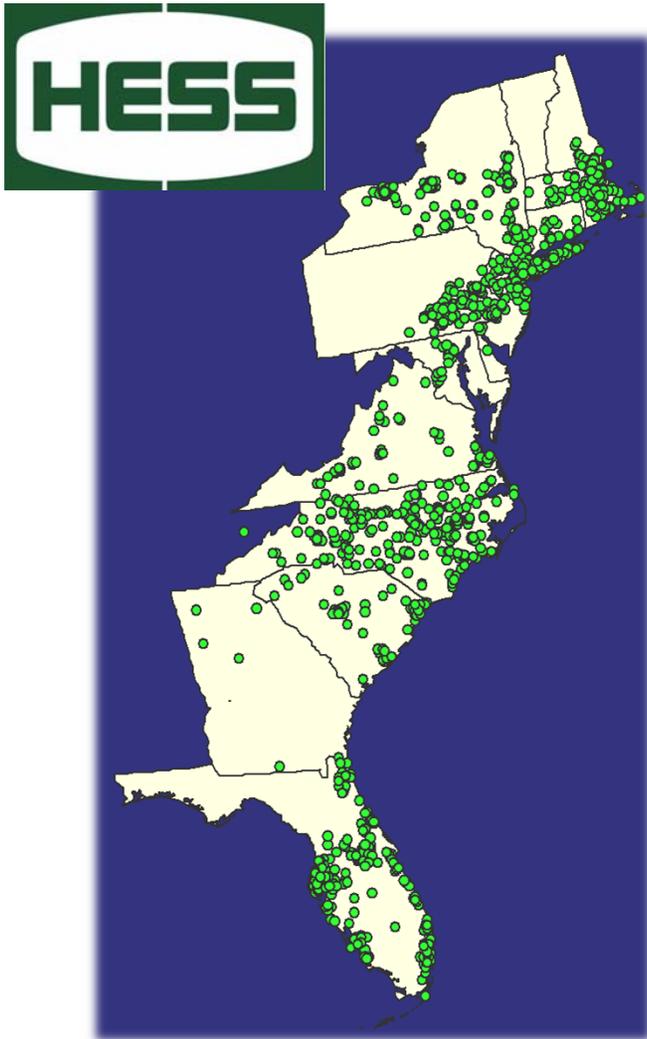


Milan, Italy (EU)



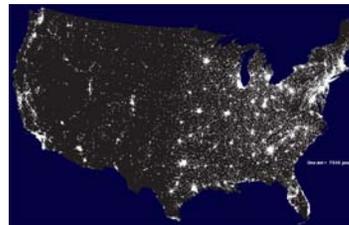
Nuvera Fuel Cells, Billerica, USA is ISO 9001: 2008 certified

US Refueling Opportunity



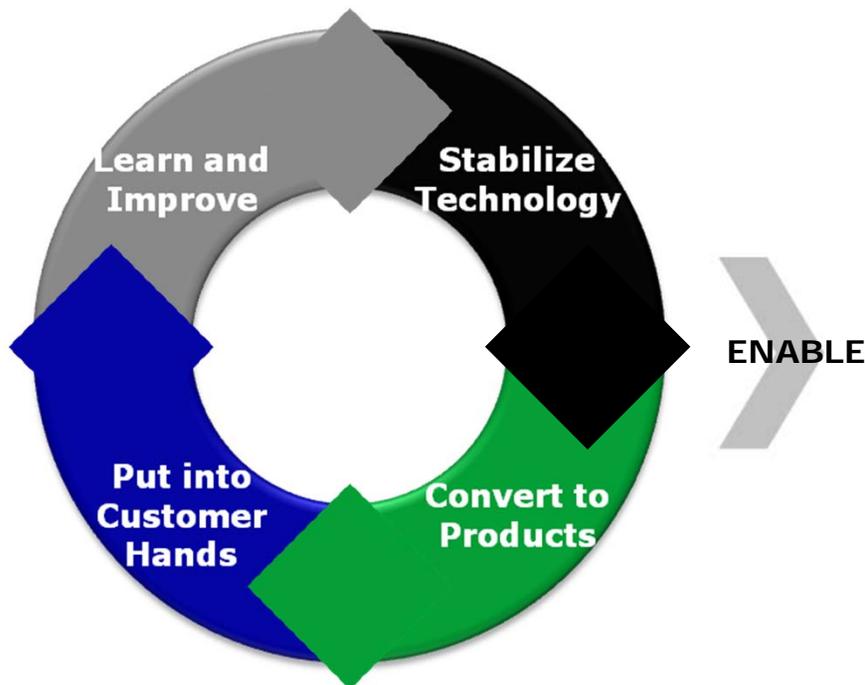
Hess station network (1400 stations)
>95% Corporate Owned & Operated

Covers #1, 4 & 5 rated sub-regions
identified as early FCEV adopters locales
(NREL 2006) and >30% U.S. Population



- 1) New York—Northern NJ—Long Island
- 2) Los Angeles—Riverside—Orange County
- 3) San Francisco—Oakland—San Jose
- 4) Boston—Worcester—Lawrence
- 5) Philadelphia—Wilmington—Atlantic City
- 12) Hartford
- 19) Providence—Fall River—Warwick
- 20) Rochester

Development cycles of learning



- Technology Development
- Product Development
- Key Suppliers Engagement
- Manufacturing Process Development
- Customer/User Focus

Technological Milestone

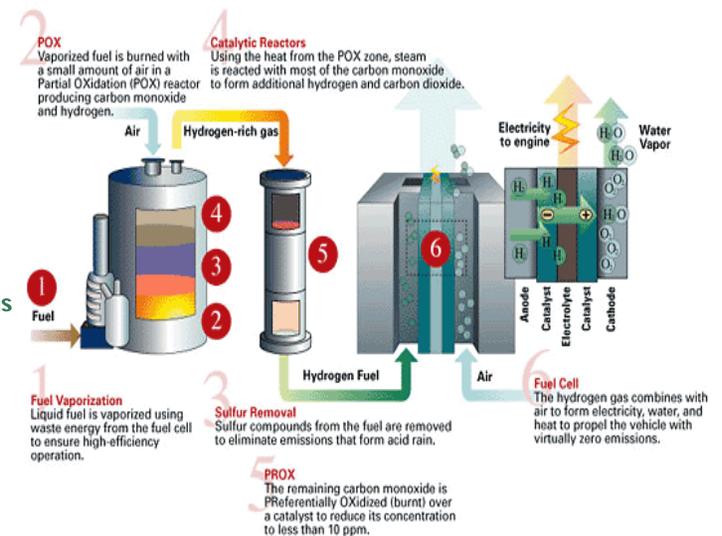
Nuvera conducted the world's first successful demonstration of converting gasoline to electricity with a fuel cell.

1997



Fuel Source

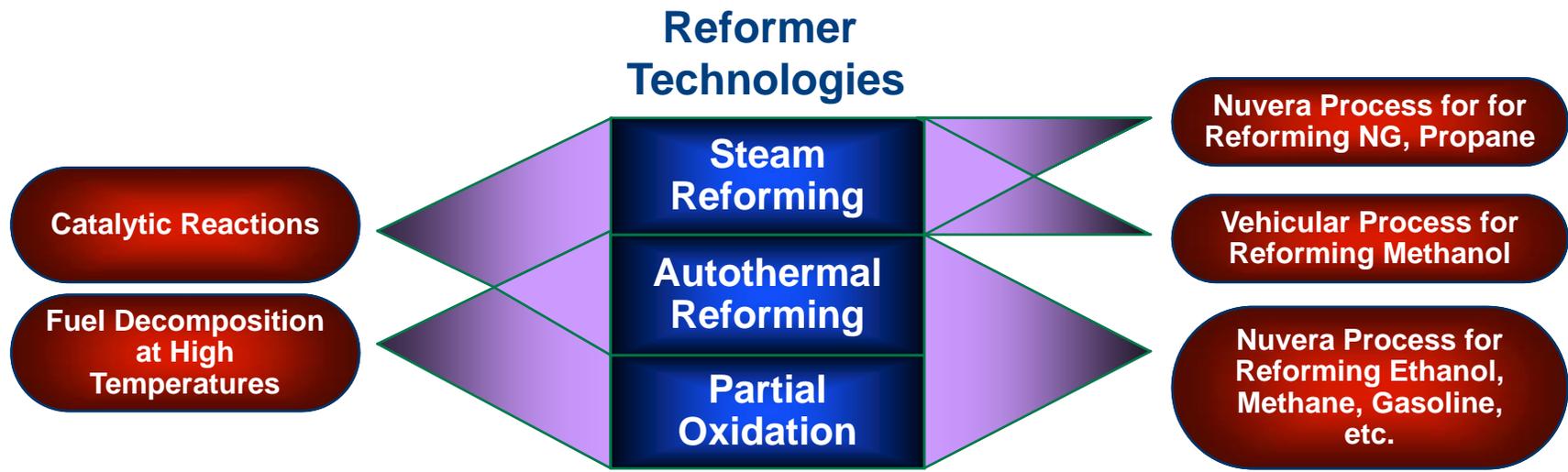
- Gasoline
- Ethanol
- Methanol
- Propane
- Butane
- Natural Gas
- Naphtha
- DME
- Synthetic Fuels
- Etc.



Nuvera 50 kW_e Multi-Fuel Processor, LANL 10kW_e PROX, Plug Power 500 W_e PEM Test Setup

Fuel Processing Technology

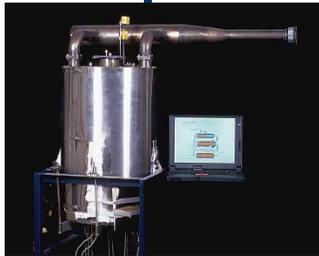
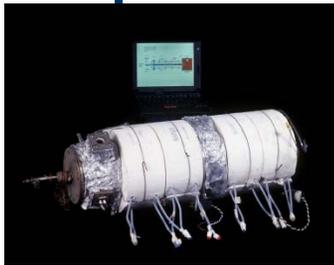
Hydrogen Production Options



These technologies are used in large-scale, dedicated H₂/CO facilities, and increasingly in smaller on-site/on-board applications.

Early Successes: Fuel Processors 1993 – 2000

1993



1995



1997



1998



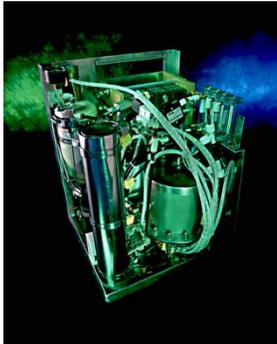
1999



2000



Early Successes: Systems: 1998 – 2000



300W Propane FCPS



30 Nm3/h 99.99% Pure
Hydrogen Generator



1 kW Propane/NG FCPS



1 kW Propane FCPS



5 kW Endurance FCPS



5 kW NG ATR FP



50 kW Gasoline FP



10 kW Gasoline FP



5 kW NG FCPS



2 x 1kW H2 FCPSs

Lessons learned: Avanti



KYUNGNAM ENERGY CO., LTD.



- ✓ Global Partnerships
- ✓ Customer Req'ts
- ✓ Cyclic SMR's
- ✓ Durable XDS fuel cell
- ✓ Champion Efficiency
- ✓ Aggressive Cost-outs
- ✓ Supervisory Controls
- ✓ ECU Development
- ✓ Cost of Reliability



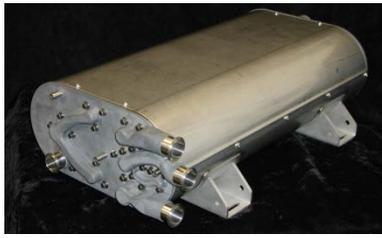
2	5	5	Deployments
16%	22%	>30%	NetAC Eff'y (HHV)
1.00	0.42	0.16	Normalized Cost
PowerStream Circa 2001	Avanti GEN1.2 Circa 2003	Avanti GEN3.0 Circa 2005	Product Offering



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Hydrogen Generation History

On-Board



STAR™, gen 1
2000



STAR™, gen 3
2007

CHP



PowerStream™, gen 1
2001



Avanti™, gen 4
2006

Hydrogen



First Hydrogen Generator
1998



PowerTap™, GEN I
2005



PowerTap™, GEN II
2009 - Present



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The Nuvera Difference – Stack Technology

Our Competitor

Third Party Stack Technology

Limited control over stack design

Graphite Plates

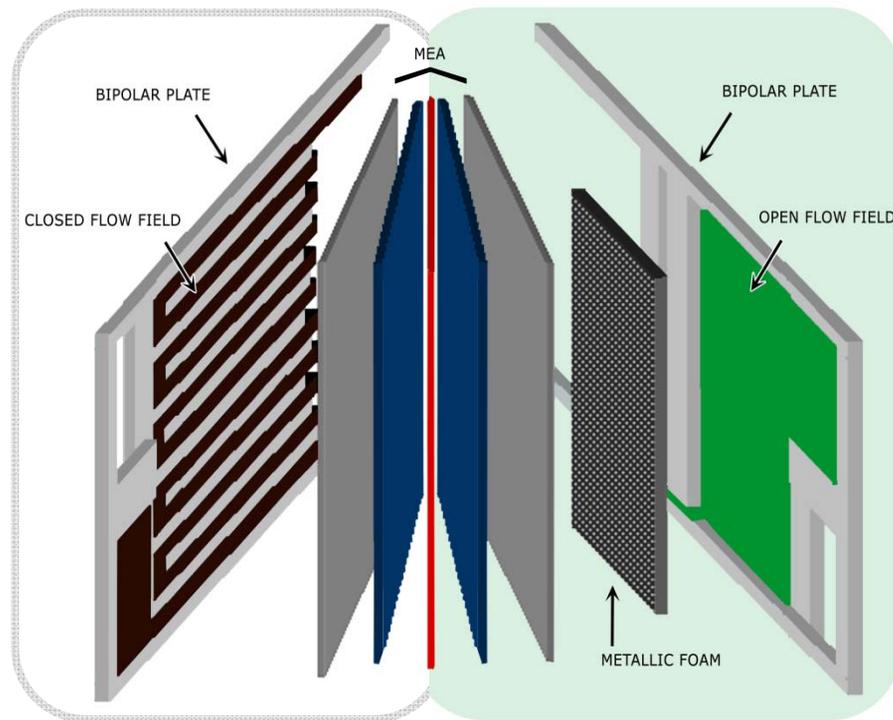
Less durable over lifecycle

Closed Channel-Land Flow Field

Sensitive to temperature extremes

Cooling Cell

Adds complexity to balance-of-plant



Conventional Stack

The Nuvera Technology Difference

Our Stack

Nuvera Stack Technology

Nuvera is in full control of stack design and is focused on continuous improvement

Metallic Bi-Polar Plates

Durable, reliable, and cost-effective

Open Flow Field

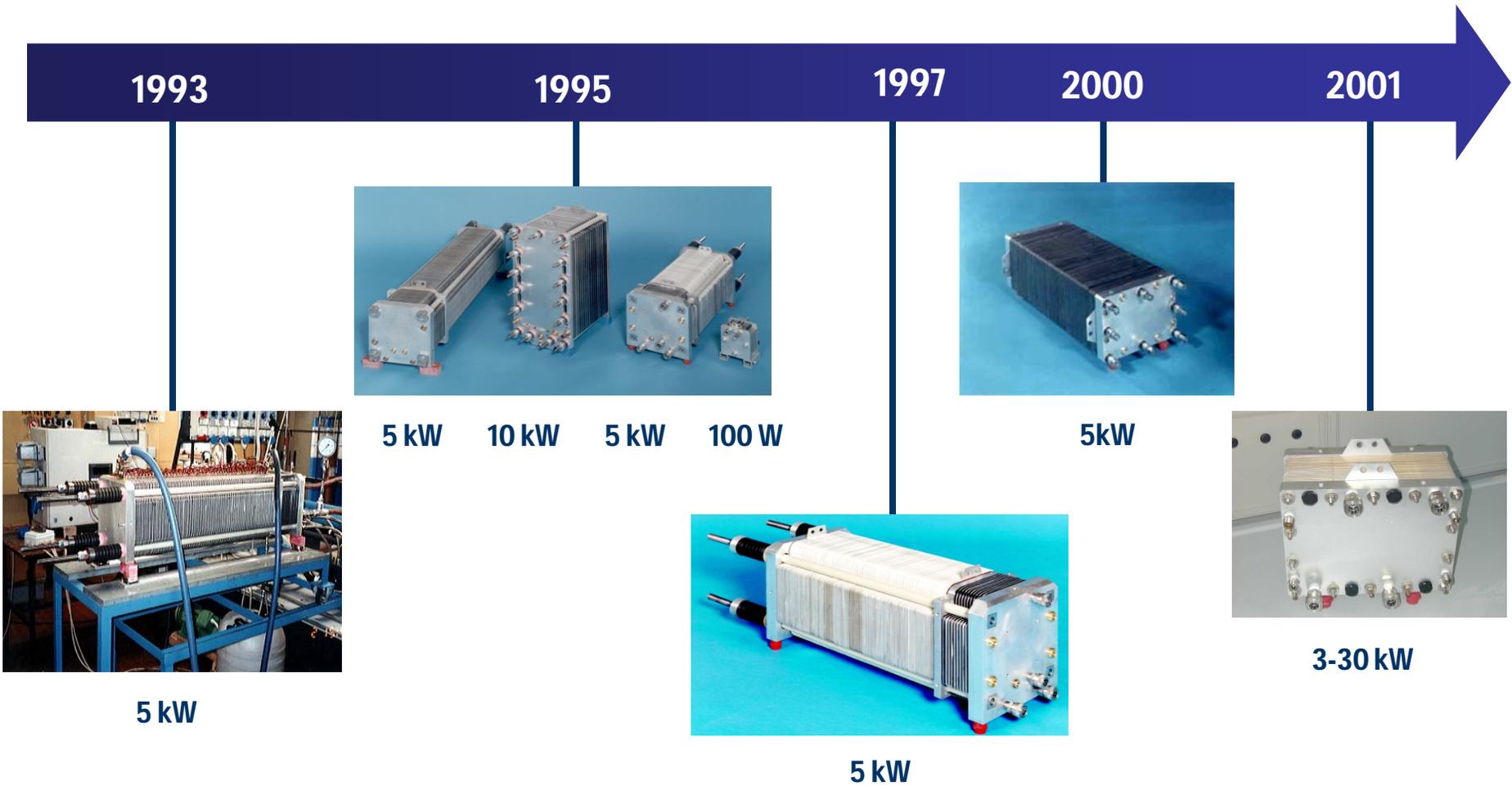
Increases the active area of each cell MEA

Cathode Water Injection

Simplified balance-of-plant reduces on-going costs

Early Successes: Fuel Cells: 1993 – 2001

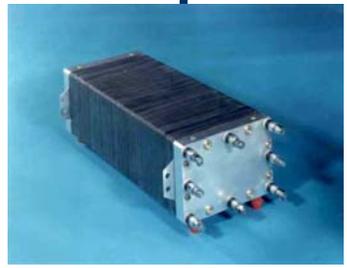
Residential MicroPower fuel cell stack example



5 kW



5 kW 10 kW 5 kW 100 W



5kW



5 kW



3-30 kW



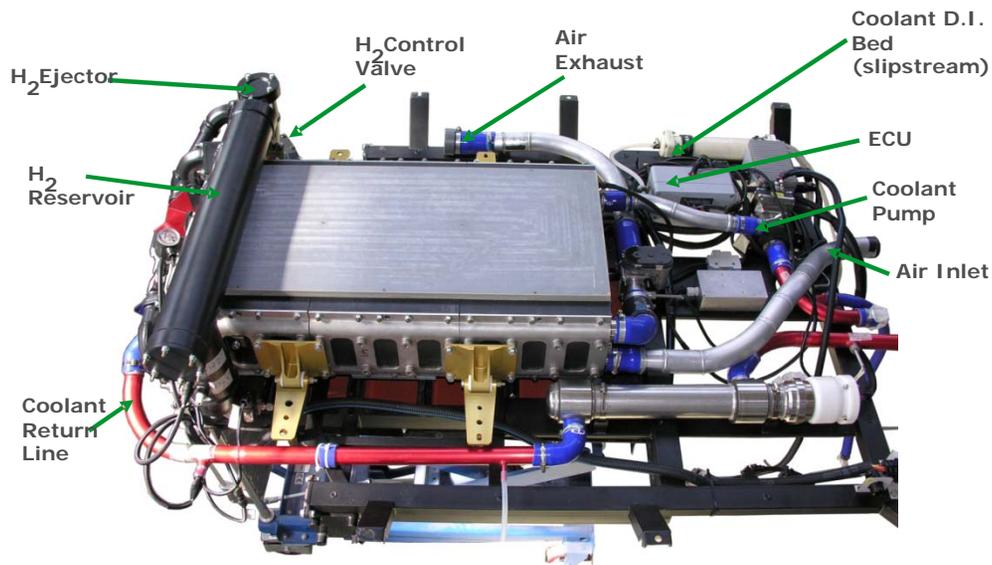
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Advanced PEMFC Engines

Nuvera has been working with automotive OEMs for over 10 years

- Metallic architecture since 1993
- Patented open flowfield
- 8 MW produced in 7 generations
- High durability and low cost



Fiat Seicento
Elettra 7kw RE, 2000



Fiat Seicento
50kw FCEV, 2003



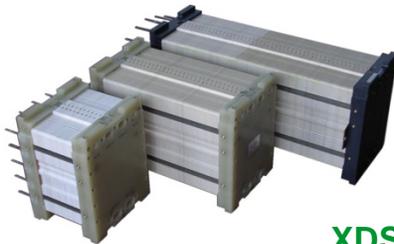
Fiat Panda
80kw FCEV, 2006



Alfa Romeo Mito
80kw FCEV, 2010

PEMFC Stack Design Convergence

Industrial



XDS-900

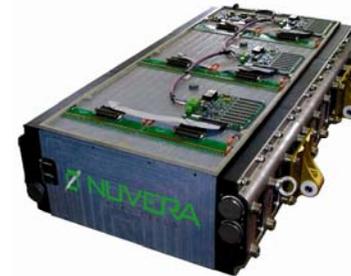
- High durability
- 3 generations of hybrid motive FC systems
- Commercial stage



Broad range of industrial vehicle platforms



Automotive/Aerospace



ANDROMEDA

- High power density
- 9 car installations
- R & D stage



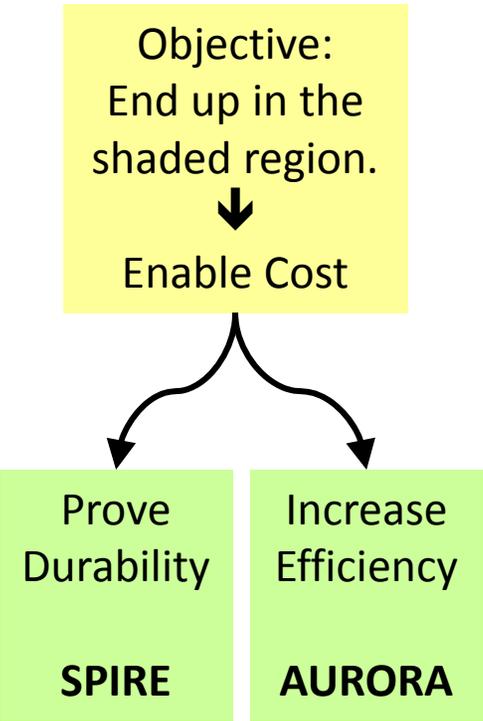
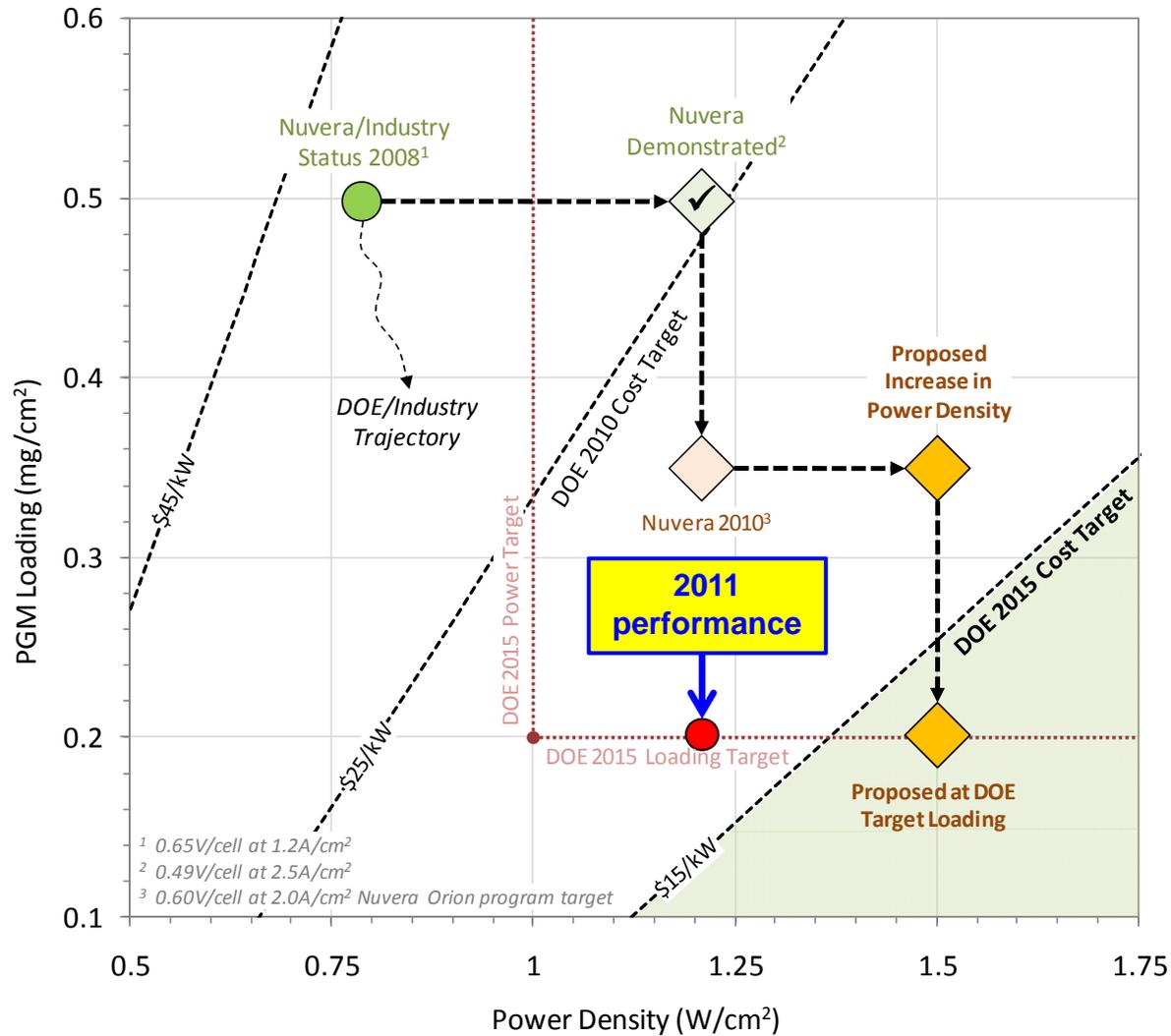
ORION



- Single architecture
- All mobility markets



Cost Roadmap (2008)



Nuvera is uniquely positioned to push the envelope of cost-competitiveness.



Nuverera - Market applications



Light Duty EV & Range Extender



Fuel Cell Forklifts



Ground Support Equipment

Industrial Mobility



Truck APU & Reefer



Fuel Cell Tractors

Transportation



Fuel Cell Bus



Fuel Cell Vehicle



Aerospace APU



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Total Power Solution

PowerEdge™ Motive Power Solution

- Direct Replacement of Forklift Lead-Acid Battery



PowerTap™ Hydrogen Supply Chain

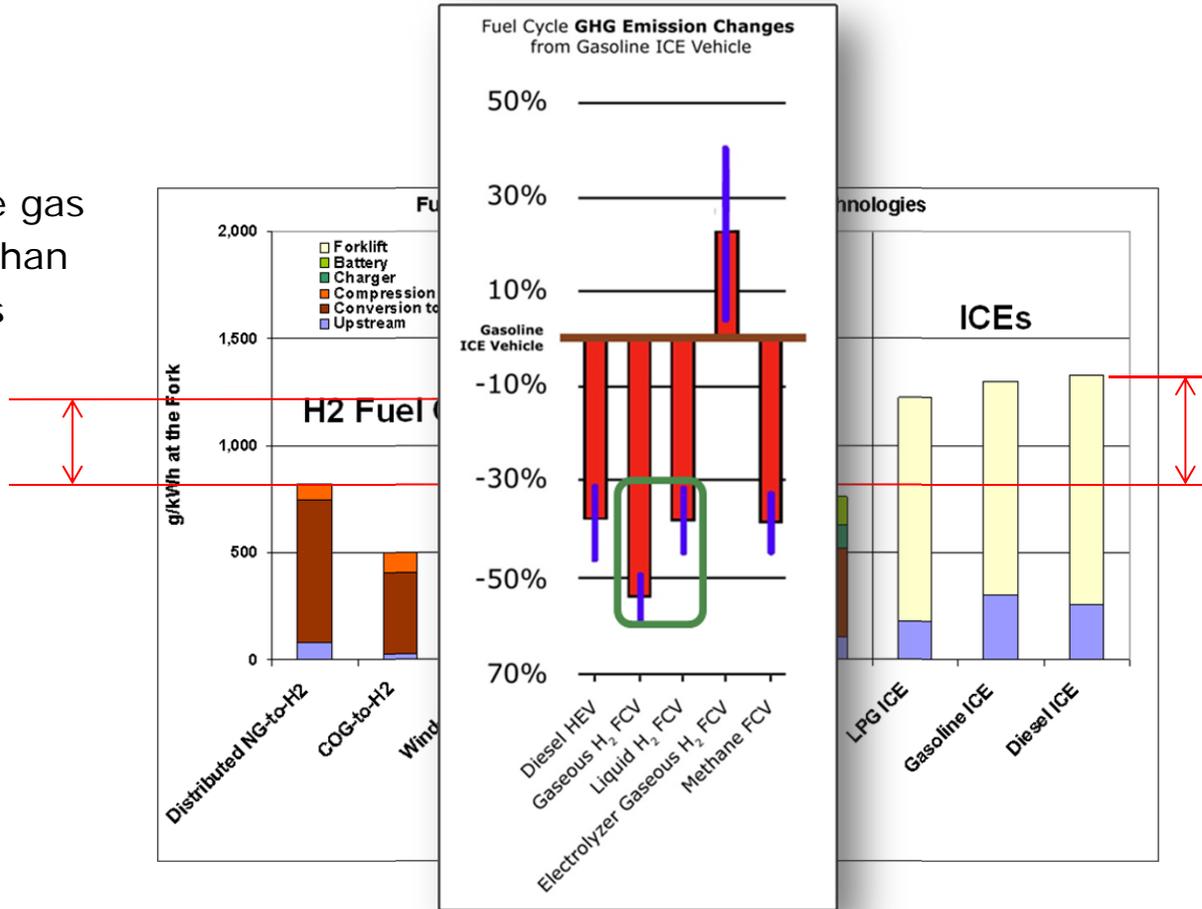
- On-Site Hydrogen Generation, Storage, and Compression



An integrated
productivity enhancement
system for material
handling

Reducing Carbon Footprint

33% less greenhouse gas emissions than battery EVs



34-42% less greenhouse gas emissions than propane, gasoline, or diesel IC trucks

Comparison of well-to-wheel GHG Emission Pathways.
Source: ANL, M. Wang, 2002

Source:
Full Fuel Cycle Comparison of Forklift Propulsion Systems,
Center for Transportation Research, Argonne National Laboratory, October 2008.

Nuverera On-Site Experience

Nuverera's PowerTap is serving customers in multiple markets



Market	Material Handling
Customer	HEB San Antonio, TX
Statistics	22 months on site 11,500 hours 6,000 kg H2 delivered 99.995% purity > 99.5% availability of H2 at pump

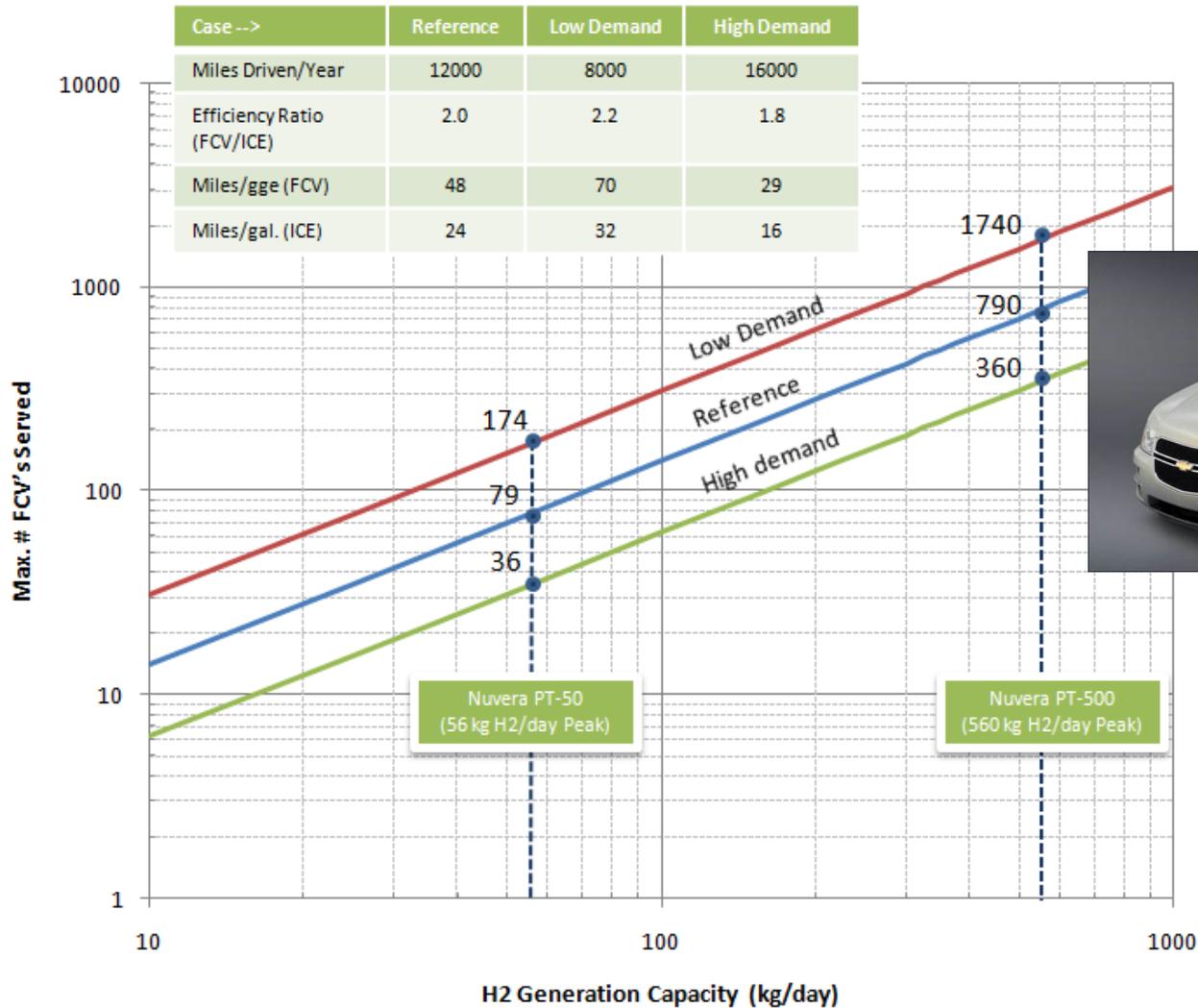
Market	Merchant Hydrogen
Customer	Sacramento, CA
Statistics	7 months on site 3,300 hours 5,800 kg H2 delivered 99.9995% (UHP) purity Consistent generation of UHP Hydrogen at customer site

Relative Scaling (Material Handling vs. Automotive)

Application	H2 Generator Peak Rating (kgH2/day)	H2 Generator Peak Rating (scfh)	Average H2 Refueling Station Production Capacity ^{1,2} (kg/day)	Maximum Vehicle Refuels per Day ^{3,4}	Average No. of FCV's Supported ⁴	PTH 1X Storage Bank Scale Factor ⁶	Maximum Class II Forklift Trucks Supported ^{2,7,8}
Small Community Station	56	~1000	38	10	92	1	13
Small-Medium Community Station	112	~2000	76	20	184	2	25
Medium-Large Community Station	280	~5000	189	50	461	5	64
Large Community Station	560	~10,000	379	100	921	9	127
Small Public Service Station	920	~16,000	622	164	1514	15	209
DOE Target Public Service Station	1500	~27,000	1014	267	2468	25	341

1. Assumes 69% Capacity Factor to account for seasonal & daily fluctuations in demand
2. Assumes 98% Station Availability (22days/yr with one 8-hr shift of service)
3. Assumes 80% Fuel Tank Opportunity Refills
4. Assumes 80-miles/gge FCV, 380-mile range & 12000-miles/year
5. Assumes 58% H2 gas utilization factor for cascade storage
6. Assumes 6500psig Cascade Storage, 3 Banks, 27 11-gal ASME cylinders, 20C ambient
7. Assumes 95% Capacity Factor for Material Handling
8. Assumes 1000Ah, 80% Discharge, 3 shift, 6 day/wk, 50 week/yr operation; RP = 52%effy

PowerTap Single Station Service Capability



PowerTap Product Suite

2010

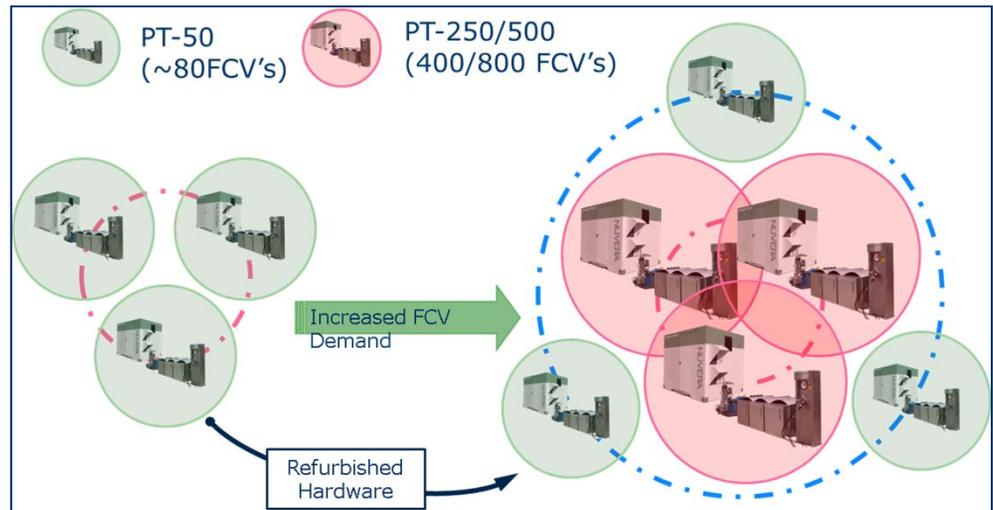


PTG-50
(12' L x 4' W x 9' H)

2014



PTG-250
(12' L x 6' W x 9' H)



PT-50

PT-500

Site layout courtesy of Hess Safety Harbor, FL

PowerTap Retail Automotive (2015)



Nuvera PowerTap™ GENIII+ Hydrogen Generator Appliance
125-250kg/day Ultra-High Purity Grade H₂ Capacity, 800-bar Output
Target Footprint Dimensions: 12'Lx6'W

Summary

- Nuvera is focused on creating foundational technologies that can provide product opportunities in many markets
 - Possible due to capabilities of the team, funding source and strategic view
- We will be focused on being a hydrogen provider for low volume applications (50-2500 kg/day)
 - Industrial mobility
 - Transportation
 - Merchant
- Leverage our high power density stack technology to partner with OEM's or integrators in many markets
- Mainly focused on North American and European Markets in the near term extending to Asia next.