Impact of Fuel Cell System Peak Efficiency on Fuel Consumption and Cost

2015 U.S. DOE Hydrogen and Fuel Cells Program and Vehicle Technologies Office Annual Merit Review and Peer Evaluation Meeting

June 9, 2015

Aymeric Rousseau

Argonne National Laboratory

Sponsored by Fred Joseck

Project ID # SA044

Project Overview

Timeline

- Start: September 2015.
- End: September 2016.
- Status: 80% complete.

Barriers

- Provide guidance on component targets and future R&D directions.
- Evaluate impact of FCTO technologies on vehicle energy consumption and cost.

Budget

- FY15 DOE Funding
  - $125,000 (FCTO)
  - $500,000 (VTO)

Partners

- Argonne Fuel Cell System Experts.
- US Drive Technical Teams
- Inputs from industry and academia.

Relevance

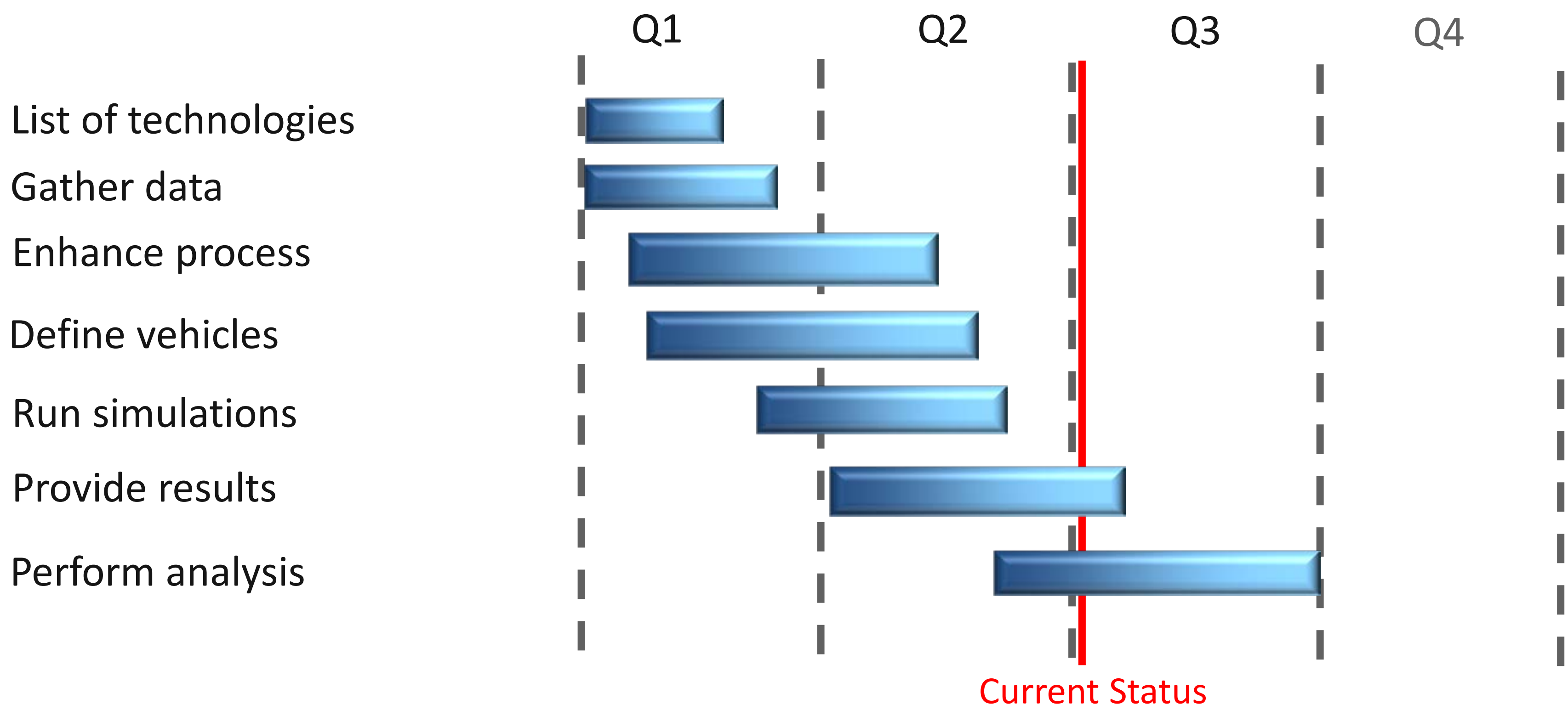
What is the Fuel Displacement and Cost of Advanced Fuel Cell Systems?

Use of current technology to determine baseline technology

R&D Improvements

- Evaluate benefits of advanced fuel cell systems and hydrogen storage from an energy consumption and cost point of view.
- What are the benefits of the USDrive Partnership in terms of petroleum displacement?
- Provide guidance on future research priorities by evaluating the potential of technologies to accelerate petroleum displacement.

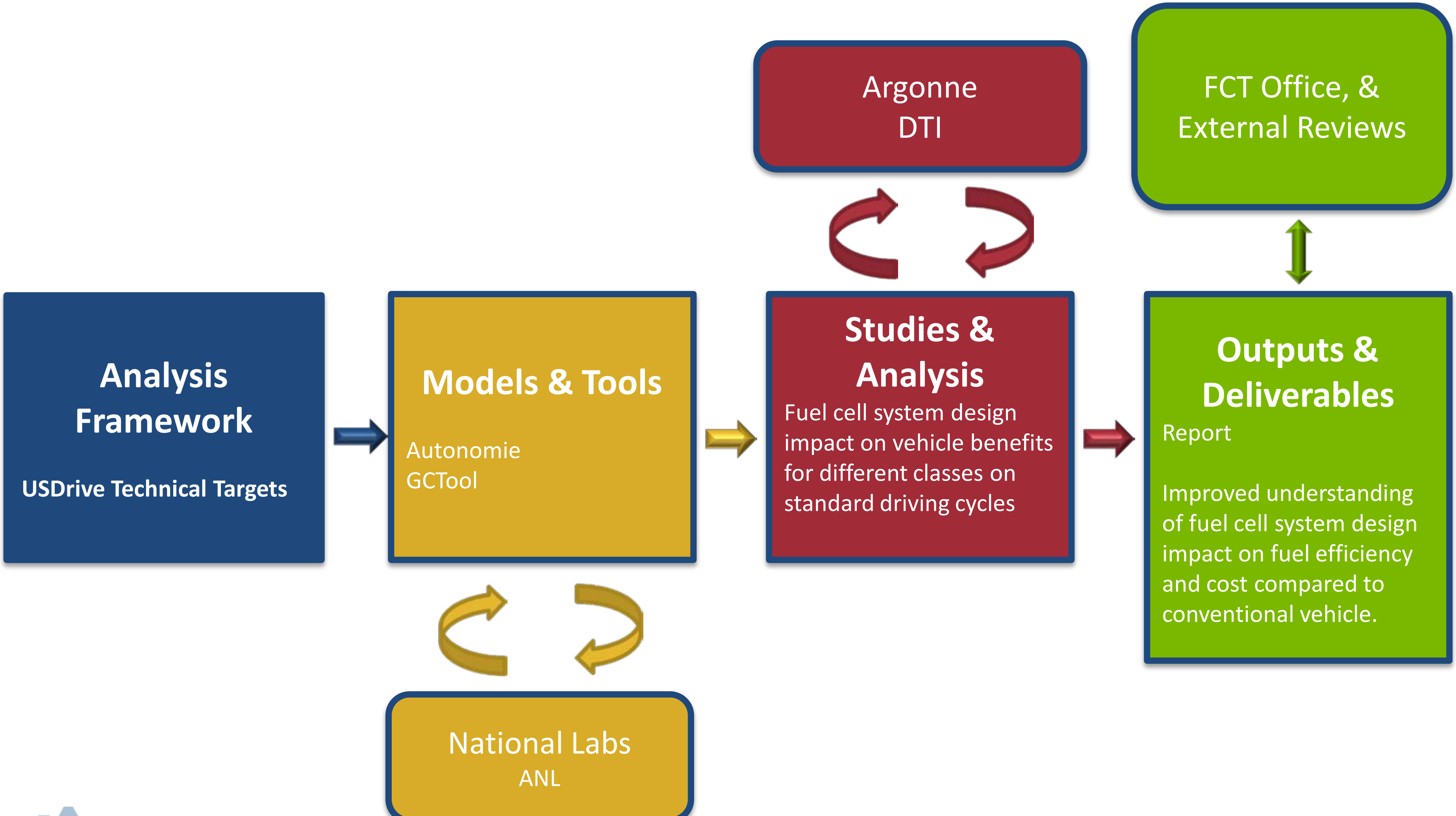
Milestones



Detailed individual reports for Fuel Cell system technology and a comprehensive report will be published in FY16.

Approach

Impact of Fuel Cell System Peak Efficiency on Fuel Consumption and Cost



Approach

- Gather component and vehicle assumptions
- Size the vehicles to meet similar vehicle technical specifications (I.e. performance, range…)
- Model several light-duty vehicle classes: compact car, midsize car, small SUV, large SUV and pickup truck
- Evaluate the impact of advanced fuel cell systems on component sizing and weight
- Perform the simulations on the US standard driving cycles (i.e. UDDS and HWFET).
- Evaluate the impact of advanced technologies on vehicle energy consumption
- Compare fuel cell hybrid vehicle energy consumption and cost to their respective vehicles with internal combustion engines

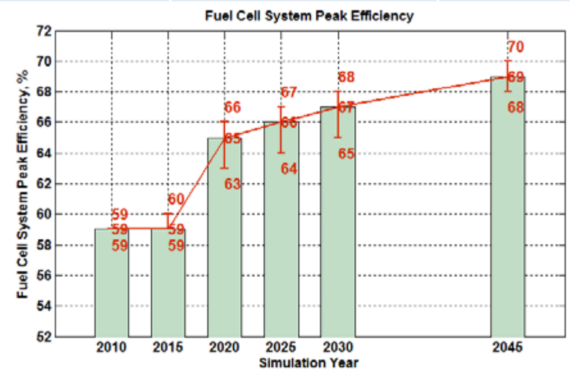
Technical Accomplishments

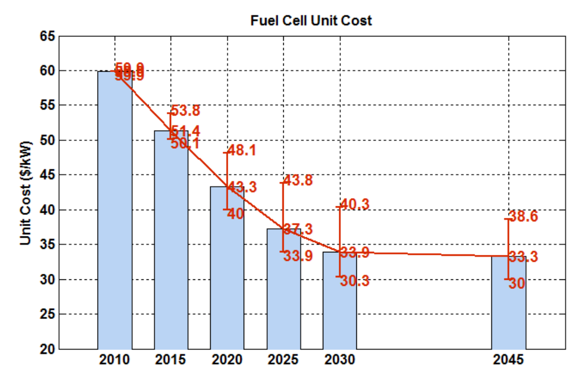
Fuel Cell System Assumptions - Peak Efficiency

Parameter	Units	2010	2015			2020			2025			2030			2045		
			low	Med	high	low	Med	high	low	Med	high	low	Med	high	low	Med	high
Peak Fuel Cell System Efficiency	%	59	59	59	60	63	65	66	64	66	67	65	67	68	68	69	70
Platinum Price	$/Troy OZ	$1,100	$1,500			$1,500			$1,500			$1,500			$1,500		

- ***Fuel.Cell.Cost = (x*1246.5*(Stack.UnitsPerYr)^-0.2583+(Pt.Price*y))***
  ****Fuel.Cell.kW*(Fuel.Cell.kW/Base.80kW)^z***
  - (x,y,z): Coefficients
  - Stack.UnitsPerYr = 500,000
  - Pt.Price: Platinium Price
  - Fuel.Cell.kW: Fuel Cell Power

- Costs are assumed for high production volumes



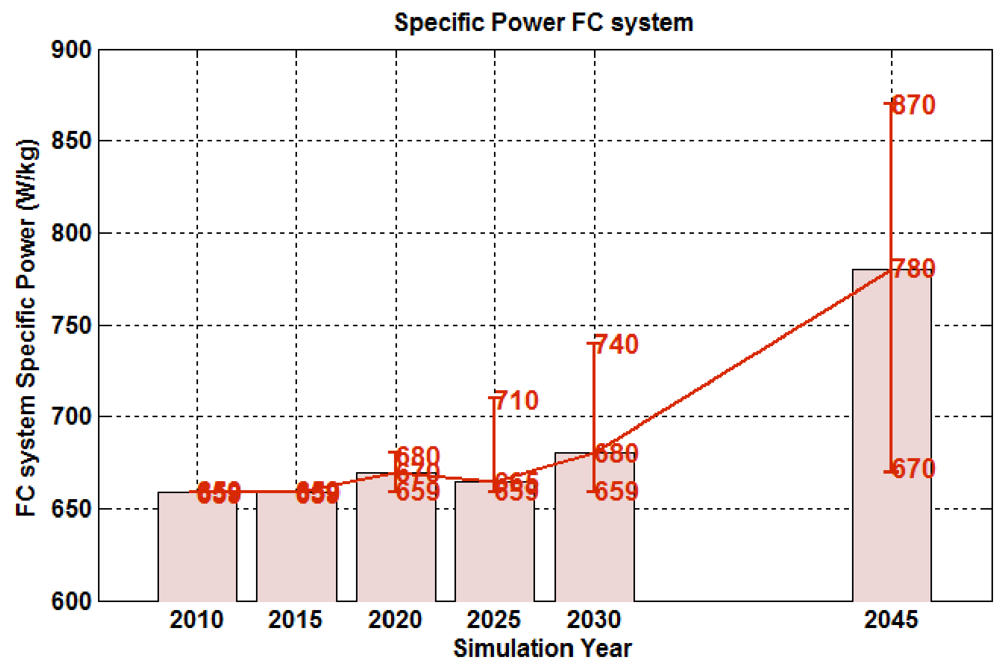


Technical Accomplishments

Fuel Cell System Assumptions - Cost and Specific Power

Parameter	Units	2010	2015			2020			2025			2030			2045		
			low	Med	high	low	Med	high	low	Med	high	low	Med	high	low	Med	high
Specific Power FC System	W/kg	659	659	659	659	659	670	680	659	665	710	659	680	740	670	760	870
Power Density	W/L	640	640	640	640	640	720	850	640	730	890	640	740	970	690	880	1150

- ***Fuel.Cell.Weight = Fuel.Cell.kW / Specific Power FC System***

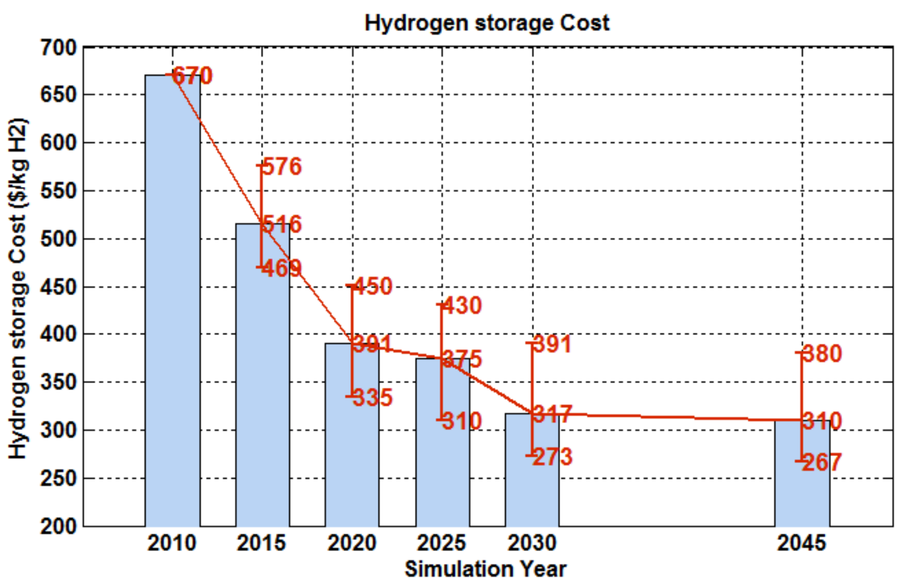


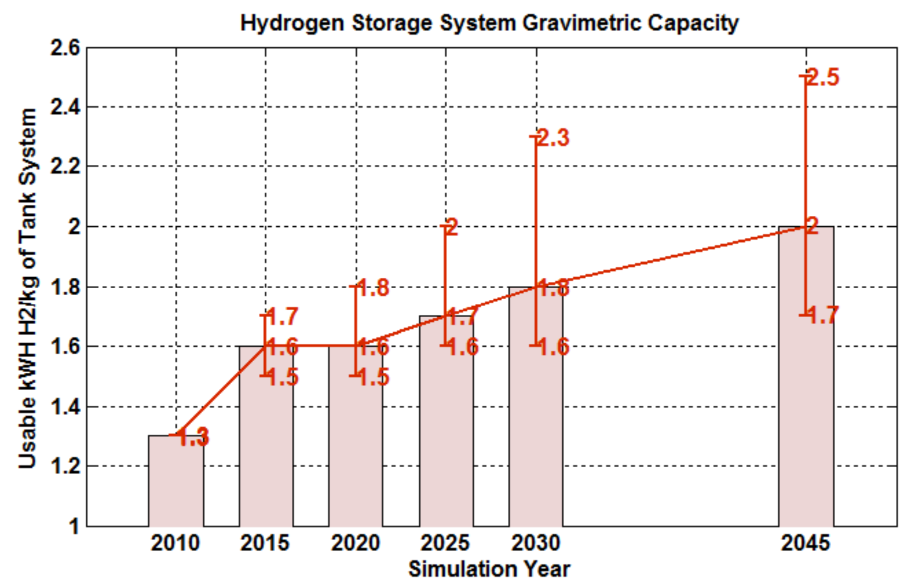
Technical Accomplishments

Hydrogen Storage Assumptions

Parameter	Units	2010	2015			2020			2025			2030			2045		
			low	Med	high	low	Med	high	low	Med	high	low	Med	high	low	Med	high
System Gravimetric Capacity	Useable kWh/kg	1.3	1.5	1.6	1.7	1.5	1.6	1.8	1.6	1.7	2.0	1.6	1.8	2.3	1.7	2	2.5
	Useable kg H2/kg of Tank	0.040	0.045	0.048	0.051	0.045	0.048	0.054	0.048	0.051	0.060	0.048	0.054	0.069	0.051	0.060	0.075
Cost	$/Useable kg H2	670	576	516	469	450	391	335	430	375	310	391	317	274	380	311	267
Percentage H2 used in Tank	%	95	96	96	96	96	96	96	96	96	97	96	97	97	96	97	97

H2.Storage.Cost=Cost.Coefficient * Fuel.Mass, ***H2.Storage.Mass=Fuel.Mass / Gravimetric.Capacity***



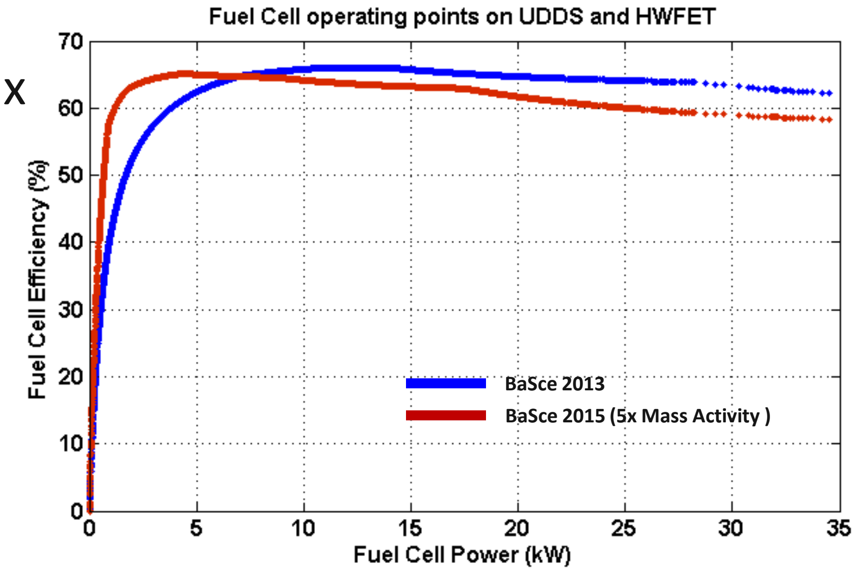


Argonne National Laboratory, SA044, Sponsored by Fred Joseck, FCTO Annual Merit Review, June 2015

Technical Accomplishments
Updated Component Assumptions - Fuel Cell System

GCTool performance maps

- Developed specific fuel cell systems using high fidelity GCTool model for 5x mass activity provided by ANL Fuel Cell experts.
- Fuel cell sized based on 70% peak power requirement (IVM-60 or US06 or grade).

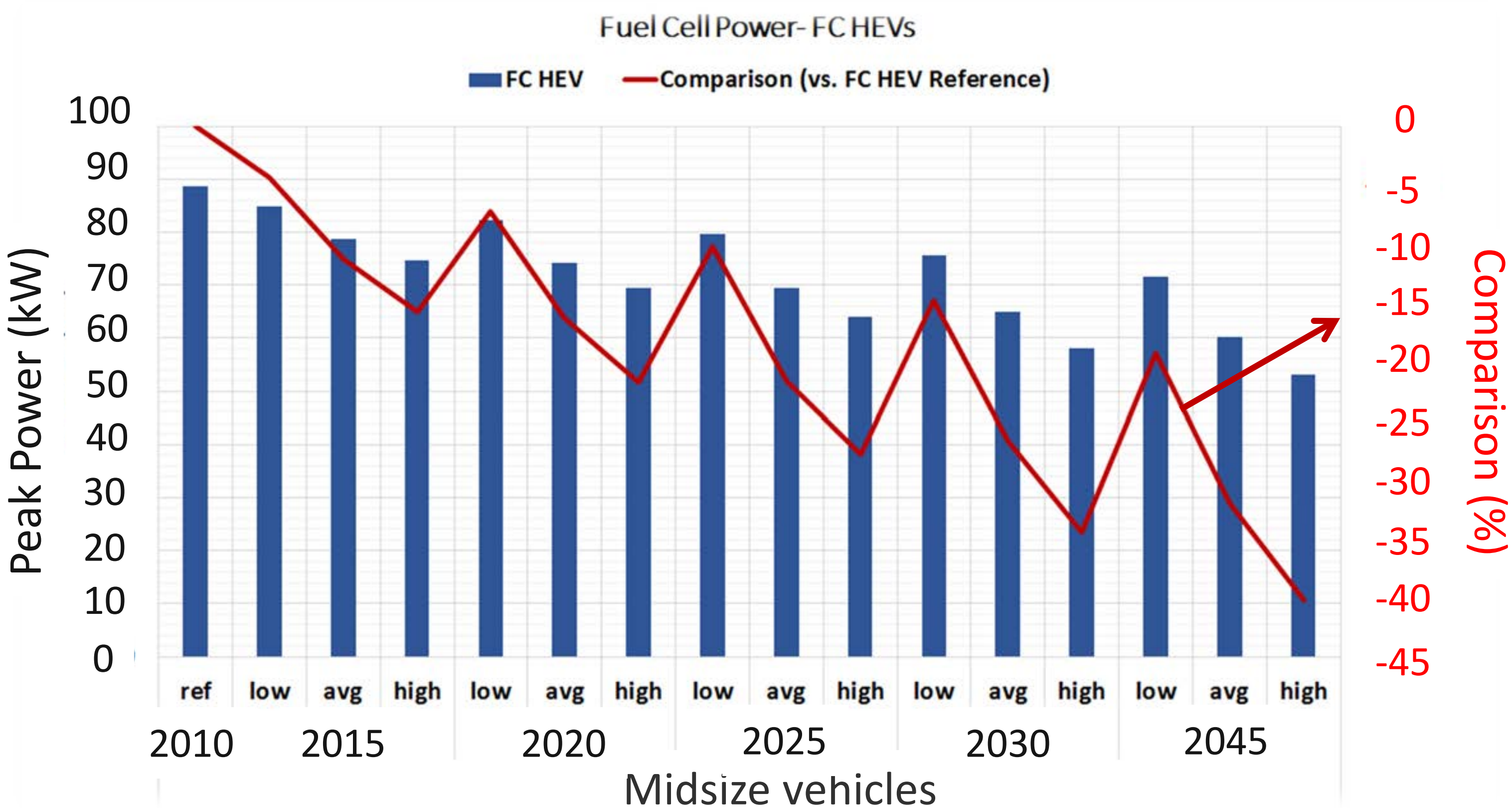


- The electric machines for fuel cell HEV/PHEV are sized based on US06 cycle and acceleration requirements (input from FCTT : the FC HEV configuration is essentially a series hybrid, and the electric motor provides all of the tractive effort. Thus the electric motor should be sized like a BEVs)

Technical Accomplishments

Fuel Cell Systems Power to meet VTS Decrease with Time

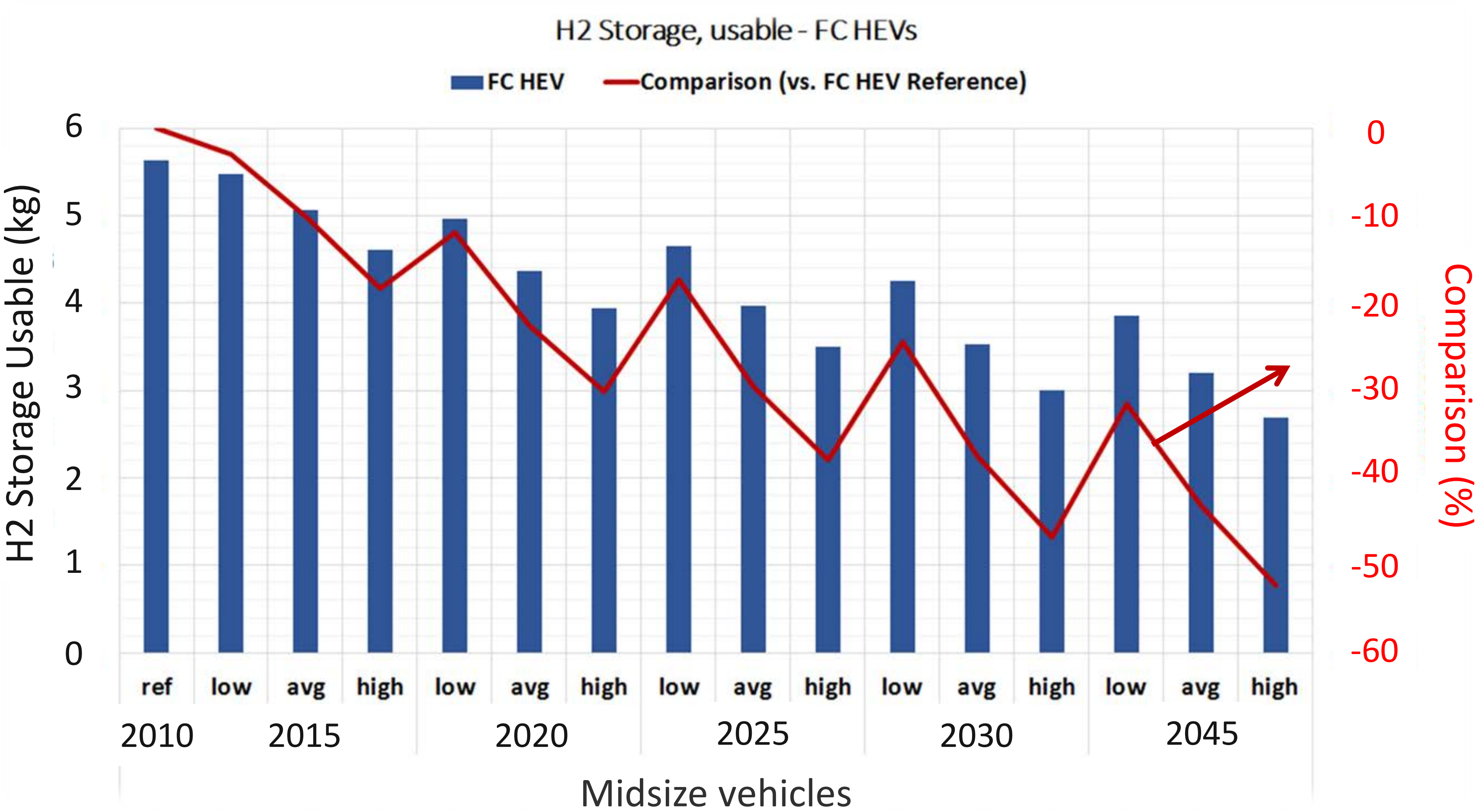
- Due to component technology improvements (fuel cell system, hydrogen storage but also electric machine, energy storage, light weighting…), the fuel cell system power are expected to decrease by up to -40%.



Argonne National Laboratory, SA044, Sponsored by Fred Joseck, FCTO Annual Merit Review, June 2015

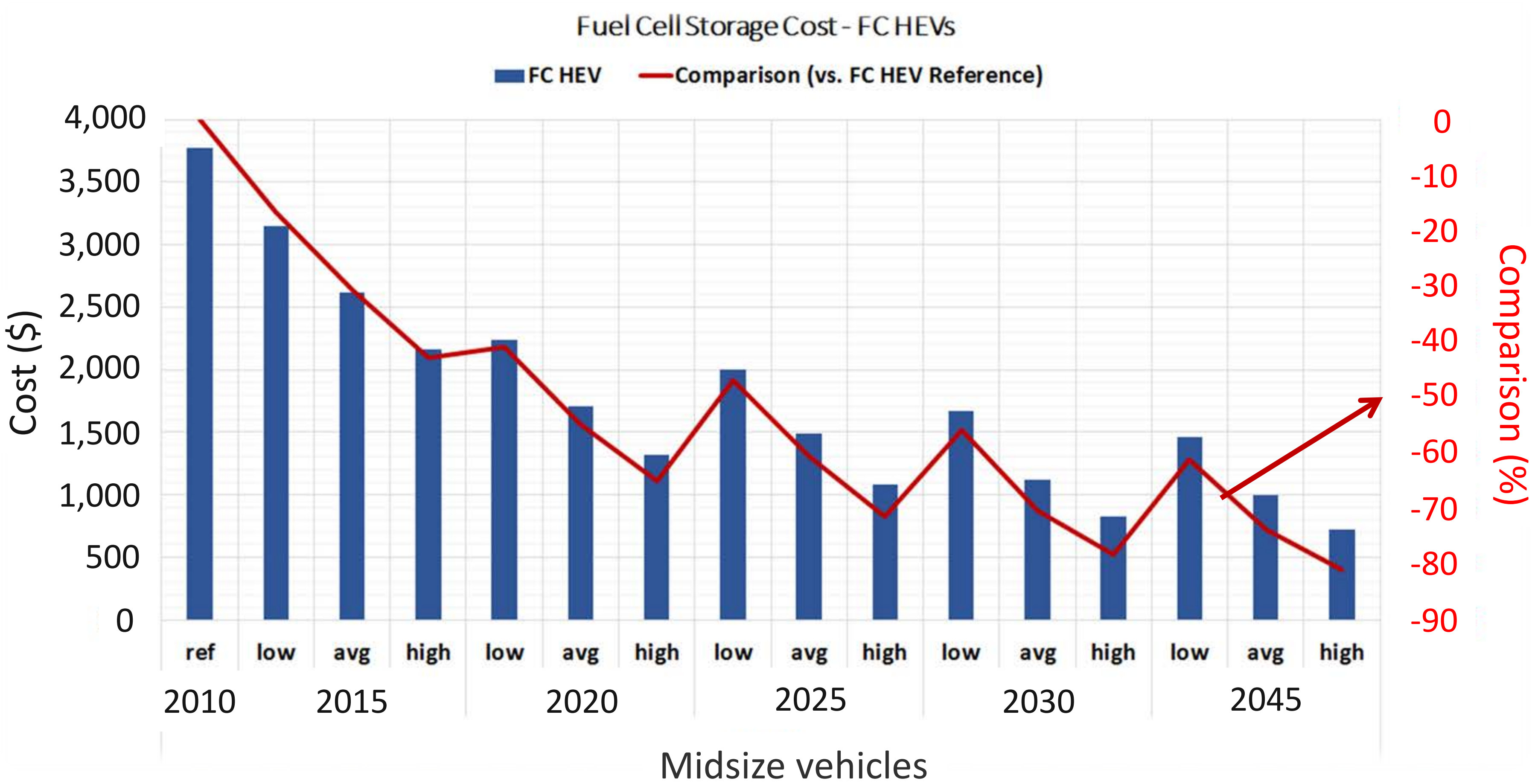
Technical Accomplishments

Required On-Board Hydrogen Fuel Mass Could Drop by 50%



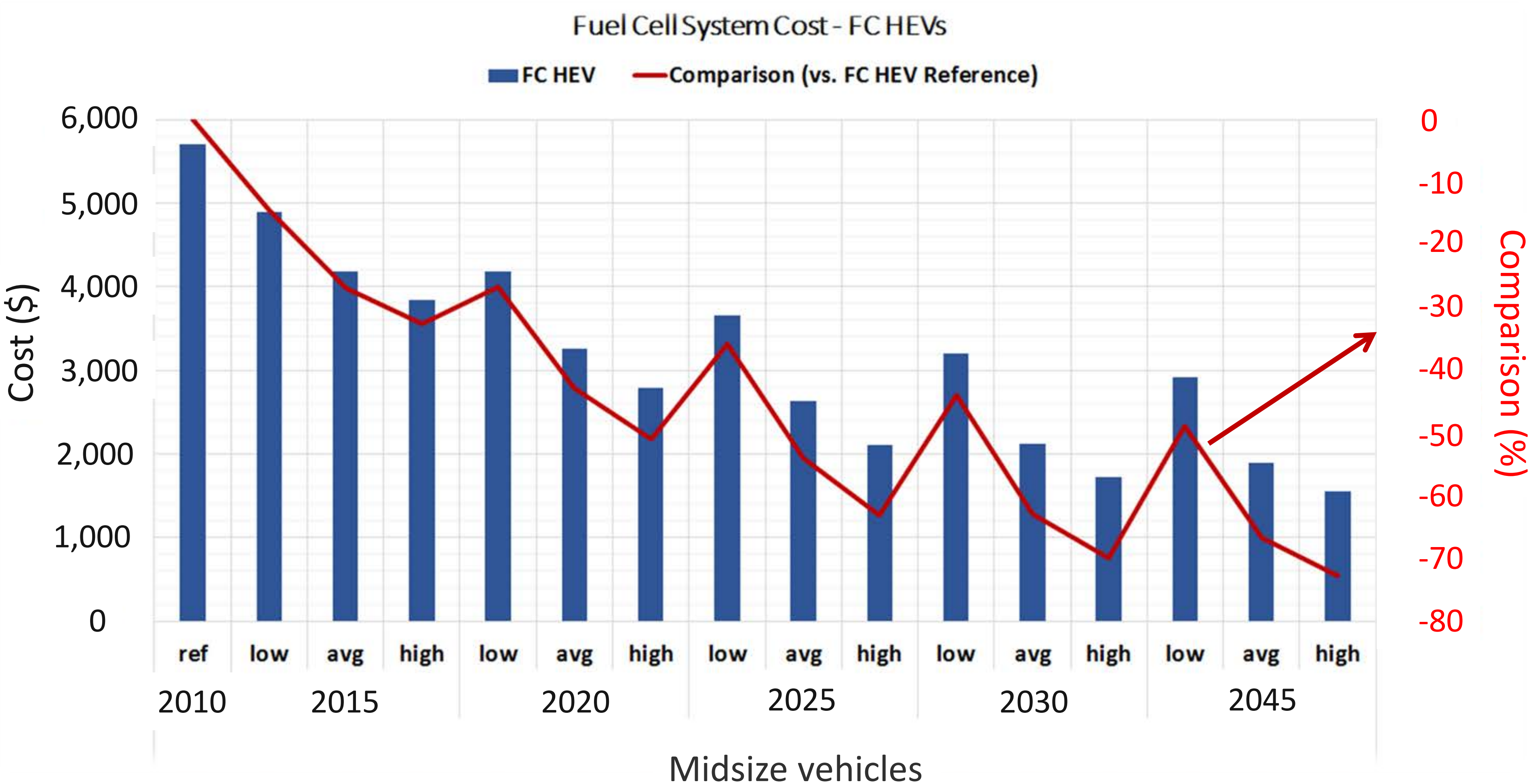
Note: Target range of 320 miles on the combined driving cycle after adjustments

Technical Accomplishments
Hydrogen Storage Cost Could Decrease by 80%



Argonne National Laboratory, SA044, Sponsored by Fred Joseck, FCTO Annual Merit Review, June 2015

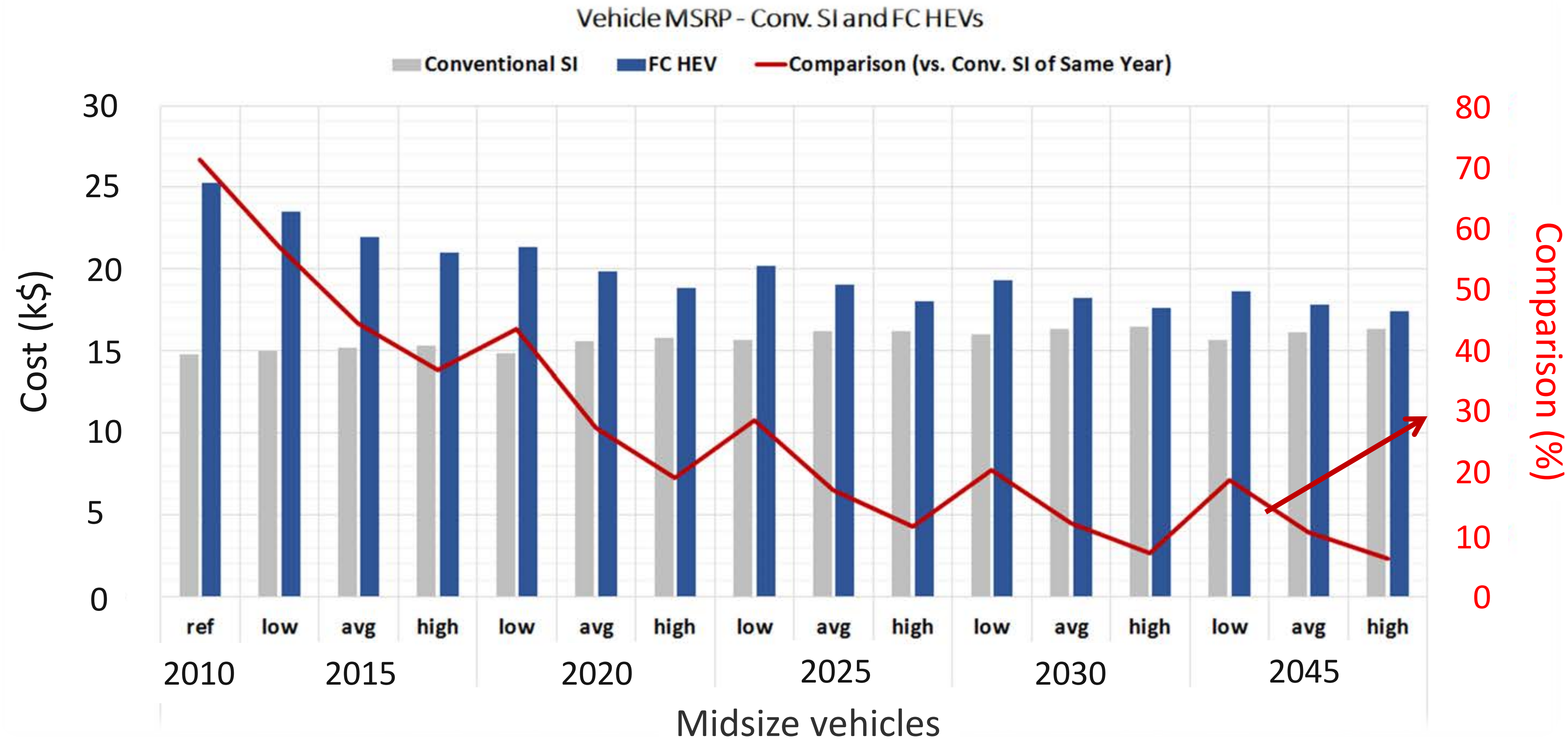
Technical Accomplishments
Fuel Cell System Cost Could Decrease by 70%



Argonne National Laboratory, SA044, Sponsored by Fred Joseck, FCTO Annual Merit Review, June 2015

Technical Accomplishments
Fuel Cell Vehicles Cost Close to Conv. Vehicles by 2030

- The cost decrease is mostly due to the decrease of hydrogen tank cost (up to 80%) and fuel cell system cost (up to 70%)

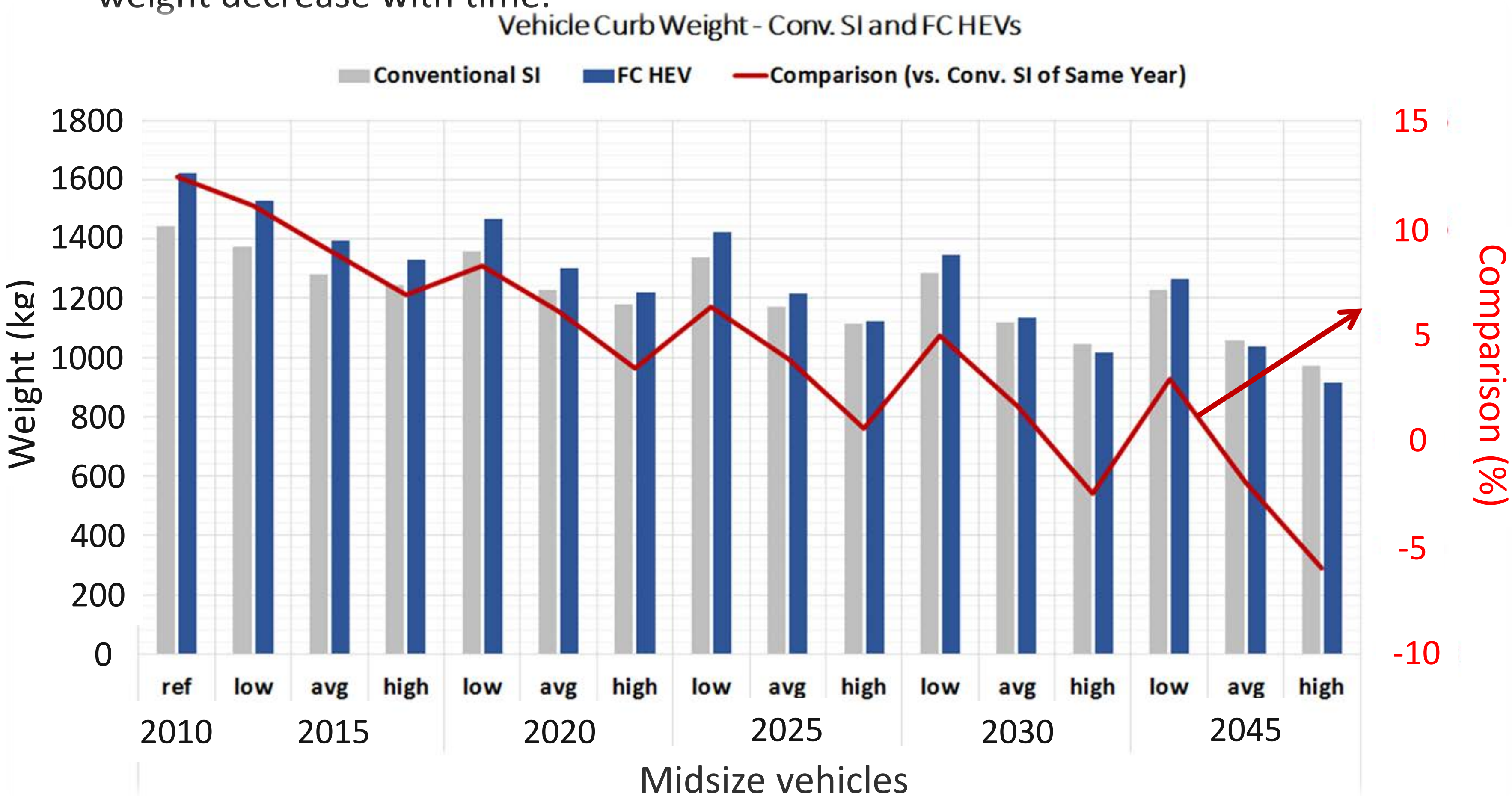


Argonne National Laboratory, SA044, Sponsored by Fred Joseck, FCTO Annual Merit Review, June 2015

Technical Accomplishments

Fuel Cell Vehicles Weight similar to Conv. Vehicles by 2025

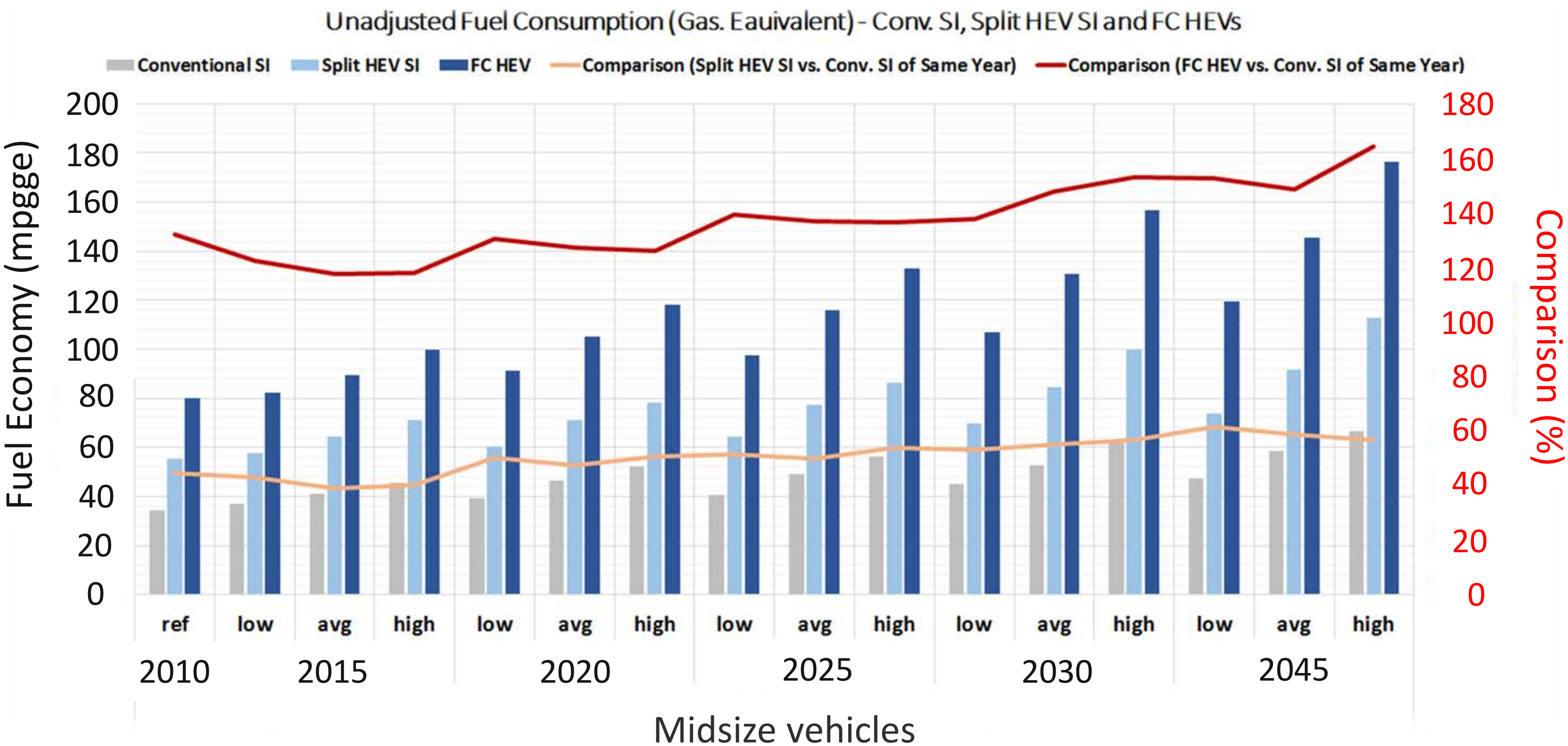
- With light weighting and improvement in component technology, fuel cell vehicle weight decrease with time.



Argonne National Laboratory, SA044, Sponsored by Fred Joseck, FCTO Annual Merit Review, June 2015

Technical Accomplishments

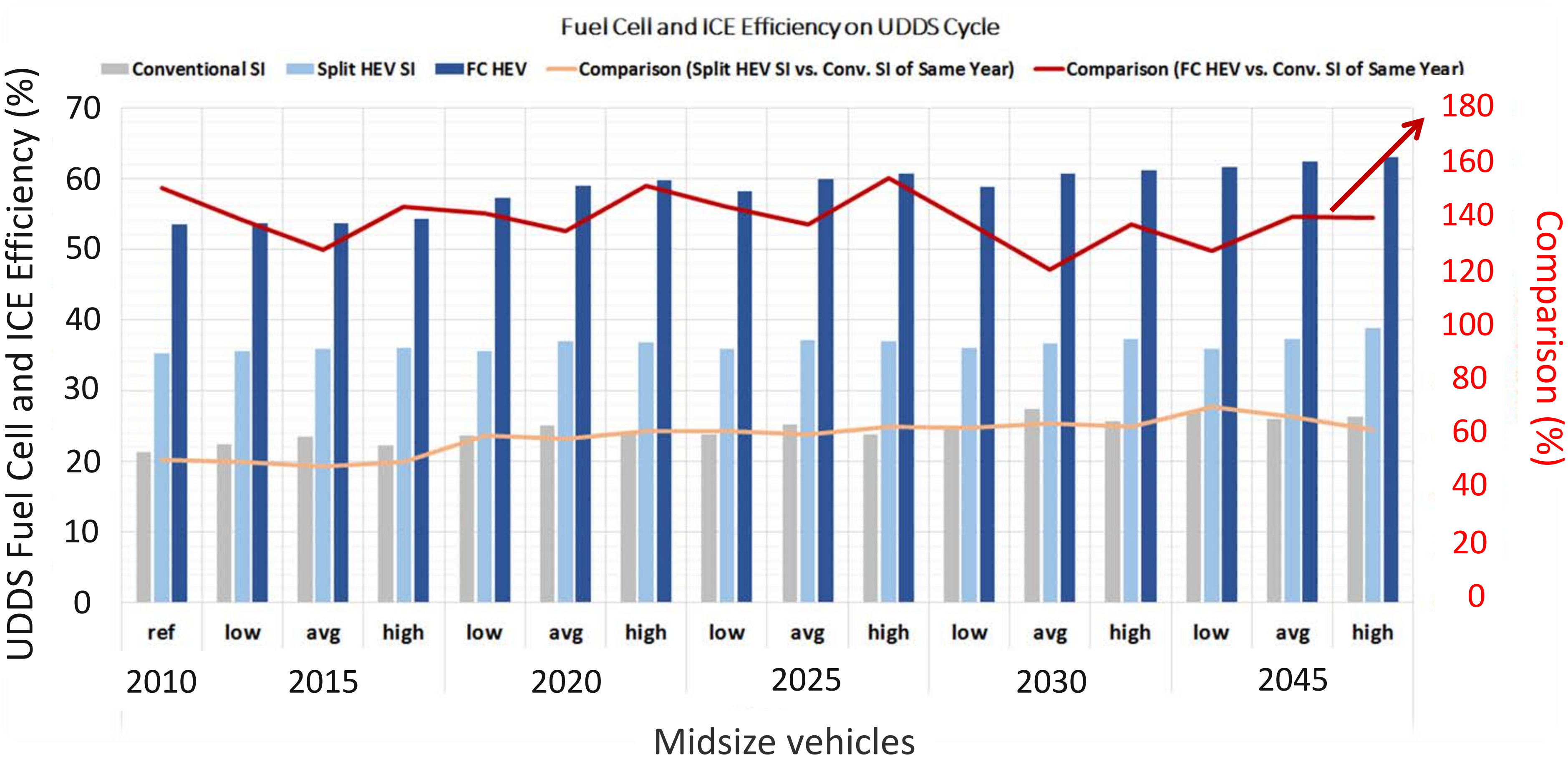
Fuel Cell Systems Leads to Significant Fuel Savings on the EPA Combined Driving Procedure



Argonne National Laboratory, SA044, Sponsored by Fred Joseck, FCTO Annual Merit Review, June 2015

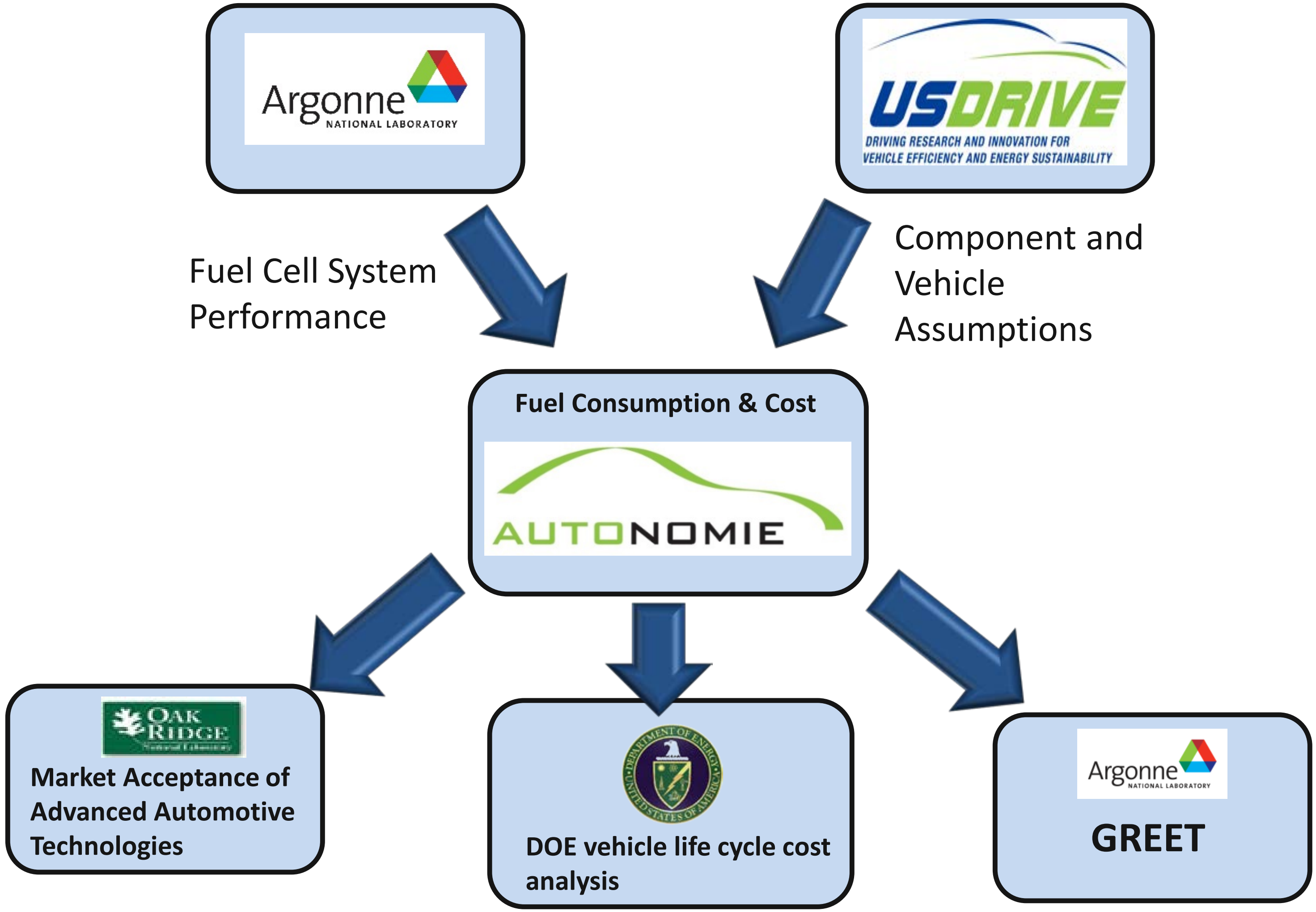
Technical Accomplishments

Fuel Cell Vehicles Remain Competitive Despite Significant Increase in ICE Engine Efficiency



Argonne National Laboratory, SA044, Sponsored by Fred Joseck, FCTO Annual Merit Review, June 2015

Collaboration and Coordination with Other Institutions



Ongoing and Future Work

FY15 On going work

- Provide results to market penetration and life cycle analysis (LCA) tools to evaluate FCTO technology benefits and understand the impact on petroleum and GHG reduction.
- Continue to refine results and add additional results parameters as needed by LCA and market penetration tools

FY16 Activities

- Understand the impact of the fuel cell system and hydrogen storage performance and cost requirements compared to other powertrain technologies to ensure successful commercialization path.
- Conduct sensitivity analysis of key parameters.
- Detailed analysis to understand impact of FCTO technology on each component (power, energy, weight).
- Provide guidance for long term requirements for peak power and onboard hydrogen weight.

Summary

- Full vehicle simulations were performed to assess the vehicle energy consumption and cost of current and future fuel cell vehicles compared to powertrains with internal combustion engines.
- Vehicle manufacturing costs decrease mostly due to the decrease of hydrogen tank cost (up to 80%) and fuel cell cost (up to 70%)
- Fuel cell vehicles are expected to have similar weight than conventional vehicles by 2045.
- Fuel cell vehicles retain a fairly constant fuel economy advantage compared to conventional vehicles (~160%) over time.

Acronyms

Acronym	Description
UDDS	Urban Dynamometer Driving Schedule
HWFET	Highway driving cycle
MPGGE	Miles per Gallon Gasoline Equivalent
FC	Fuel cell
CONV	Conventional vehicle
HEV	Hybrid electric vehicle
SI	Spark ignited
ICE	Internal combustion engine
MSRP	Manufacturer's suggested retail price
Low	Low uncertainty (90% confidence)
Medium	Medium uncertainty (50% confidence)
High	High uncertainty (10% confidence)
H2	Hydrogen
VTS	Vehicle Technical Specification