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# ***EMPLOYMENT IMPACTS OF HYDROGEN AND FUEL CELL TECHNOLOGIES***



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RCF ECONOMIC & FINANCIAL CONSULTING, INC.

# Overview

## Timeline

Start date: Oct. 2015

End date: Oct. 2018

## Barriers

Future Market Behavior (A)

Stove-piped/Siloed Analytical Capability (B)

Inconsistent Data, Assumptions & Guidelines (C)

Insufficient Suite of Models and Tools (D)

## Budget

FY16 DOE Funds: \$250k<sup>a</sup>

FY17 DOE Funds: \$250k<sup>a</sup>

## Partners/collaborators

RCF Economic & Financial Consulting

Valerie Taylor (FY 16 and FY 18)

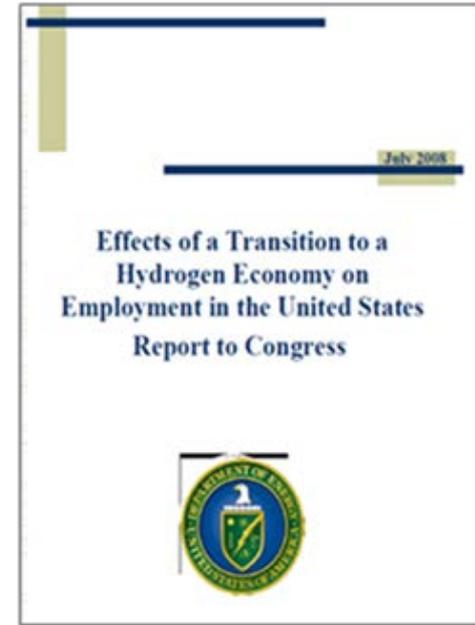
Energetics (FY 16 and FY 18)

<sup>a</sup> Includes contracting and model acquisition costs

# Updating 2008 Report to Congress “Effects of a Transition to a Hydrogen Economy”

*“The Secretary shall carry out a study of the likely effects of a **transition to a hydrogen economy** on overall employment in the United States...(including replacement effects, workforce training requirements, regional variations, etc.)...”*

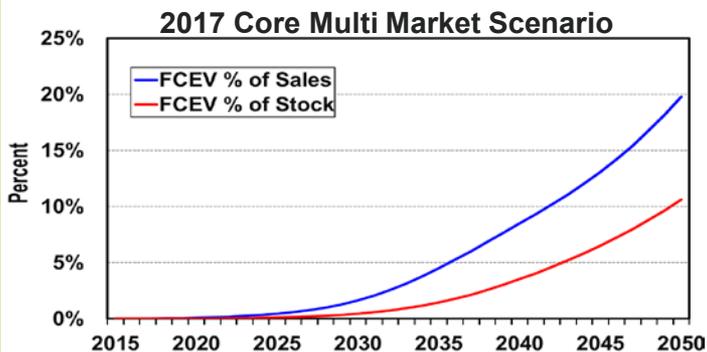
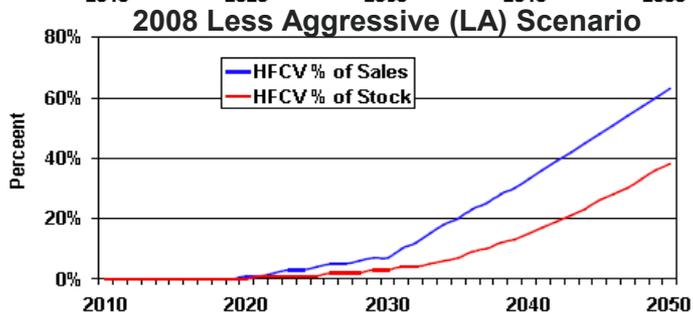
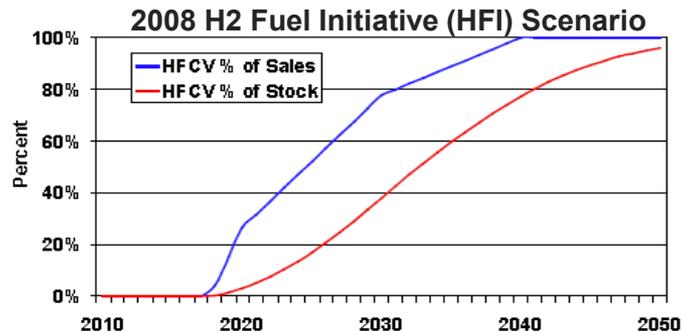
— *Energy Policy Act (PL109-58), Aug. 8, 2005*



## **Today's Focus Is on Multiple Forms of Energy in Multiple Markets**

## With Different Technology & Market Expectations

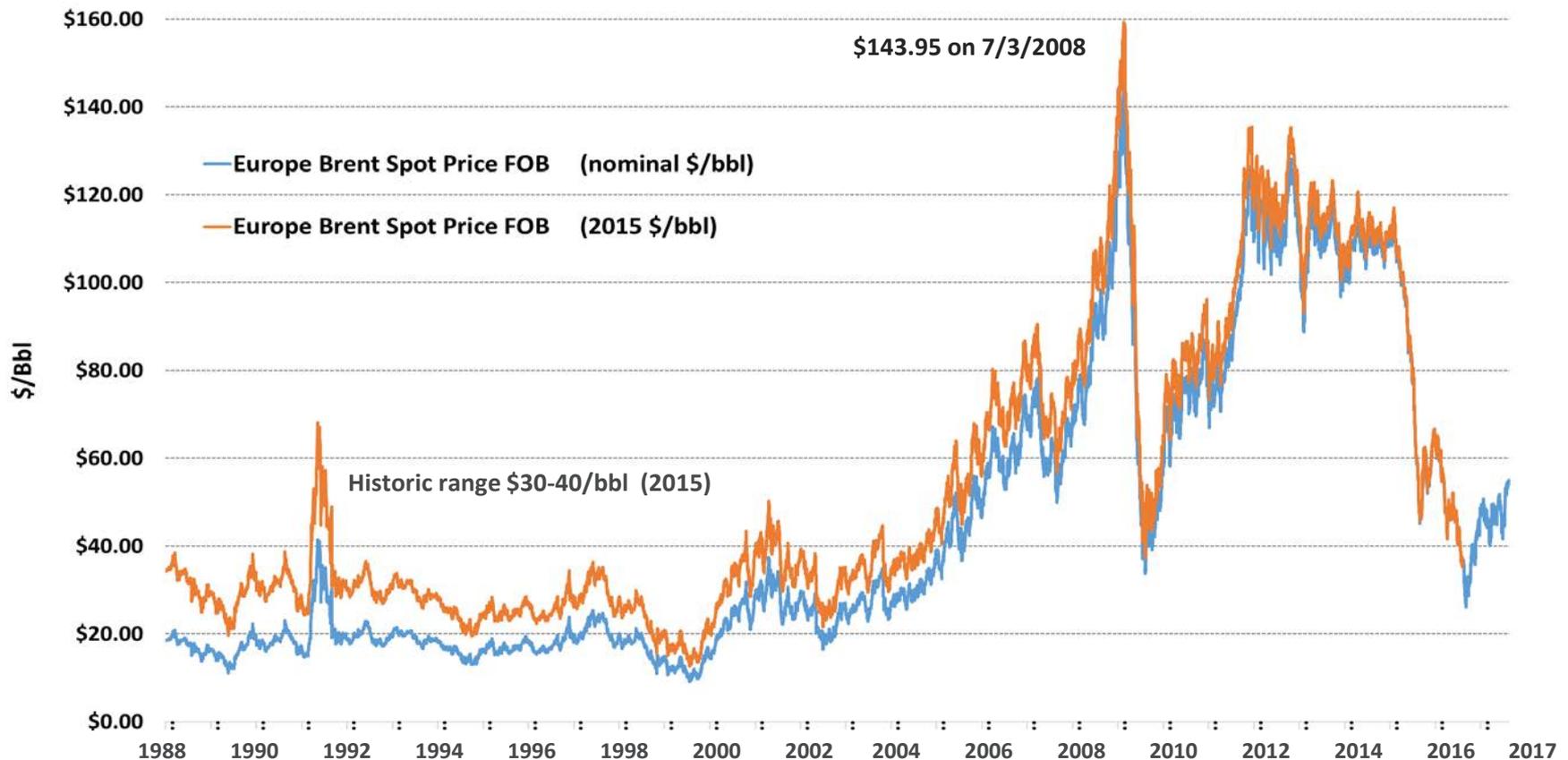
- Commercial introduction of Mirai, Clarity & Tuscan and associated station building in CA and NE and expansion of FCs in lift truck, backup power and prime power applications.
- Improved understanding of business case for fueling and vehicle adoption.



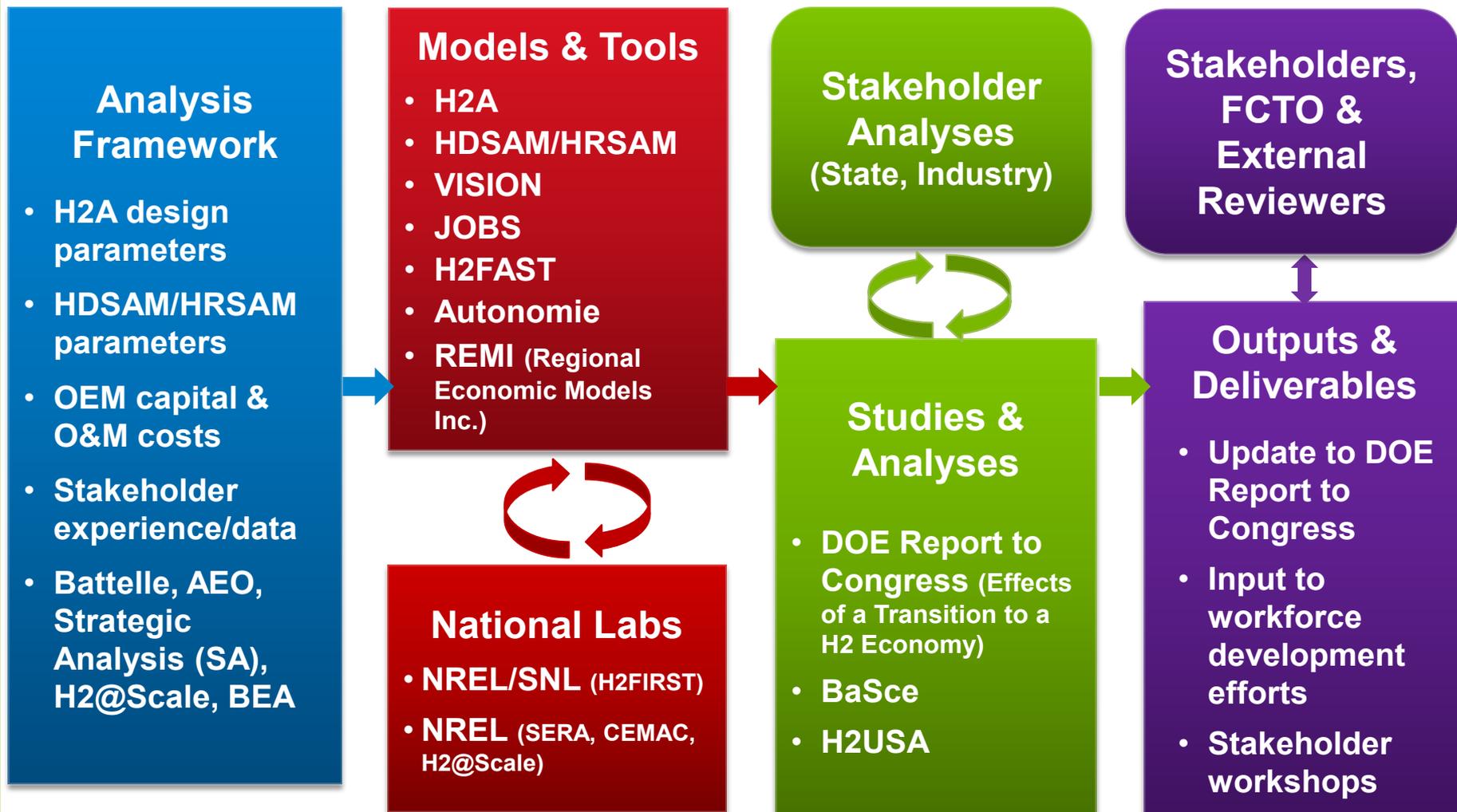
Parameter	2008 Report to Congress	2017 Analysis
LDV Scenarios	HFI (Posture Plan) & LA (AE0-06 high oil price)	Multi Market (Core) & Alternative Scenarios (both new)
Markets	LDVs, prime power	LDVs, HDVs, material handling, backup and prime power
Model & Geography	IMPLAN, national model; separate analyses of CA, Northeast, Upper Midwest, TN and Houston	REMI, regional model; National = Sum of Western, ZEV/Eastern, Central Industrial, Central Southern & Rest of US regions
2050 Forecasts:		
- GDP (bln 2015 \$)	\$47,161	\$37,058
- LDVs (mln)	362.0	314.7
- FCEV sales (mln)	23.9 (HFI)	3.7 (Core Multi Market)
- FCEVs (mln)	347.5 (HFI)	33.7 (Core Multi Market)
- Gasoline (2015 \$/gal)	\$4.38	\$3.40
Occupations	Not modeled in IMPLAN. Required separate side analyses.	Job breakdowns by occupation (95 in REMI) and industry. Occupations cut across industries.
Jobs	Gross jobs. Net jobs estimated from Base Case.	Gross supply-chain jobs (direct + indirect) by industry. Induced jobs estimated from consumer spending. Net jobs estimated from Base Case.

# And Dramatically Different Fuel Price Expectations

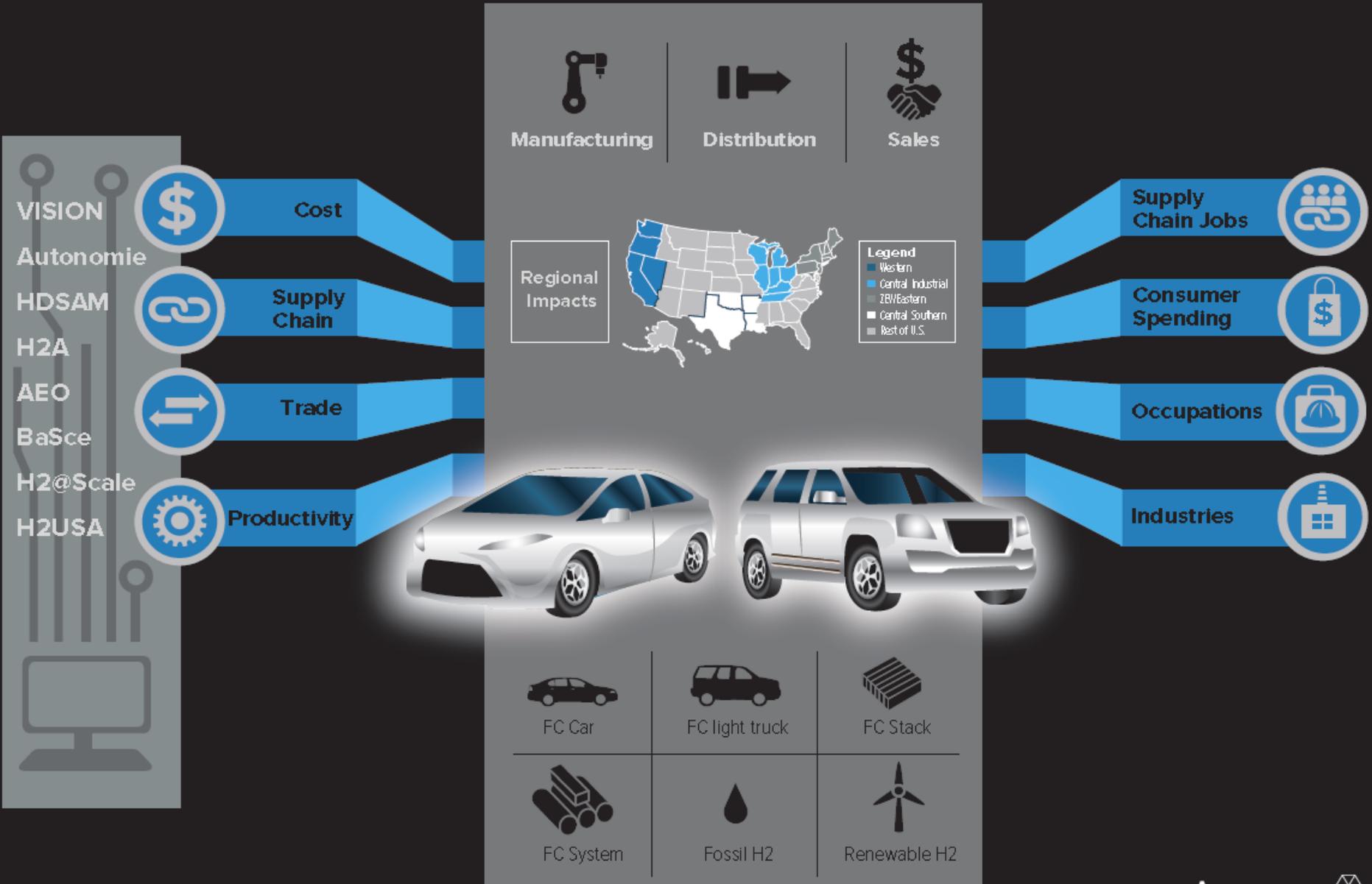
- In 2006-2008 oil price climbed sharply and was expected to remain >\$100/bbl for foreseeable future
- Since 2014 oil price under pressure with booming shale production and worldwide oversupply
- U.S. oil imports down from 66% in 2008 to 24% in 2016



# Analysis Leverages Multiple Tools & Efforts

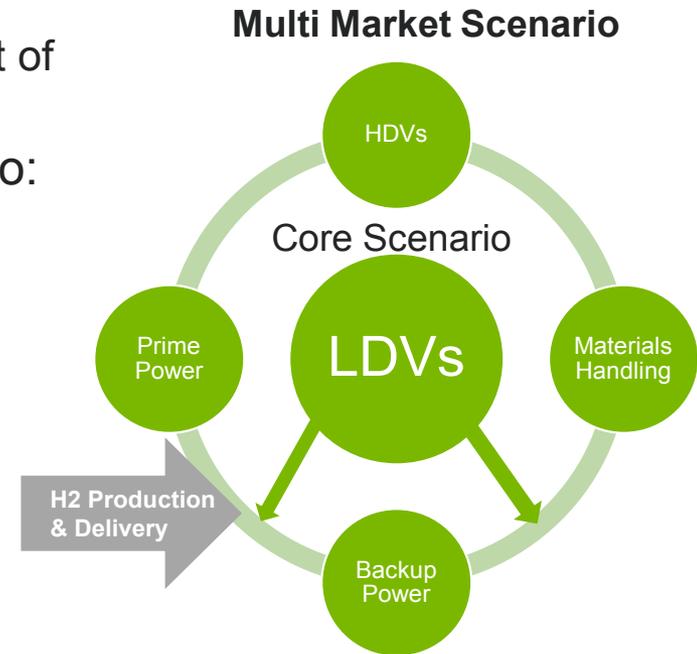


# Employment Impacts of Hydrogen and Fuel Cell Technologies



# “Multi Market Scenario” Is Key Part of Analysis

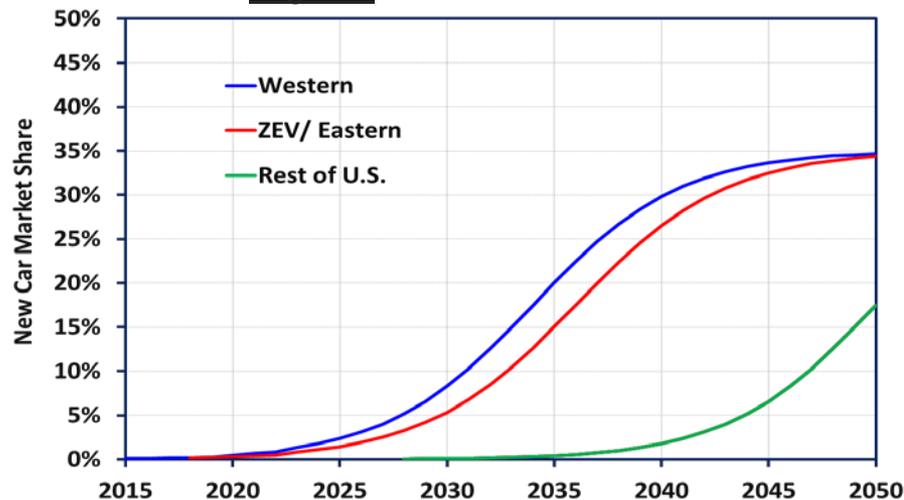
- Hydrogen Fuel Initiative/Posture Plan provided basis for 2008 Report to Congress; no comparable scenario today.
- Multi Market Scenario includes markets and H2 production & delivery (outer circle in figure).
- Core Multi Market Scenario focuses on **LDV markets**:
  - LDVs = largest hydrogen demand sector
  - Require LDV demand for FCEVs to examine impact of FCEVs & H2.
- Process of developing Core Multi Market Scenario:
  - Consumer demand (2015–2050, by region)
    - FCEV **market penetration**: cars & light trucks (LTs)
    - **LDV sales**: cars & LTs
    - FCEV **stock** and H2 use: cars & LTs.
  - FCEV manufacturing and sale (2015–2050)
    - Midsize car & midsize SUV **manufacturing cost by major component**
    - U.S. conventional and electric car & LT **sales by domestic/foreign assembly**
    - Conventional U.S. car & LT **assembly by region.**



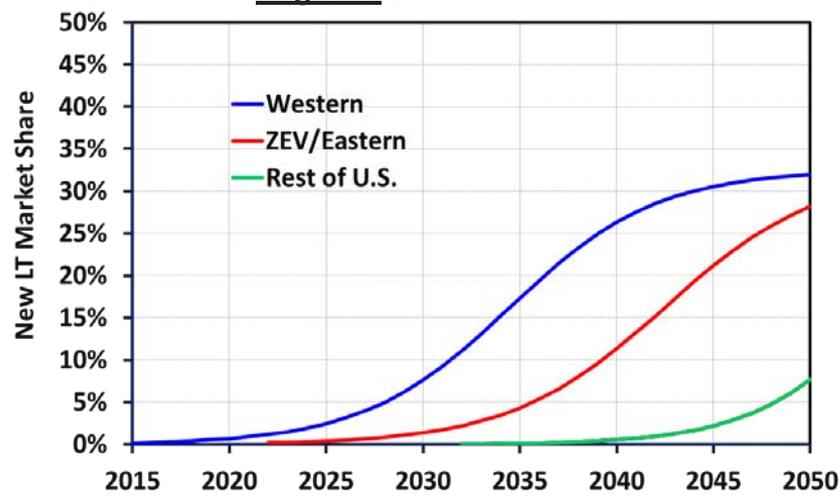
# Core Multi Market Scenario (LDV Only) Assumptions Reflect BaSce, H2USA, H@Scale Efforts

- 4 models used in BaSce analysis (ParaChoice, LAVE-TRANS, MA3T, LVCFlex) show wide variation in FCEV sales shares (6–42% of cars; 6–37% of LTs in 2050) .
- More agreement on PHEV + FCEV shares (66–74% of cars and 61–67% of LTs) in 2050.
- Core Multi Market Scenario assumes FCEVs will be 50% of mean PHEV + FCEV shares in Western and ZEV/Eastern regions in 2050 (35% of car and 32.5% of LT sales).
- Other regions assumed to follow similar market penetration trajectory.
- FCEV market shares for Western region share reflect CA roadmap through 2022. Shares for ZEV/Eastern region reflect H2USA assumptions on market entry. Shares for other regions reflect similar delay from ZEV/Eastern market entry.
- Core Multi Market Scenario is preliminary “mid” scenario in H2@Scale LDV demand analysis.

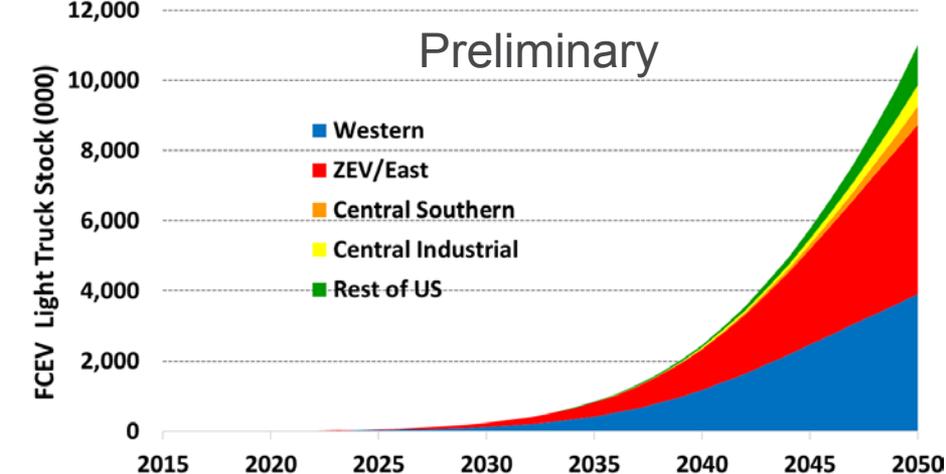
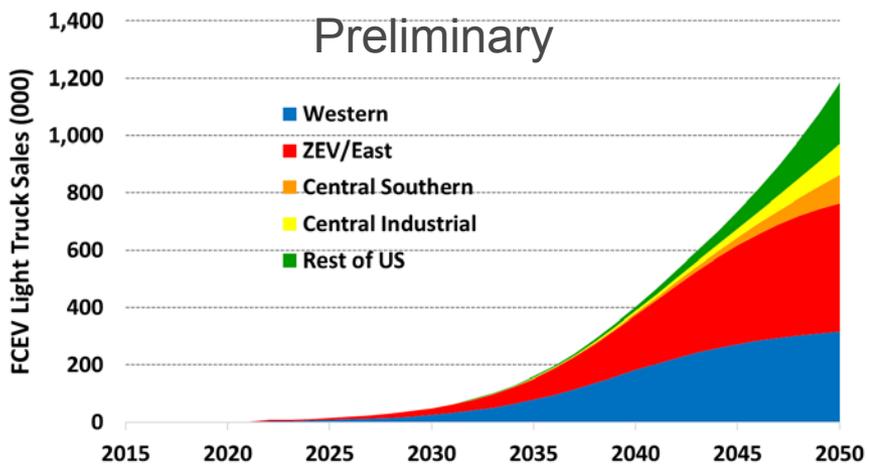
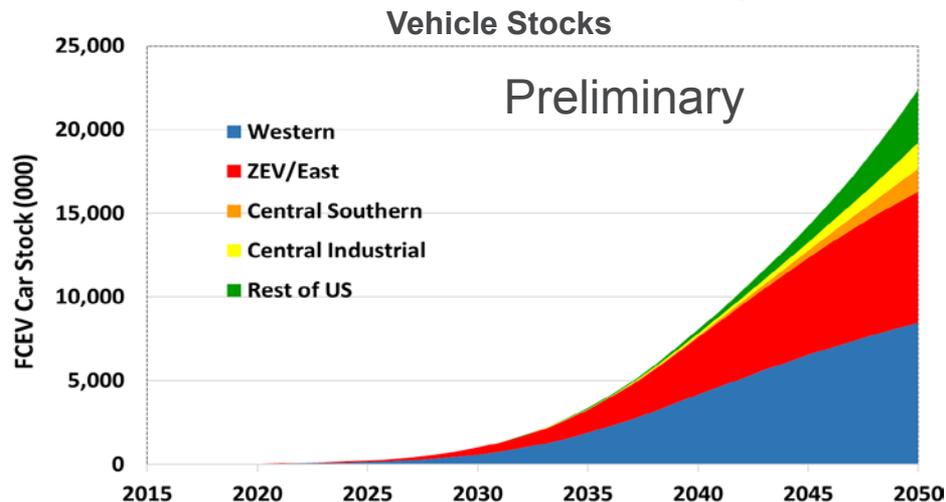
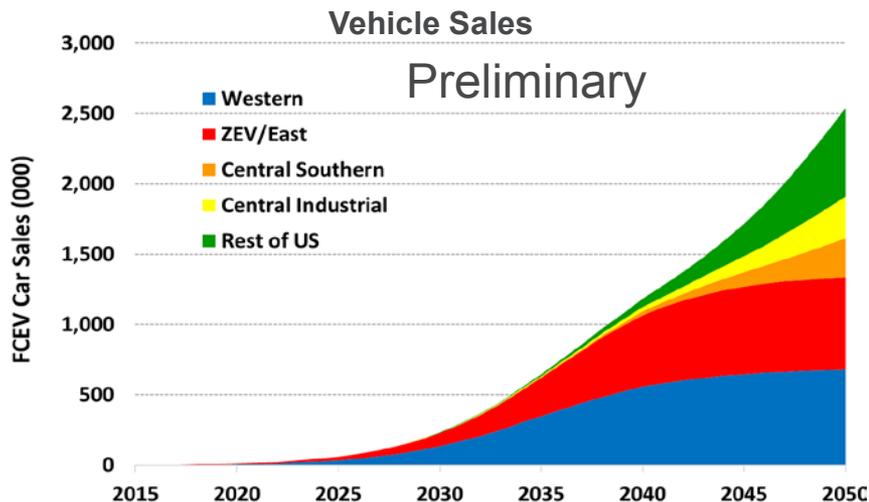
FCEV Share of Regional Car Sales: Core Multi Market Scenario



FCEV Share of Regional LT Sales: Core Multi Market Scenario

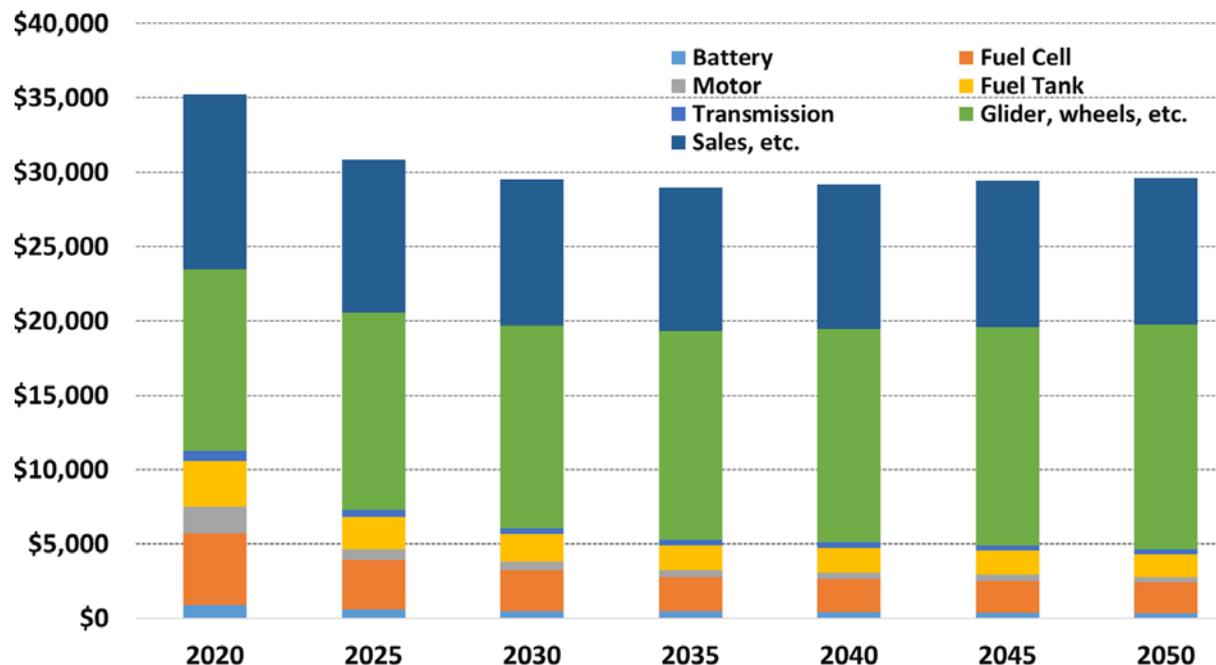


# AEO & Census Regionalize LDV Sales VISION Estimates Regional LDV Stocks



# Manufacturing Costs in Core Multi Market Scenario Reflect Autonomie & BaSce Analyses

**FCEV Cost Breakdown (2015 \$)**  
(Manufacturing and Sales/Distribution Costs)



Source: Autonomie, ([http://www.autonomie.net/publications/fuel\\_economy\\_report.html](http://www.autonomie.net/publications/fuel_economy_report.html)), BaSce Program Success, High Technology Advancement/Low Cost Case, midsized sedan.

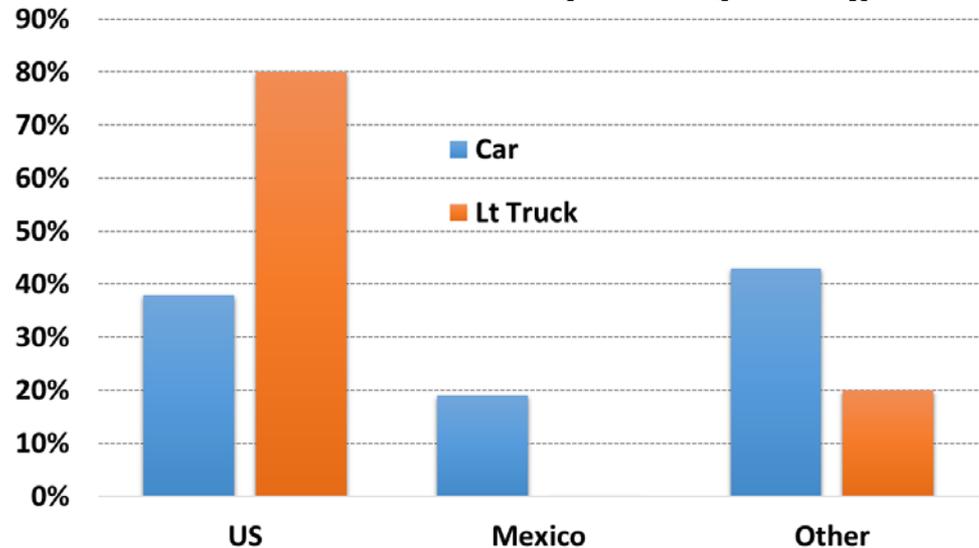
- FCEV manufacturing cost for midsized sedan and midsized SUV (Autonomie, Sept. 2016)
- FC system cost composition (SA, March 2017)
  - 53% stack/47% system
  - Labor share of manufacturing cost
  - Individual component costs allocated to intermediate demand sectors
- FCEV sales costs include:
  - Shipping/distribution
  - Sales
  - Administrative/front office

# And Domestic/Import Share of Car & Light Truck Sales

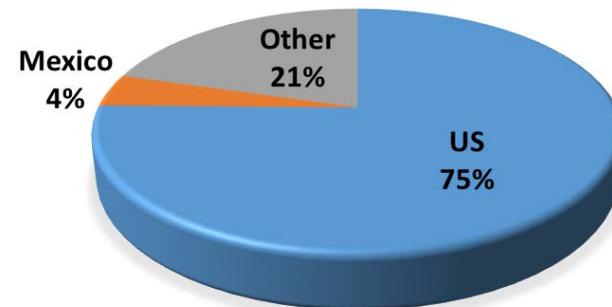
## Tools/Data Sets and Assumptions

- 38% of conventional cars sold in U.S. are assembled at U.S. plants ([https://www.bea.gov/national/xls/gap\\_hist.xlsx](https://www.bea.gov/national/xls/gap_hist.xlsx)).
- 80% of conventional light trucks sold in U.S. are assembled at U.S. plants
- 67.5% of PHEVs and 75.3% of BEVs sold in U.S. are assembled in U.S. ([http://www.transportation.anl.gov/technology\\_analysis/edrive\\_vehicle\\_monthly\\_sales.html](http://www.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html)).
- **U.S. assembly of conventional LDV's assumed to continue at current rates** (38% of cars; 80% of light trucks).
- **U.S. assembly of FCEVs assumed to follow BEV pattern** for cars (75%) and conventional pattern for light trucks (80%).

U.S. LDV Sales by Country of Origin



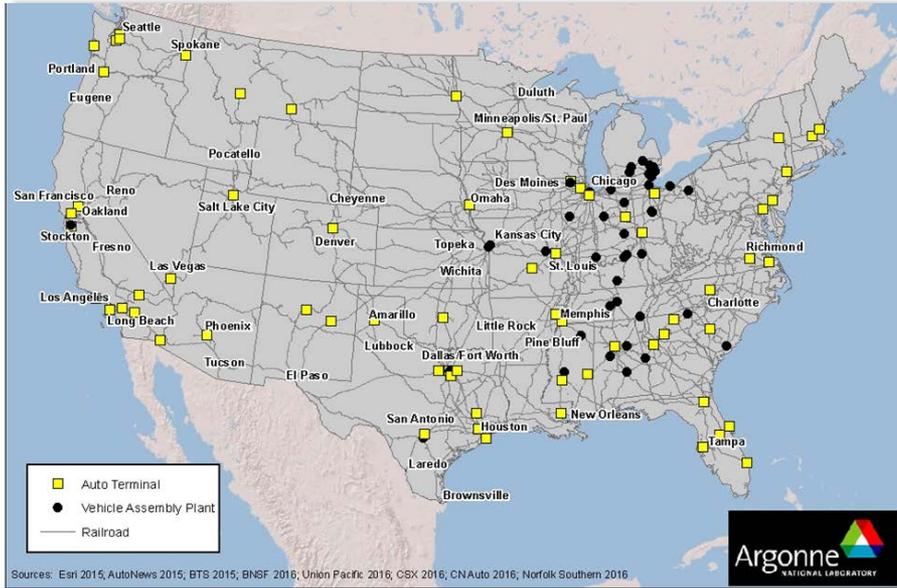
BEV Sales by Country of Origin



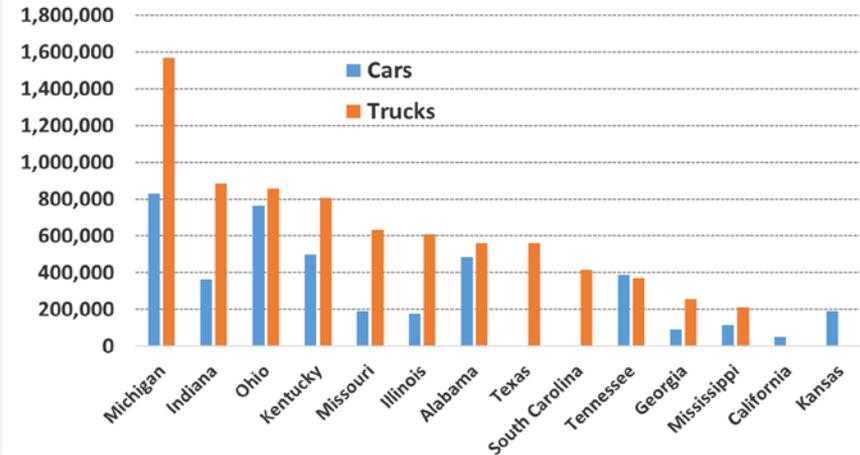
# Manufacturing Assumptions in Multi Market Scenario Reflect Geography of Vehicle Assembly



LDV Assembly Plants & Auto Terminals



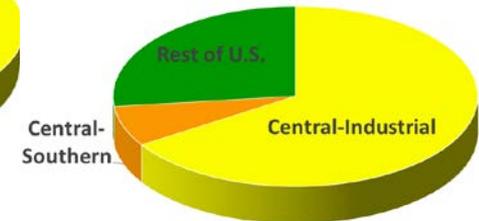
2015 US Car & Light Truck Production



Tools/Data Sets and Assumptions:

- Automotive News: Current LDV production by assembly plant → REMI regional shares. **Regional manufacturing shares assumed to remain constant.**
- AEO-2016: Future car & light truck sales by Census region. Allocated to states based on BuCen forecasts of driving age population. **State shares of vehicle sales change over time.**
- VISION: Run on state level to forecast VMT & fuel use by cars & light trucks. Results aggregated to REMI regions.

75% of Cars Assembled in Central Industrial Region



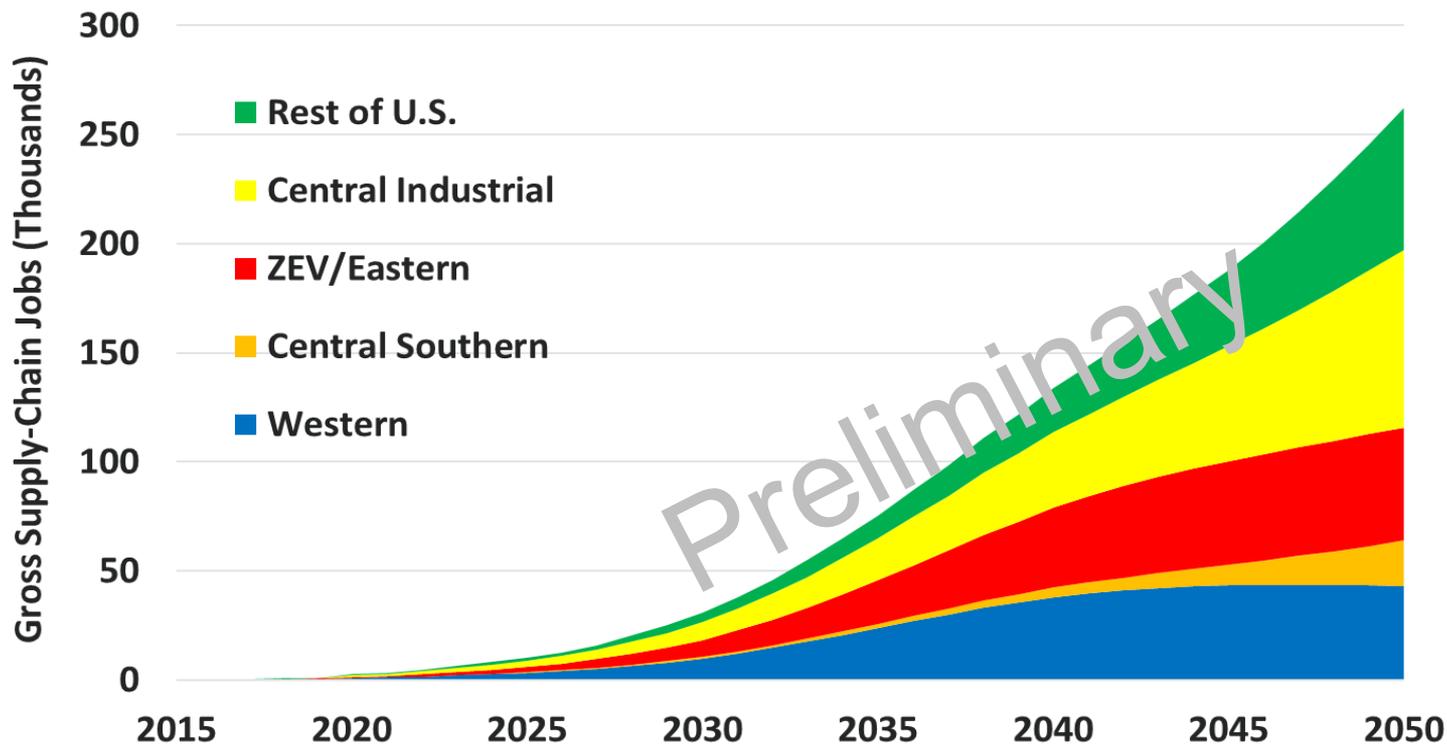
Light Trucks



# In 2050 ~260,000 Jobs Associated with FCEV Manufacturing, Distribution & Sale (MDS)

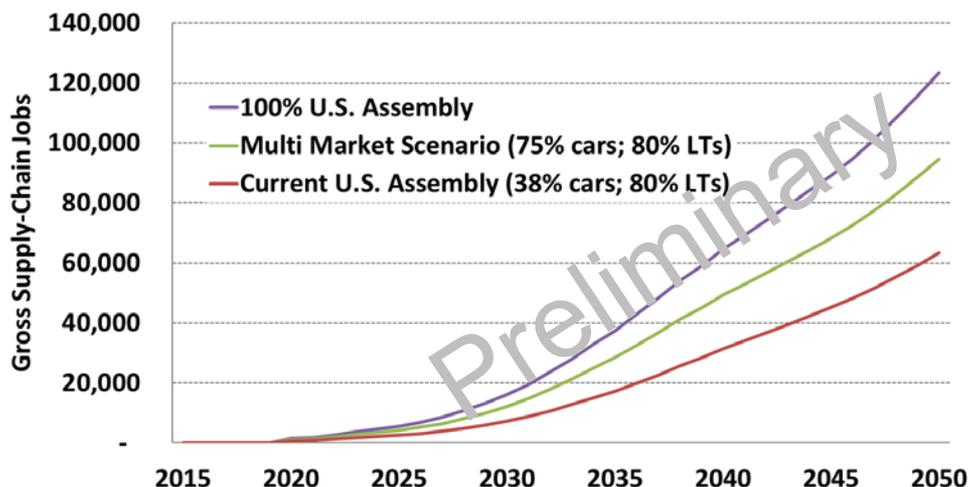
**Multi Market Scenario, Supply-Chain Employment (Direct + Indirect)**

- ~100,000 gross supply-chain jobs (36%) associated with FCEV manufacturing
- ~160,000 gross supply-chain jobs (64%) associated with FCEV distribution & sales, independent of where FCEV is assembled



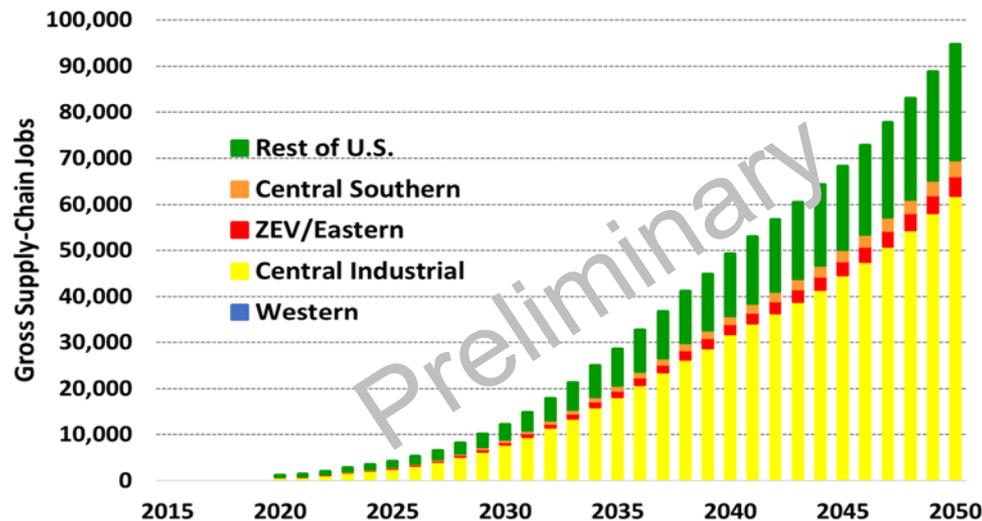
# Jobs in FCEV Manufacturing Depend on Assembly Location

Jobs in FCEV Manufacturing by U.S. Versus Foreign Assembly



- In Core Multi Market Scenario ~100,000 gross supply-chain jobs are associated with FCEV manufacturing in 2050.
- Gross supply-chain jobs associated with FCEV manufacturing can vary from 60,000 to 120,000 depending on U.S. vs. foreign assembly.
- Most manufacturing jobs are in Central Industrial region where existing motor vehicle supply chains are concentrated.
- Manufacturing jobs are not only in manufacturing industries.

Jobs in FCEV Manufacturing in Core Multi Market Scenario by Region

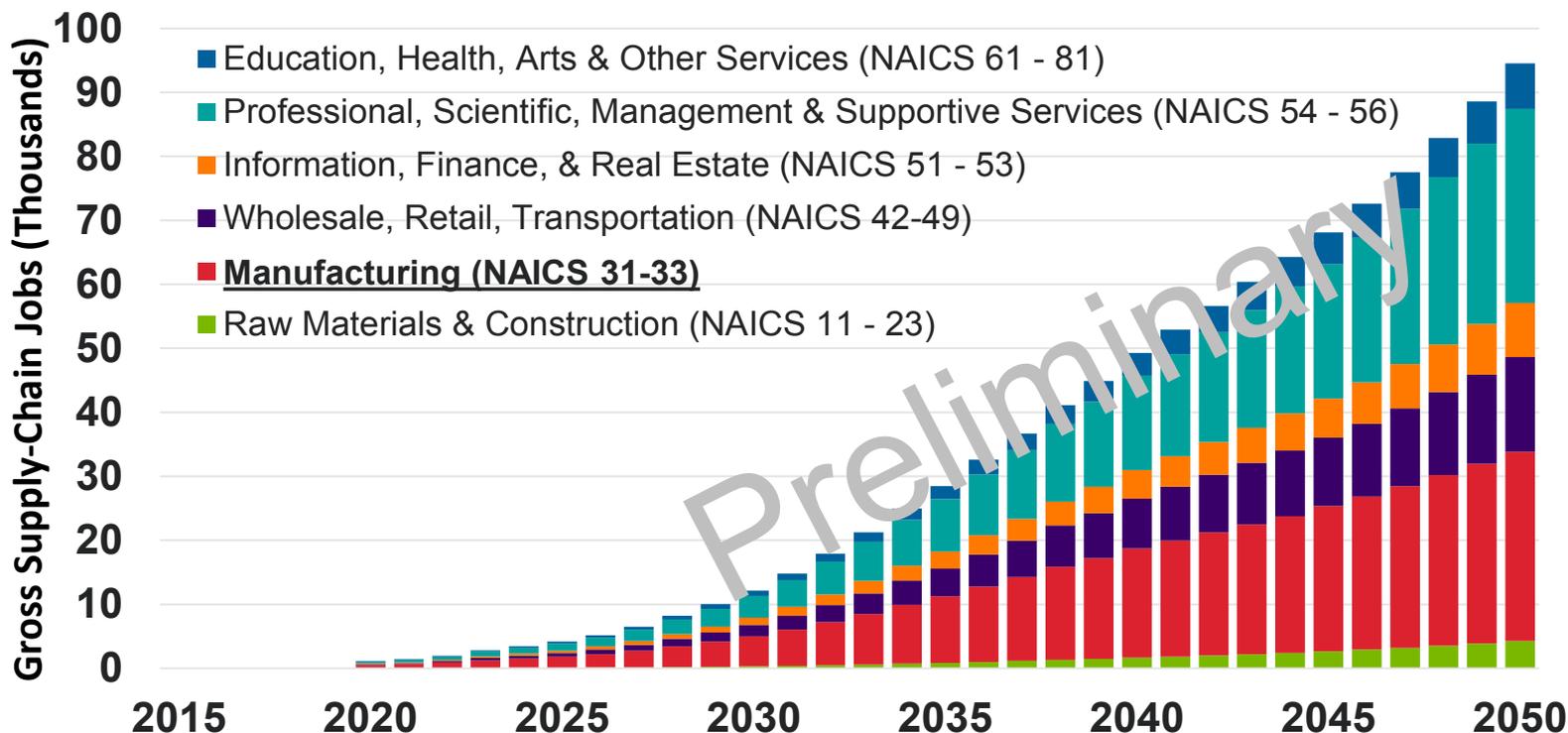


# Jobs in FCEV Manufacturing Are in Many Industries

Core Multi Market Scenario, Supply Chain Employment (Direct + Indirect)

- In 2050 jobs in manufacturing industries account for a third of gross manufacturing supply-chain employment in Core Multi Market Scenario.
- Jobs in Professional, Scientific, and Support Services comprise another third.
- Remaining third is split among many industries.

FCEV Manufacturing Gross Jobs (Direct + Indirect) by Industry, All Regions



# Only ~30% Supply-Chain Jobs in FCEV Manufacturing Are in Manufacturing Industries

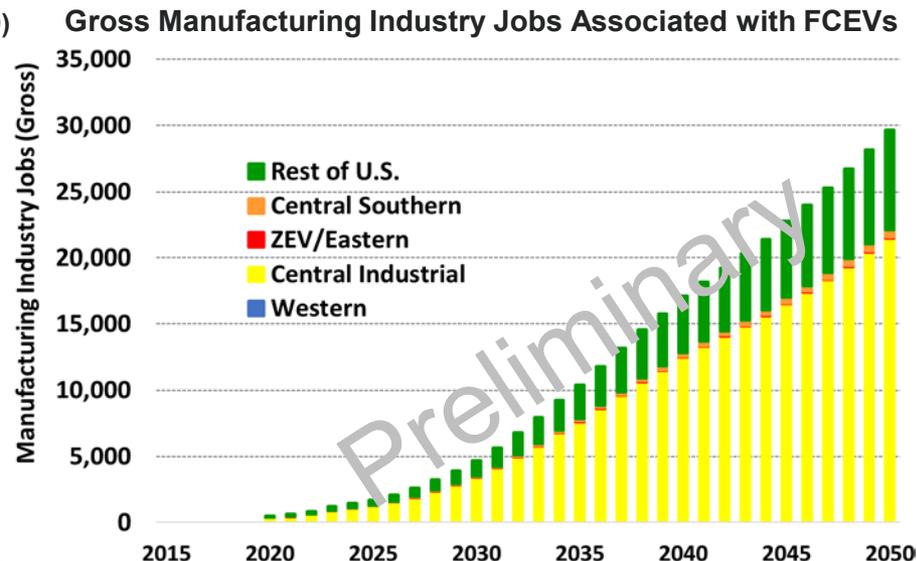
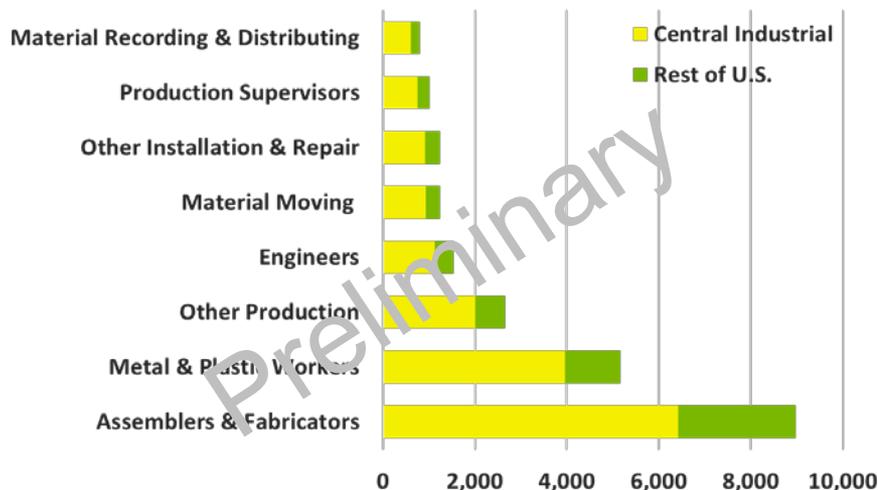
Core Multi Market Scenario, Gross Supply-Chain Employment (Direct + Indirect)



- Most manufacturing industry jobs are in Central Industrial region, where existing motor vehicle supply chains are concentrated.
- Top occupations benefiting from FCEV manufacturing are assemblers/fabricators and metal/plastic workers.
- ~70% of supply-chain manufacturing jobs are in other industries.



Top Occupations of Jobs in Manufacturing Industries<sup>a</sup>  
Associated with FCEVs (Gross Supply Chain, Select Regions, 2050)



<sup>a</sup>Industries Represented: Manufacturing (NAICS 31-33)

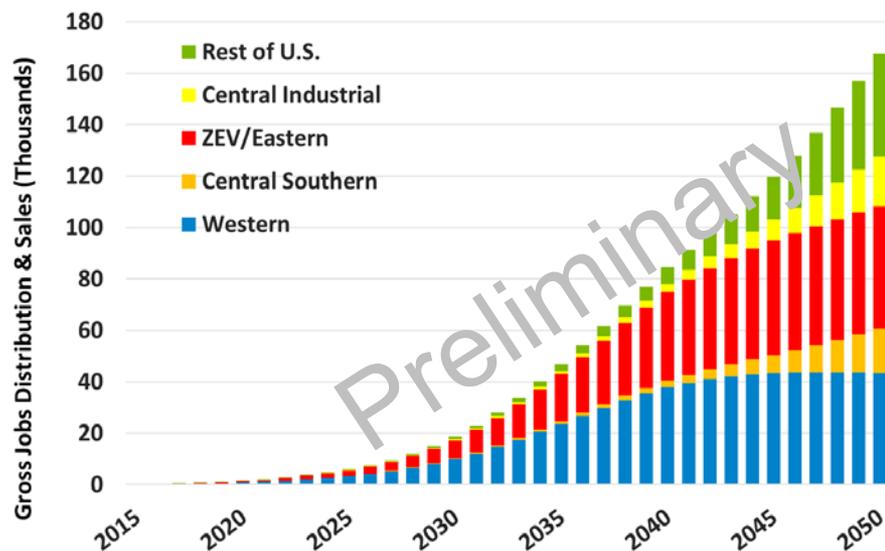
# Distribution/Sales Industries Account for Majority of Jobs in FCEV Manufacturing, Distribution & Sales (MDS)

Core Multi Market Scenario, Gross Supply-Chain Employment (Direct + Indirect)

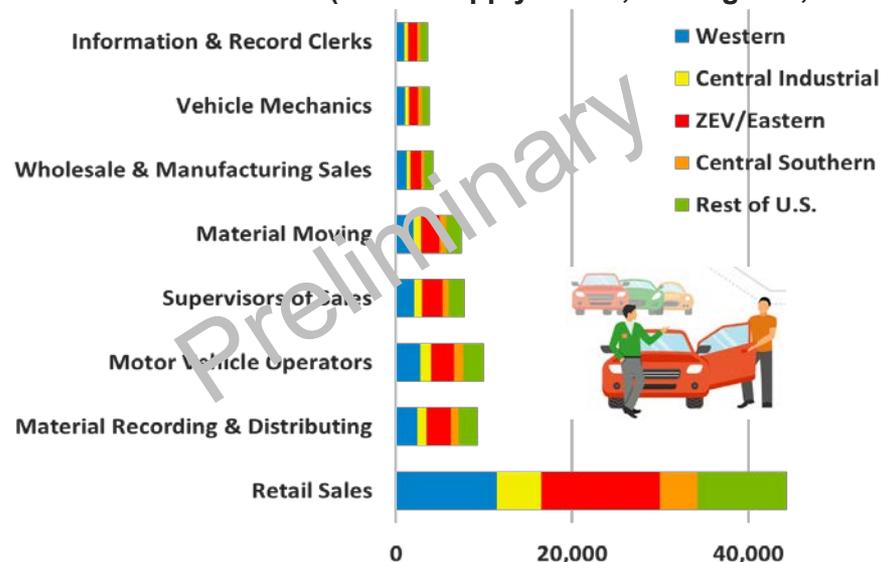
- 64% of supply-chain jobs associated with FCEV MDS are in distribution and sales industries.
- Retail sales is top occupation.
- Sales/distribution jobs concentrated in regions with highest FCEV sales.



Jobs from Distribution/Sales (Direct + Indirect, All Industries)



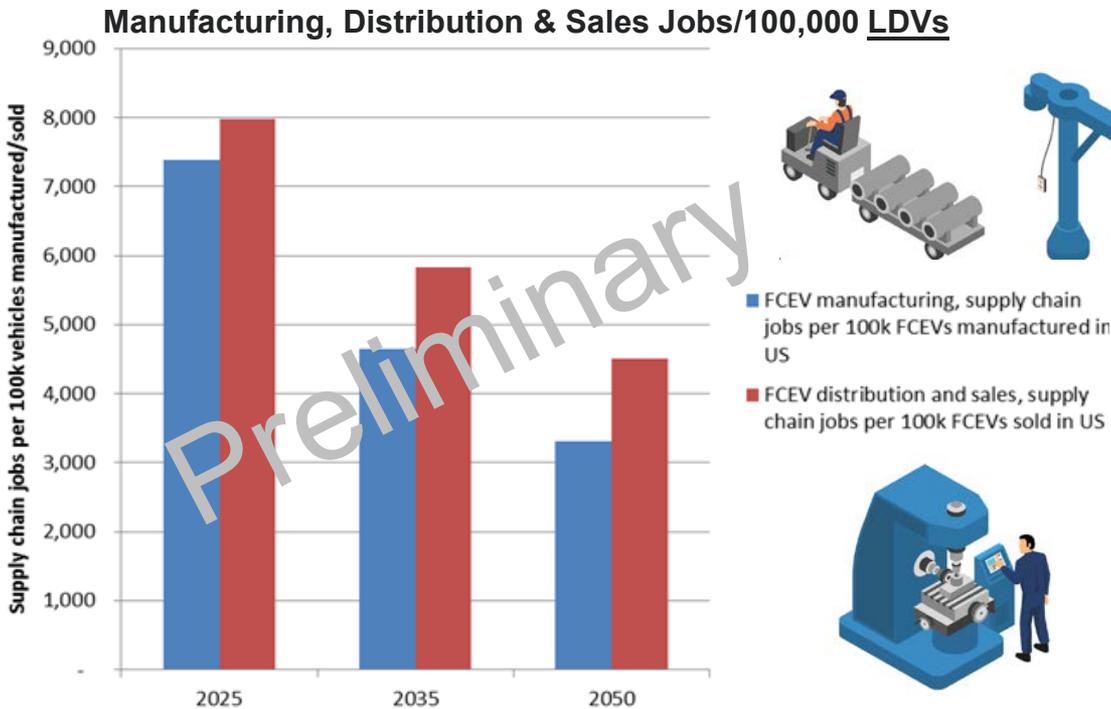
Top Occupations of Jobs in Distribution/Sales<sup>a</sup> Industries Associated with FCEVs (Gross Supply-Chain, All Regions, 2050)



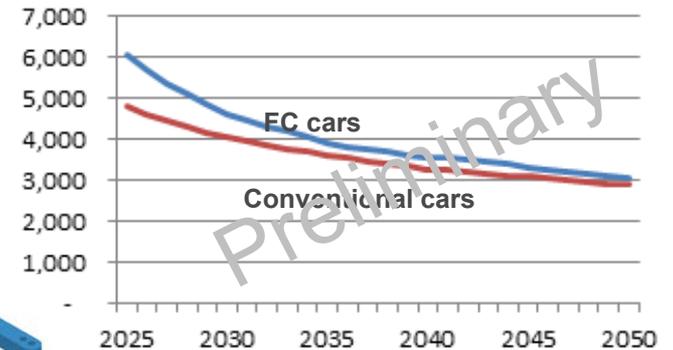
<sup>B</sup> Wholesale (NAICS 42), Retail (NAICS 44-45), Transportation/Warehousing (NAICS 48-49)

# MDS Jobs Per 100,000 FCEVs Produced or Sold Decline with Improved Productivity

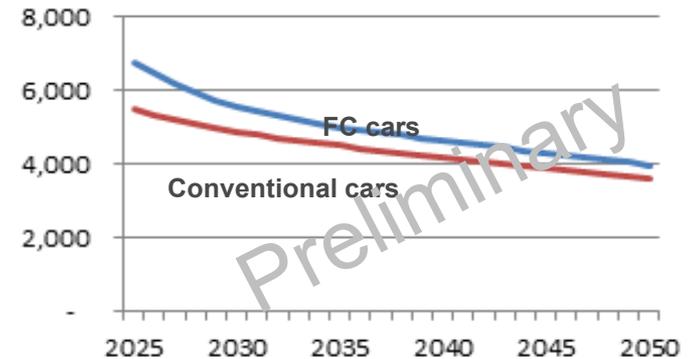
- Manufacturing jobs reflect U.S. share of FCEV manufacturing (75% of cars; 80% of LTs) in Core Multi Market Scenario. Distribution & sales jobs apply to all FCEVs sold.
- Rates decline with improved supply chain efficiency.
- Jobs for manufacturing & distribution/sales per 100,000 cars exceed rate for conventional cars.



**Manufacturing Jobs Per 100,000 Cars Produced in U.S.**



**Sales/Distribution Jobs Per 100,000 Cars Sold in U.S.**



# FY 2017–2018\* Tasks and Status

Milestone	Status (%)
Development of Base Case & Core Multi Market Scenario	100
Development of REMI custom sectors	75
Economic analysis of Core Multi Market Scenario	75
Development & analysis of Alternative Scenario	30
Expansion of Multi Market Scenario to additional markets	30
Stakeholder workshop	0
Economic analysis of Expanded Multi Market Scenario	0
Sensitivity and workforce development analyses	0
Validation and documentation	20

FY 2017

FY 2018

Multi Market & Alternative Scenarios and  
REMI Custom Industries, Initial Analysis of  
Employment Impacts

Expanded Scenarios, Sensitivity Analysis,  
Analysis of Occupational & Workforce  
Development Needs

\* Proposed future work subject to change based on funding levels.

# Advisors & Collaborators Add Unique Expertise

**Advisor:**

- Public agencies
- Fuel cell and hydrogen suppliers
- Researchers (NREL, SA, VTO BaSce & Analysis teams)
- OEMs (H2USA)

**Role:**

- Defaults (data/analyses)
- Scenarios
- Future directions/needs
- Review

Role	Collaborator
Management and coordination; scenario development; engineering data collection and analysis; quality assurance; outreach; documentation	Argonne
Economic data collection and analysis; development of custom industries and economic modeling, quality assurance; code development and application; documentation	RCF
Scenario development/review	Advisory Group
Workforce development	Valerie Taylor
Outreach planning, facilitation and documentation	Energetics

# Summary

- **Relevance:** Update *2008 Report to Congress*. Improve understanding of employment from H2/FC deployment. Fill gap in analysis portfolio.
- **Approach (Entire Project):** Develop Base Case reflecting AEO-2016 and internally-consistent Multi Market and Alternative Scenarios leveraging DOE-supported efforts. Develop 6 REMI custom industries to assess changes in employment & economic metrics associated with Multi Market Scenario.
- **Accomplishments and progress (Year 2):**
  - Developed Base Case and Core Multi Market Scenario for five regions, 35 years.
  - Revised REMI standard industry sectors and developed 4 custom sectors.
  - Estimated roughly 100,000 jobs associated with manufacturing, and 160,000 jobs associated with distribution and sale of 3.7 million FCEV cars and light trucks (Core Multi Market Scenario) in 2050.
- **Collaborations:** Active partnership between ANL & RCF. Extensive assistance from advisors and other researchers.
- **Future work (subject to funding):**
  - Remainder Year 2 (FY 2017):
    - Complete H2 custom industries; estimate employment; document results.
    - Complete Alternative Scenario; estimate employment; document results.
  - Year 3 (FY 2018):
    - Expand Multi Market & Alternative Scenarios to HDVs & early markets; evaluate impact.
    - Analyze sensitivities and workforce development needs.
    - Continue interaction/outreach with stakeholders and advisors.

# Thank You!

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