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AN 035

Employment Impacts of Infrastructure Development for Hydrogen and Fuel Cell Technologies

Marianne Mintz, Argonne National Laboratory

Catherine Mertes and Eric Stewart, RCF

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RCF Economic & Financial Consulting, Inc.

Argonne National Laboratory

Overview

Timeline

Start date: October 2010

End date: Project continuation and direction determined annually by DOE

Percent complete: 30% (FY2013)

Budget

DOE share: 100%

Funding for FY12: $72k

Funding for FY13: $150k*

* AOP commitment. Initial $25k received Oct. 2012. Additional funds expected April 2013.

Barriers

- Lack of Readily Available, Objective, and Technically Accurate Information (A)
- Regional Differences (E)
- Difficulty of Measuring Success (F)

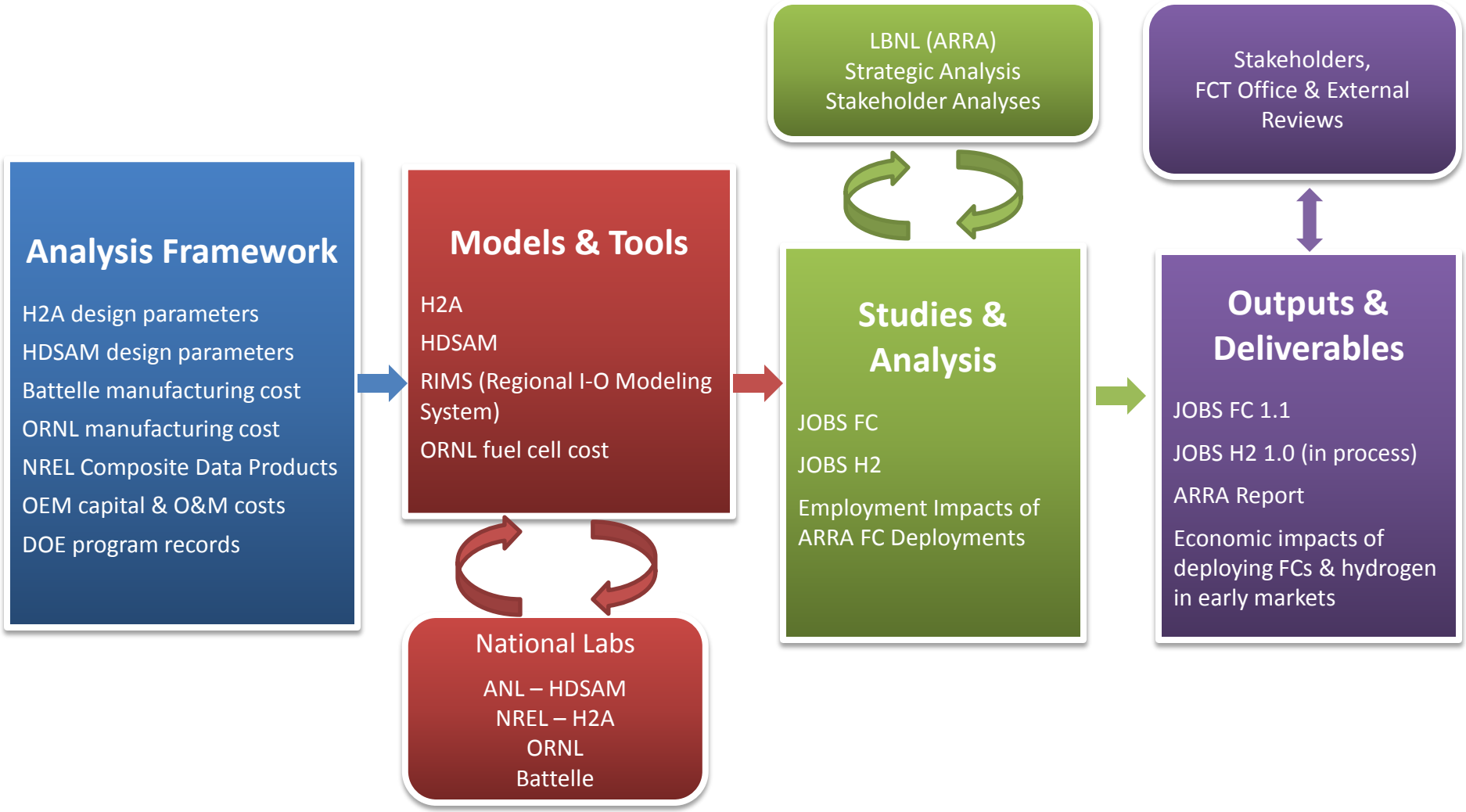
Partners

- Argonne National Laboratory
- RCF Economic & Financial Consulting
- Stakeholders:
  - Public agencies
  - Industry organizations
  - Manufacturers
  - Researchers

Relevance

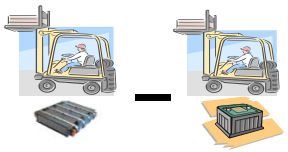
- Provide consistent platform/model to examine employment and other economic impacts of hydrogen (H2) and fuel cell (FC) investments
  - JOBS FC (JOBS and economic impacts of Fuel Cells) and JOBS H2 (JOBS and economic impacts of Hydrogen) models translate investment and operations expenditures into estimates of gross and net employment, earnings and economic activity
  - Downloaded tools, web-based training and support permit analyses of economic impacts of fuel cells and hydrogen infrastructure
- Analyze fuel cell and infrastructure deployment
  - For particular programs/projects or scenarios
  - To provide input for R&D priorities
- Support stakeholders
  - Robust, user-friendly tools with appropriate functionality
  - Acquire/review input data and methodologies and validate results for different geographies and applications. This is essential information for local, state and national policy decisions, public and private investment decisions and program planning and analysis.

Employment Impacts of Infrastructure Development for Hydrogen and Fuel Cell Technologies

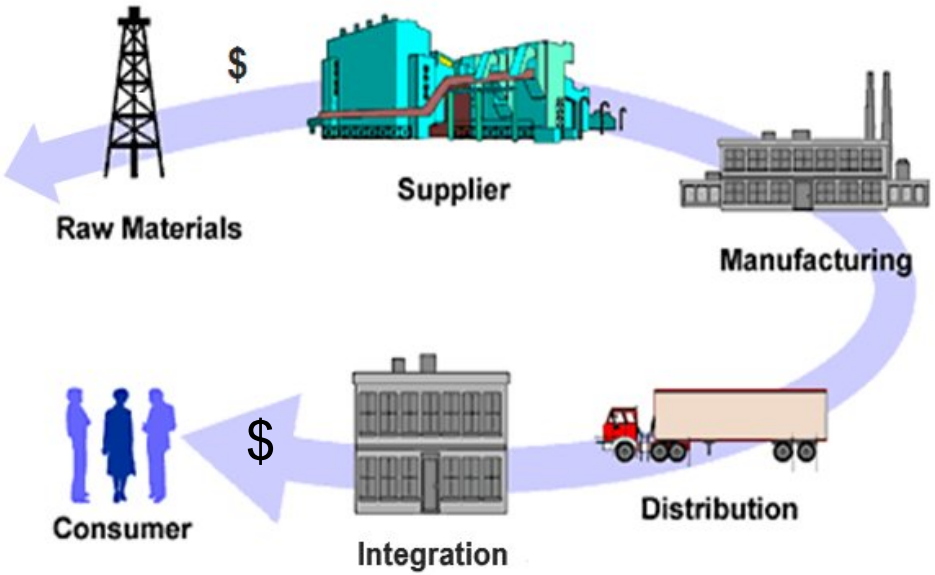


JOBS tools are based on input-output methodology and associated assumptions

- JOBS FC and JOBS H2 are **spreadsheet** tools that estimate economic impacts based on **user-specified scenarios**
- Economic impacts from **major activities:**
  - Manufacturing, deploying and operating fuel cells (FCs)
  - Constructing fueling infrastructure to operate FCs
  - Producing fuel to power FCs
- **User inputs**:
  - Geographic region of interest
  - Number, capacity and type of fuel cells manufactured
  - Number of FCs imported to or exported from region
- **Default values** (in lieu of user inputs) based on stakeholder input and published literature
- **Input-output analysis**: tracks flow of dollars spent on activities into economic impacts in the economy including ripple effects (re-spending)
- Economic impacts based on relationships between employment and materials used in industries associated with expenditures, as determined by RIMS Input-Output model



Gross Job-years **Displaced Job-years** **= Net Job-years**



1 Job-Year = 1 year of work for one person
NOT census count

Jobs are created at each stage in H2 and FC production, installation, infrastructure construction, O&M, and fuel supply chains (**direct + indirect jobs**), as well as from ripple effects (**induced jobs**). Economic benefits flow in both directions within supply chains.

JOBS FC models expenditure flows through FC supply chain

Courtesy of Ballard Power Systems.

Fuel Cell Application Cost Breakdown

- FC Fueling
  - Reforming
  - Fueling Equipment
  - Fuel Storage
- FC O&M
  - Maintenance
  - Operating Labor
- FC Manufacturing
  - Facility Cost
    - Building and Structures
      - materials
      - labor
      - equipment
    - Machinery and Tooling
    - Land
  - Production Costs
    - Stack
      - MEA
        - electrodes
        - electrolyte membrane
        - GDL
        - catalyst
        - labor
      - Bipolar Plates
      - End Plates
      - Tie rods
      - Current Collectors
      - Gaskets
      - Manifolds
      - Labor
    - BOP
    - System Assembly Labor
    - Utilities
    - General Expenses
  - Testing
  - Packing
- FC Shipping
  - Modal Costs
    - Rail
    - Truck
  - Handling
- FC Installation
  - Site Preparation
  - Infrastructure
    - Transportation Access
    - Utilities
    - Buildings
  - Electrical
    - On-Site Power
    - Grid Connection

Unit Capacity Assumptions	PEM (kW)	PAFC (kW)	MCFC (kW)
Class I/II Forklift	10		
Class III Forklift	2		
Backup Power	5		
Prime Power (with CHP)		400	1400

JOBS H2 models expenditure flows for retail H2 stations

Dispensing Assumptions	Delivered GH2	Delivered LH2
350 bar	200, 500 kg/d	200, 500 kg/d
700 bar	200, 500 kg/d	200, 500 kg/d

H2 Station Cost Breakdown, LH2, 700 bar

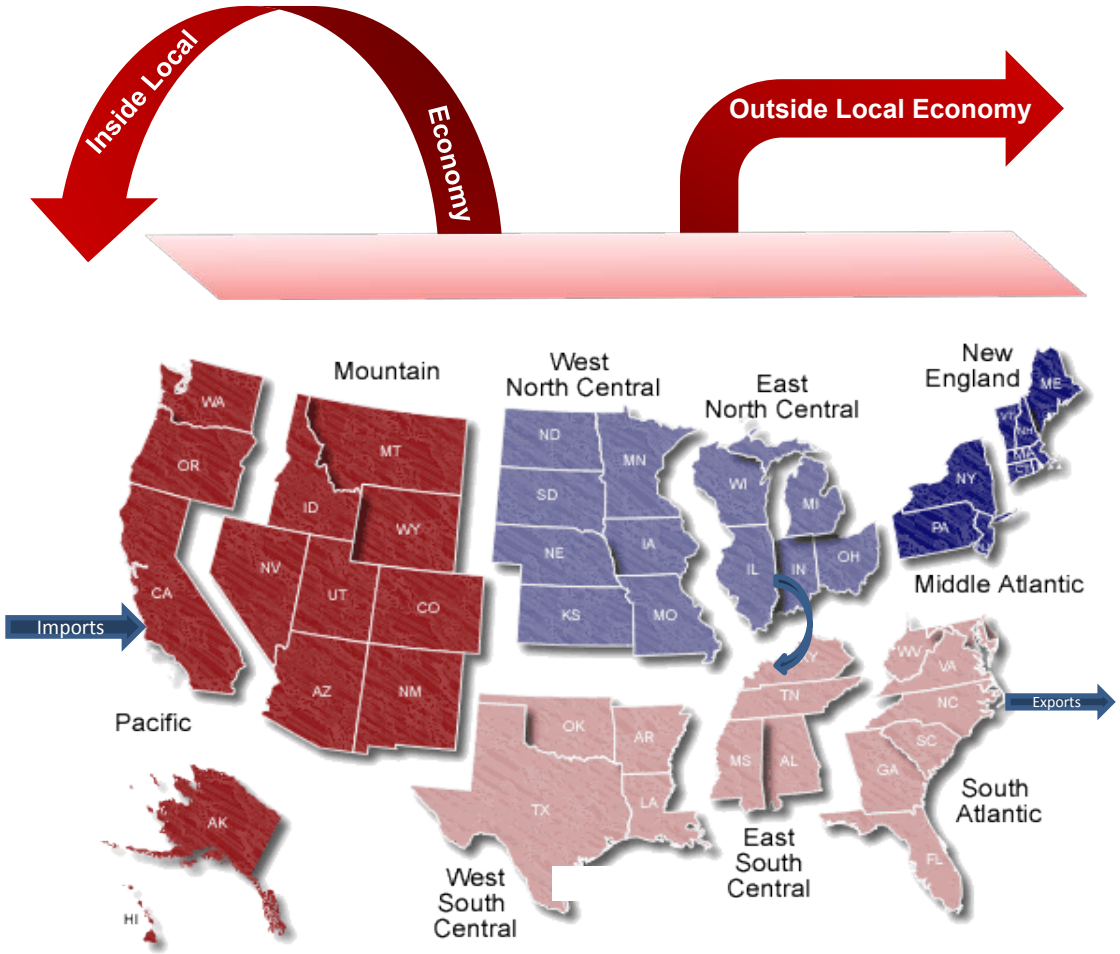
- **Hydrogen Fuel**
  - Hydrogen Production
  - Hydrogen Liquefaction
    - Fuel/Utilities
    - Liquefiers
    - Pressure Vessels
  - Bulk LH2 Storage
    - Cryogenic Tanks
  - LH2 Transport

- **LH2 Station Component Manufacturing**
  - Production Costs
    - Liquid Storage Tanks
    - Pumps
    - Evaporators
    - Compressors
    - Cascade Systems
      - Tanks
      - Manifolds
      - Sensors/Controls
      - Valves
    - Cooling
    - Dispensers
      - Hoses
      - Nozzles
      - Controls
      - Card Reader
    - Balance of Plant
      - Pipe
      - Sensors
    - System Assembly Labor
    - Utilities
    - General Expenses
  - Testing

- **LH2 Station Component Shipping**
  - Packing/Handling
  - Modal Costs
    - Rail
    - Truck
- **LH2 Station Components O&M**
  - Maintenance
  - Operating Labor
  - Fuel/Utilities

JOBS tools facilitate regional impact analyses

Jobs occur where expenditures occur. Local manufacturing, installation and use create the most jobs.



Map by the Indiana Business Research Center, Kelley School of Business, Indiana University

- JOBS models use RIMS multipliers for 60 different geographies to account for geographic variation
- In **JOBS FC** jobs are created from imported or exported fuel cells
- **JOBS H2** adds local shares for production of fuel & fueling equipment, installation, O&M, etc. to better account for local economic development efforts
- Key metrics:
  - Economic output = Σ goods + services produced over time
  - Earnings = Σ wages + salaries + proprietor's income over time
  - Employment = Σ jobs held by workers over time (job-years, not census)

FY 2013 Accomplishments

Due date	Milestone	Current Status
12/12	**JOBS FC 1.1**	**Complete**
12/12	Preliminary ARRA Analysis	Complete
4/13	**Draft Final ARRA Analysis Report**	**Complete**
9/13	**JOBS H2 LH2 Module Webinar and Beta Test**	**25%**
12/13	JOBS Analysis Report	15%
12/13	JOBS H2 1.0 Launch	20%

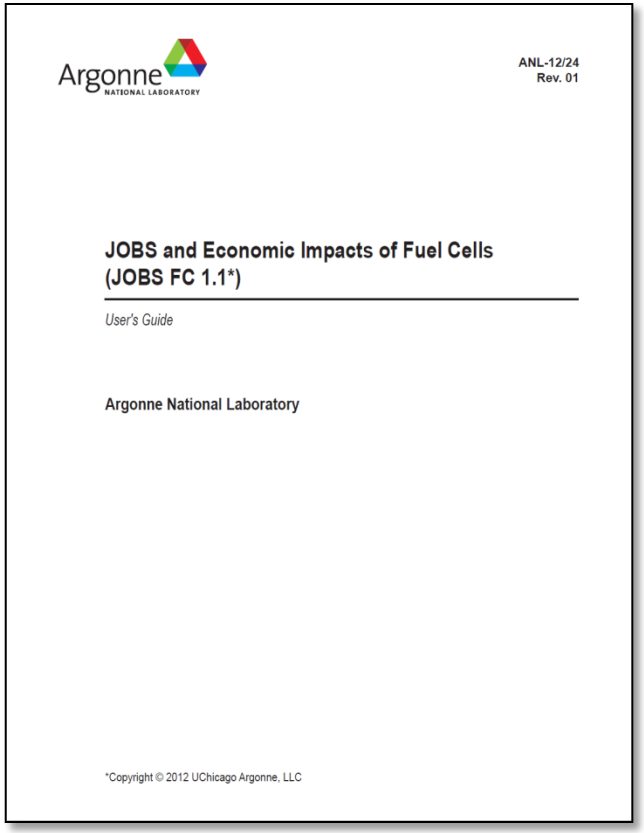
JOBS FC 1.1 launched Dec. 2012

Products:

- JOBS FC 1.1 and Updated Users' Guide
- http://JOBSFC.es.anl.gov website
- JOBS FC 1.1 EERE webinar 12/11/12 (http://www1.eere.energy.gov/hydrogenandfuelcells/webinar_archives_2012.html#date121112)

Enhancements:

- Added manufacturing facility construction module for prime power FCs
- Revised PAFC and MCFC component cost breakdowns and supply chain linkages
- Revised prime power cost estimates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ANL-12/24
Rev. 01

JOBS and Economic Impacts of Fuel Cells
(JOBS FC 1.1*)

User's Guide

Argonne National Laboratory

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JOBS FC 1.1 captures impact of building manufacturing facility to produce FCs for prime power

* * * PRIME MANUFACTURING FACILITY CONSTRUCTION MODULE * * *

RESET - CLEAR ALL USER-SPECIFIED VALUES

REQUIRED USER INPUT FIELDS

Step 1 - Choose Region

Select State or Region	<Please select>

Step 2 - Annual Manufacturing Capacity

What is the maximium number of MWs that the new facility will be able to produce annually?

Enter Desired Annual Capacity	***User-specified value***	**Notes**	**Value used in model**
Desired annual production capacity (MWs)			-

Go to PRIME Facility RESULTS

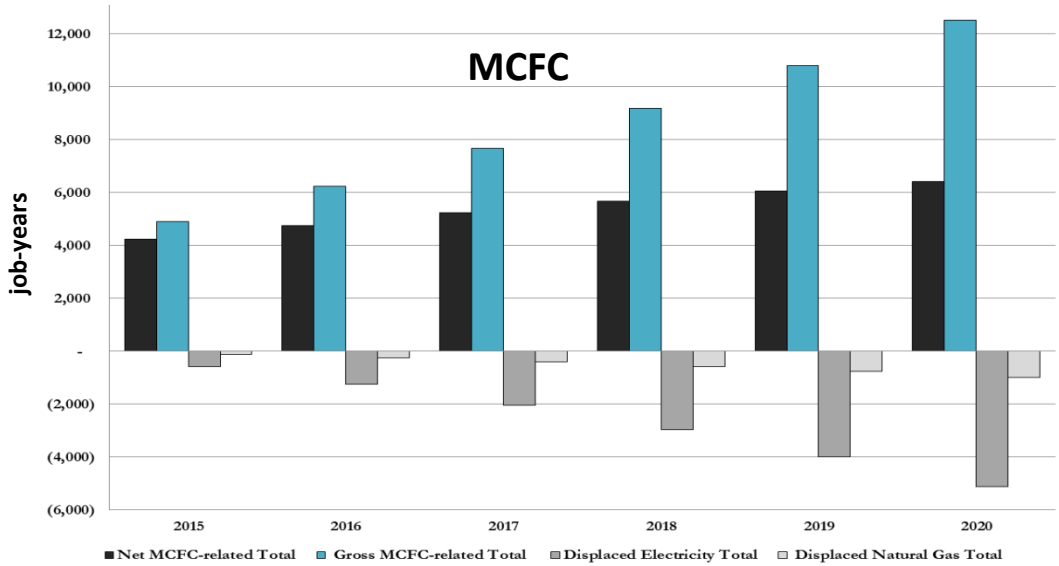
OPTIONAL USER INPUT FIELDS

All dollar values are in 2010$. All user-specified entries must be entered in 2010$.

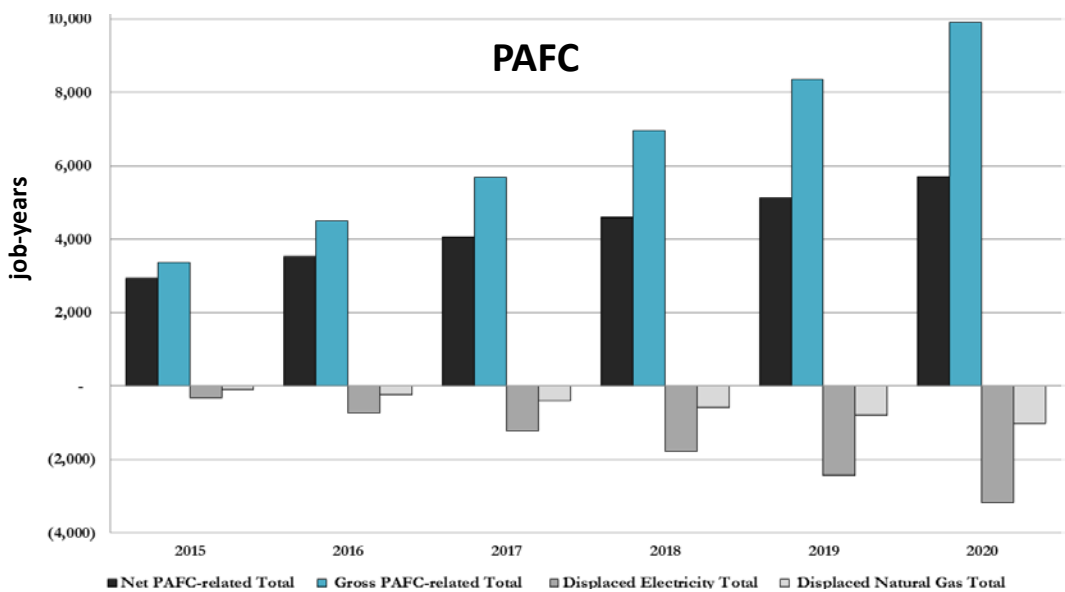
Step 3 - Facility Expenses (land, development, construction, equipment, etc.)

Enter Facility Expenses	***User-specified value***	**Default**	**Notes**	**Value used in model**
Land cost ($)		$171,800	**Land cost** is used to estimate **LTE** but does not impact output or	$171,800
Land transaction expenses (LTE) ($)		$10,300	other results. **LTE** are assumed to be 6% of **Land costs.**	$10,300
Site design and engineering ($)		$1,175,700	**Capacity** in Step 2 determines the default square footage and the	$1,175,700
Construction ($)		$4,702,800	default total equipment costs. $250/sq ft is the default cost for the sum	$4,702,800
Equipment ($)		$9,000,000	of **Site design** and **Construction** costs which is assumed to include	$9,000,000
Total	*Calculated value*	$15,060,600	installation of equipment.	$15,060,600

JOBS 1.1 reference scenarios show large potential job gains



Reference Scenario Assumptions	Prime Power	
	PAFC	MCFC
Capacity (kW)	400	1400
Installations: 2015	100	50
2016	125	60
2017	150	70
2018	175	80
2019	200	90
2020	225	100



Net job-years = gross – displaced

<u>Job displacement assumptions</u>:

- PEM: US-manufactured batteries and generator sets, diesel fuel, electricity
- PAFC: grid electricity, natural gas
- MCFC: grid electricity, natural gas

Analysis of employment impacts of ARRA FC deployment

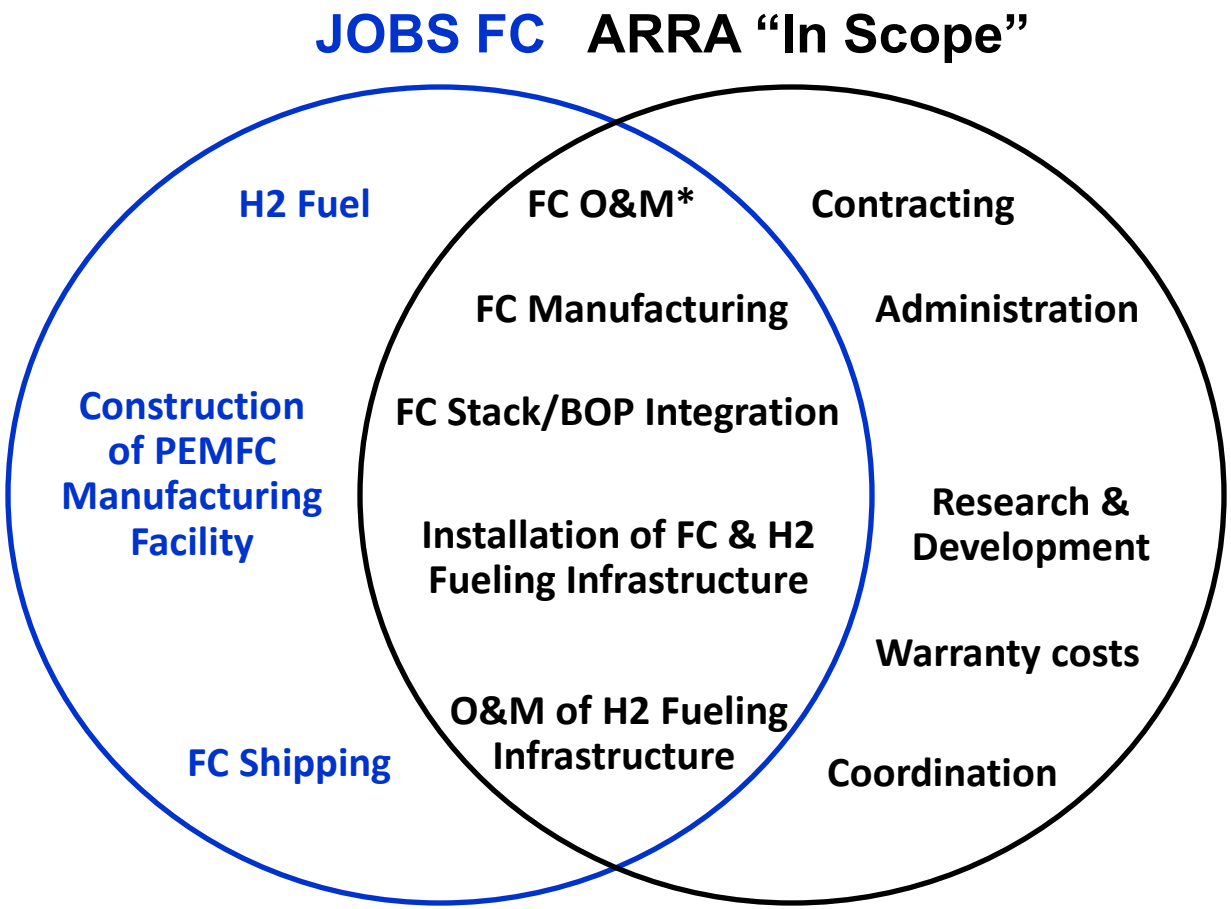
Key assumptions:

- All assembly, manufacturing, non-manufacturing, and associated labor to produce ***fuel cell systems*** occurred in the US
- The location (US or foreign) of assembly, manufacturing, non-manufacturing, and associated labor to produce ***fuel cell stacks*** and ***balance-of-plant (BOP)*** components varied with award
- Location assumptions based on input from stakeholders and other industry experts
- Import assumptions for indirect and induced impacts are embedded in RIMS multipliers

Expenditures (million $)	Forklift Projects	BUP Projects	Total
DOE	$9.7	$18.5	$28.2
Industry	$11.8	$30.8	$42.6
TOTAL	$21.5	$49.3	$70.8

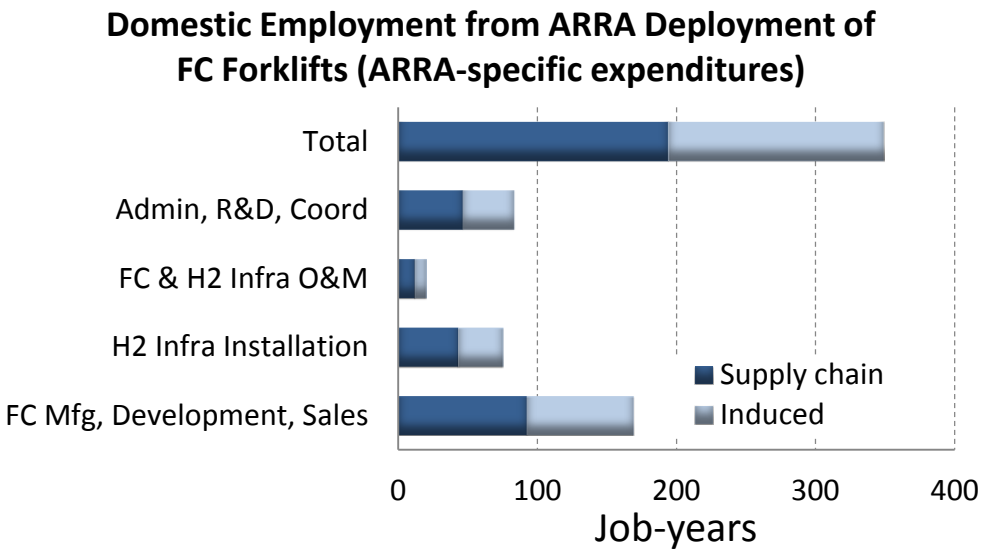
ARRA-Funded Fuel Cells	Forklifts		Cell Tower Backup Power
	Class I/II	Class III	
Units in operation, Dec. 2012	226	258	734
Ave. capacity (kW)	8	2	2.2
H2 fuel expense ($/FC/yr)	$2,750	$320	$62
Fuel infrastructure O&M ($/site/yr)	$27,000	$27,000	NA
FC O&M ($/unit/yr)	$1,600	$1,200	$450

JOBS FC & RIMS estimated impact of ARRA FC deployments



- "In scope" expenditures → **Total job-years** for production/installation of stacks, balance-of-plant, fueling infrastructure during time of ARRA projects
- "Out of scope" expenditures → **Annual job-years** for H2 fuel and O&M of fuel cell and hydrogen fueling infrastructure during and after ARRA projects

~1300 job-years created/retained during ARRA FC program

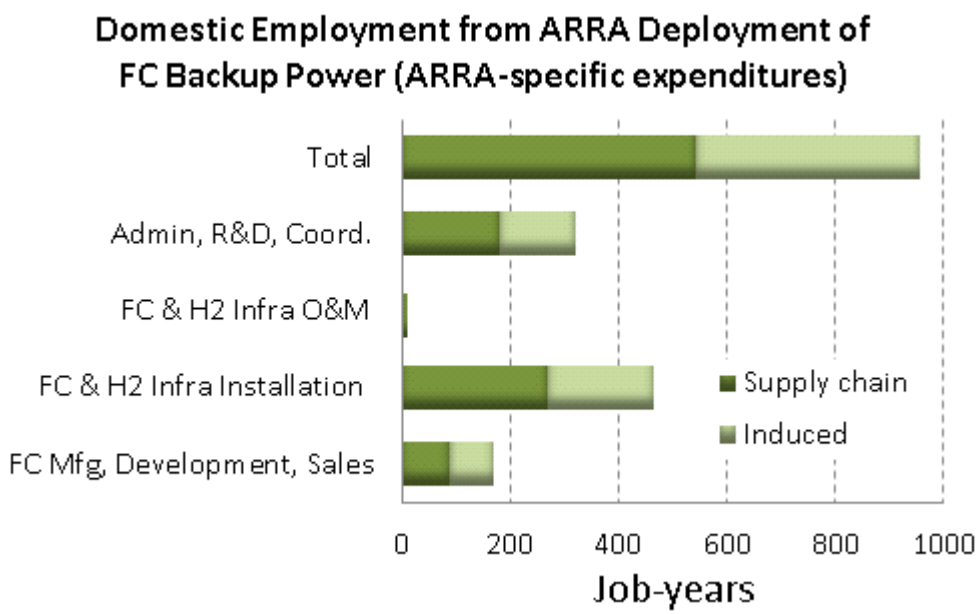


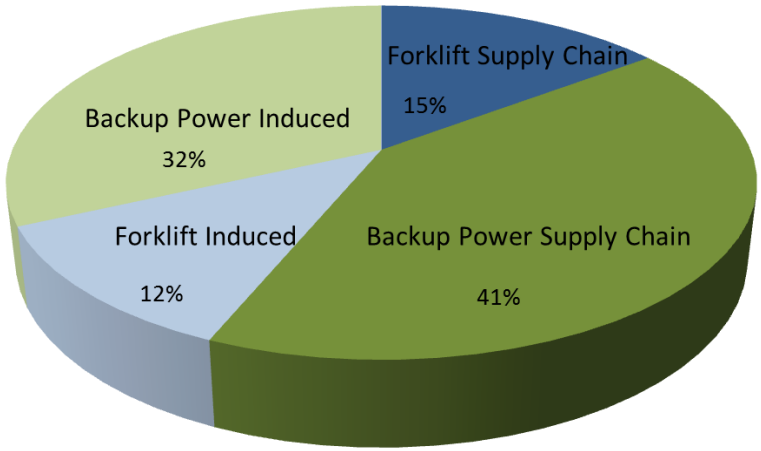
Forklift results:

- 350 total job-years created/retained
- ~50% from FC manufacturing, integration, sales
- Induced employment = 44 % forklift employment

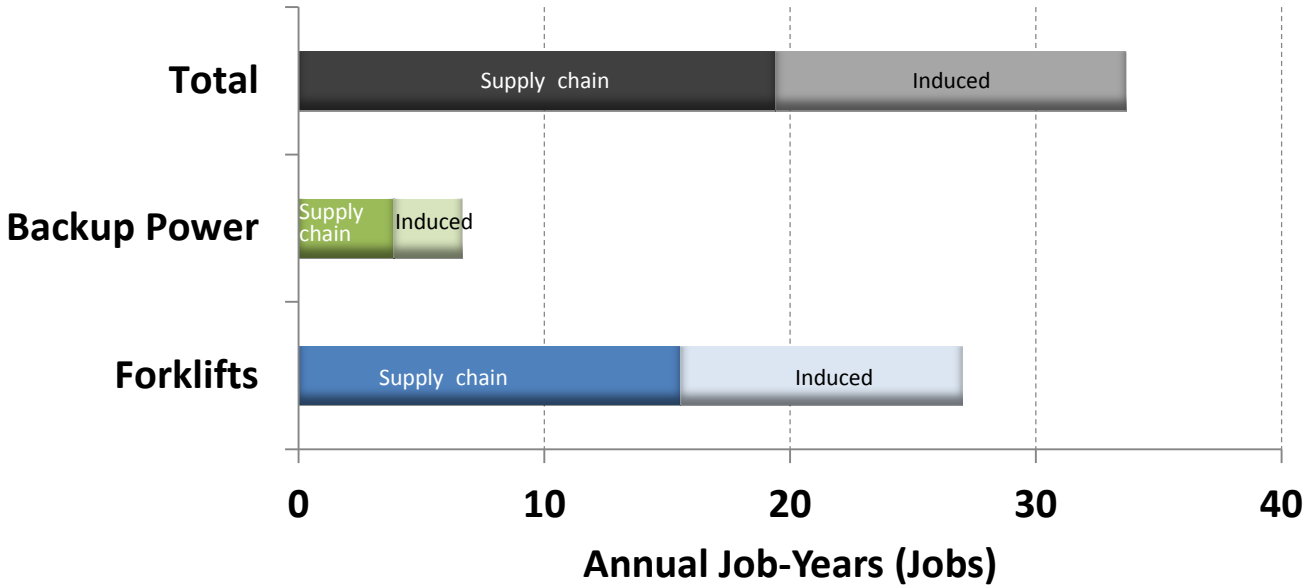
Backup power (BUP) results:

- ~ 950 total job-years created/retained
- ~ 45% from FC & H2 infrastructure installation
- Induced employment = 44% BUP employment
- BUP = 73% total ARRA-related FC employment





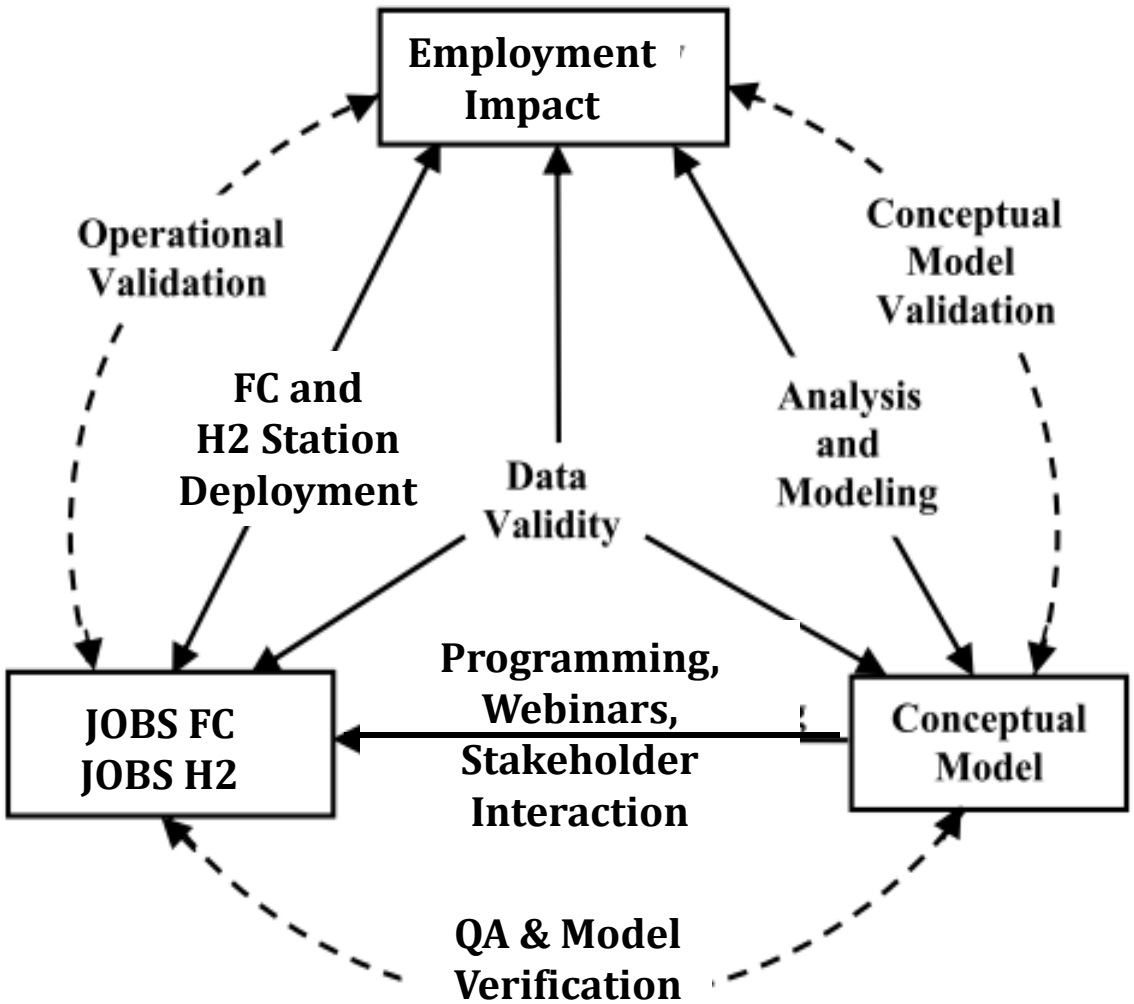
Continued operation of fuel cells deployed under ARRA generates ~35 additional jobs/year, mostly for forklift fueling



"Additional" annual jobs result from:

- "Out-of-scope" JOBS FC-based expenditures on fuel and infrastructure O&M
- JOBS FC estimates based on:
  - Industry estimates of delivered H2 cost, energy efficiency
  - NREL/CDP-based estimates of infrastructure O&M cost, utilization

Validating JOBS models is a continual, multi-faceted process



Structural Validation

- Are proper components being modeled?
- Are components properly linked?

Data Validation

- Are input data appropriately descriptive of components?
- Are input numbers representative?
- Does output data address appropriate issues?

JOBS H2 options: LH2 & GH2 delivery, 350 & 700 bar dispensing

HYDROGEN STATION CONSTRUCTION INPUTS

Steps 1-3 are required for a user to run an analysis. In these steps the user may choose the region and time period for analysis as well as the type, size, and quantity of stations which are to be constructed. Steps 4-6 allow the user to specify various expenditures associated with the station including equipment and shipping, site design, construction, and installation. Although not required, users are encouraged to at least carefully review all default values. Steps 7-8 allow the user to specify local share percentages for the different expenditure categories. Only the expenditures which occur in the region of interest will yield economic impacts in the region of interest. Users are strongly encouraged to carefully review these assumptions and adjust accordingly to most accurately estimate economic impacts for the selected region.

REQUIRED USER INPUT FIELDS

Step 1 - Choose Region and Starting Year for Analysis

Select State or Region	USA-National
Enter starting year of analysis	2014

Step 2 - Hydrogen Station Design

Category	*User-specified value*	Default	Notes		Value used in model
Station capacity (kg/day)		500			500
Delivered fuel type	Gaseous	Liquid			Gaseous
Dispensing pressure (psi)		5,000			5,000

Step 3 - Number of Stations Constructed

Enter Number of Stations	*User-specified value*	Default	Notes		Value used in model
2014		-			-
2015		-			-
2016		-			-
2017		-			-
2018		-			-
2019		-			-
2020		-			-
2021		-			-
2022		-			-
2023		-			-

STATION CONSTRUCTION RELATED EXPENSES

Step 4 - Station Equipment Prices and Quantities

	Equipment Expense ($/unit)	Equipment Quantity (units/station)	Equipment Expense ($/unit)	Equipment Quantity (units/station)	Equipment Expense ($/unit)	Equipment Quantity (units/station)
	User-specified value	*User-specified value*	Default	Default	Value used in model	Value used in model

Stakeholders are key collaborators for JOBS FC & JOBS H2 peer review, data collection/validation & beta testing

Public Agencies:

- **South Carolina Hydrogen and Fuel Cell Alliance**
- California Stationary Fuel Cell Consortium
- **Connecticut Center for Advanced Technology**
- Ohio Fuel Cell Coalition
- NYSERDA
- Clean Energy States Alliance
- **California Fuel Cell Partnership**
- Virginia Clean Cities
- **South Coast AQMD**

Trade Associations:

- FCHEA
- Fuel Cells 2000

Customers:

- Sprint-Nextel
- Metro PCS
- Whole Foods
- Sierra Nevada

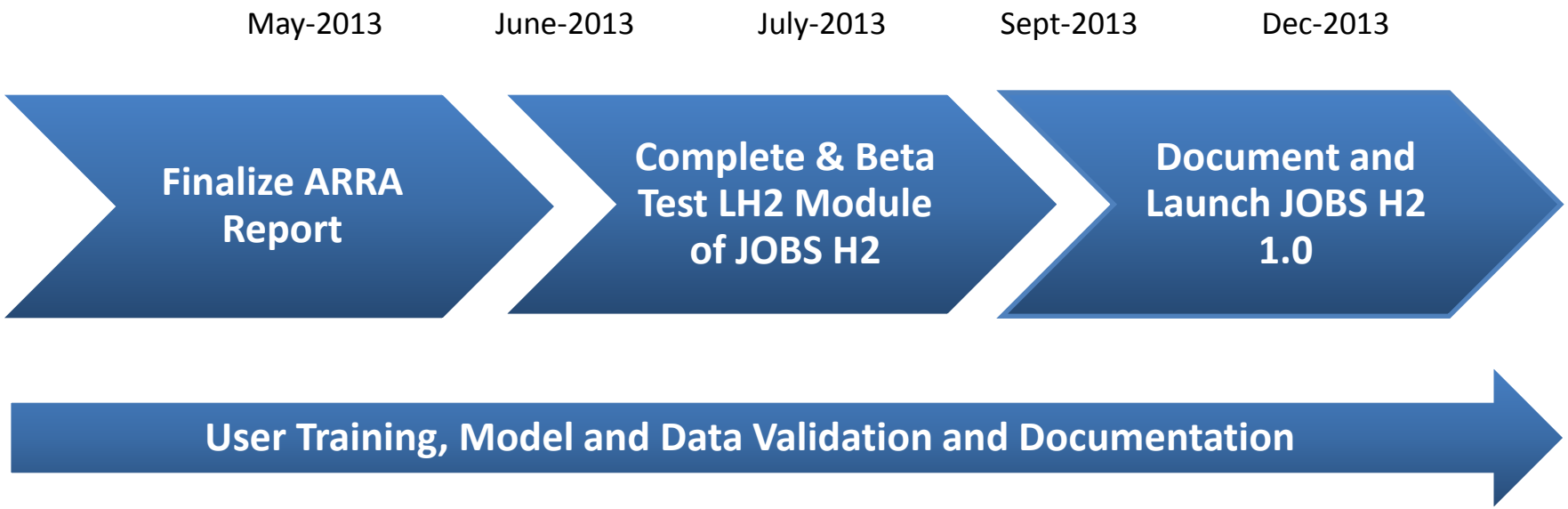
Researchers:

- ORNL
- **NREL**
- **ANL/PNNL**
- Battelle
- LBL
- SNL
- **Strategic Analysis**

Suppliers:

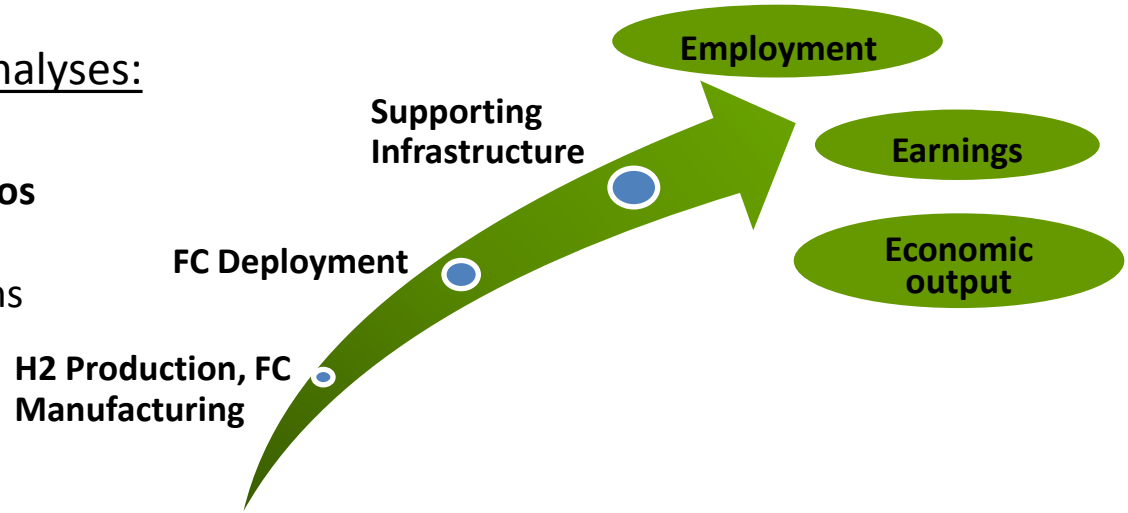
- PlugPower
- ReliOn
- Idatech
- UTC Power
- Fuel Cell Energy
- Ballard
- **Linde**
- **Pdc Machines**
- **Hexagon-Lincoln**
- **Etc.**

Tool expansion & analysis is focus of FY 2013 and beyond



Future model expansions/analyses:

- **JOBS H2 1.1 (GH2)**
- **H2 station rollout scenarios**
- Novel H2 station options
- Transportation applications
- SOFC, HT PEMFC
- CHHP



Summary

- **Relevance:** Provide a consistent platform to analyze employment and other economic impacts of alternative hydrogen and fuel cell investments. Assist DOE and stakeholders with data acquisition/validation and analysis to estimate economic impact of deploying FCs and hydrogen infrastructure in early markets.
- **Approach:** Use input-output economic modeling within the context of user-friendly tools to calculate supply chain and induced employment, earnings and economic output.
- **Collaborations**: Active partnership between ANL & RCF. Extensive stakeholder interaction.
- **Technical accomplishments and progress:**
  - JOBS FC 1.1 with updated MCFC and PAFC costs and supply chains, and new capability to estimate economic impact of prime power manufacturing facility construction.
  - Webinars (JOBS FC 1.0 and 1.1 launch), Users Guide and website (http://JOBSFC.es.anl.gov).
  - Employment impacts of ARRA-funded FC deployments for forklift and backup power.
  - Formulated and initiated model validation process.
- **Future research**:
  - Complete JOBS H2 and conduct web-based launch and user training.
  - Continue to validate and refine FC and H2 infrastructure operational and economic defaults.
  - Analyze H2 station rollout scenarios and alternative station options.
  - Add transportation applications, high temperature PEMFCs and SOFCs, CHHP.