# Status and Prospects of the N.A. Non-automotive fuel cell industry: 2014 Update

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

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# Overview

## Timeline and Budget

- Project Start Date: 10/1/2013
- FY14 DOE Funding: $50,000
- FY15 Planned DOE Funding: $50,000
- Total DOE Funds Received to Date: $50,000

**Market and Policy Analysis:**
Assess opportunities and needs for diverse applications of fuel cells, including the potential for job growth, workforce development needs, manufacturing capacity, and the effects of a federal fuel cell acquisition program on fuel cell costs and market sustainability.

## Barriers

- **Future Market Behavior**
- **Insufficient Suite of Models and Tools**: Model validation is required to ensure credible analytical results are produced from the suite of modeling tools
- **Unplanned Studies and Analysis**

## Partners

- HD Systems
- ANL
- ORNL
- UT Dept. Industrial Eng.
- Fuel Cell OEMs
- Fuel Cell Customers

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# Our project’s objective is to contribute to the formulation of effective and efficient policies for deployment of fuel cell technologies and development of a sustainable fuel cell industry.

Assess the impacts of ARRA deployments on the Fuel Cell Backup Power (BuP) and Material Handling Equipment (MHE) industries.

- Estimate impacts on scale economies and learning-by-doing.
- Estimate additional sales induced by ARRA deployments.

Re-assess the effects of key policies on the sustainability of the non-automotive (PEM) fuel cell industry in North America.

- Estimate effects of the Investment Tax Credit and its potential termination after 2016.
- Estimate effects of extending the ITC via a phasing-out by 2022.

**Market and Policy Analysis:**
Assess opportunities and needs for diverse applications of fuel cells, including the potential for job growth, workforce development needs, manufacturing capacity, and the effects of a federal fuel cell acquisition program on fuel cell costs and market sustainability

# "Think probabilistically."
# "Know where you are coming from."
# "Try, and err."

Nate Silver, *The Signal and the Noise*, "Conclusion", Penguin Books, London, 2012.

The first step was to gather information about developments since 2011.

- Interviews with fuel cell OEMs
- Published peer-reviewed and gray literature and annual reports
- Small-sample survey of customers (not complete as of 4/10/2015)

Update and revise industry model

- Compare past predictions with recent history
- Revise cost estimates and key parameters
- Incorporate changes in industry model

Estimate additional effects of ARRA deployments

Estimate effects of extension of ITS and phase-out by 2022

**This project was not reviewed last year.**

# Method

The analysis uses the North American non-automotive fuel cell industry model described in Upreti et al. (2012) and Greene et al. (2011) cited in the publications slide.

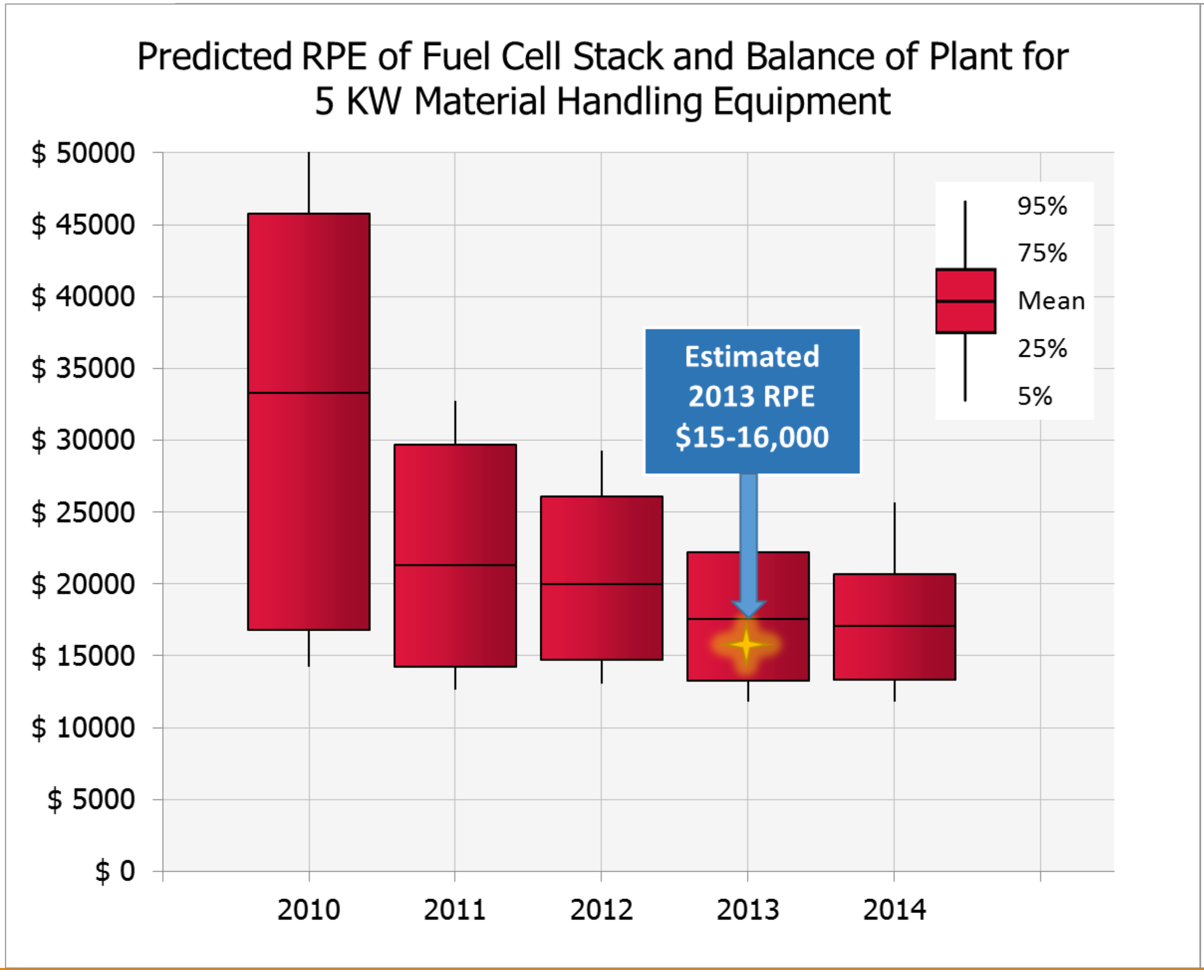
How to estimate the ARRA's additional impact?

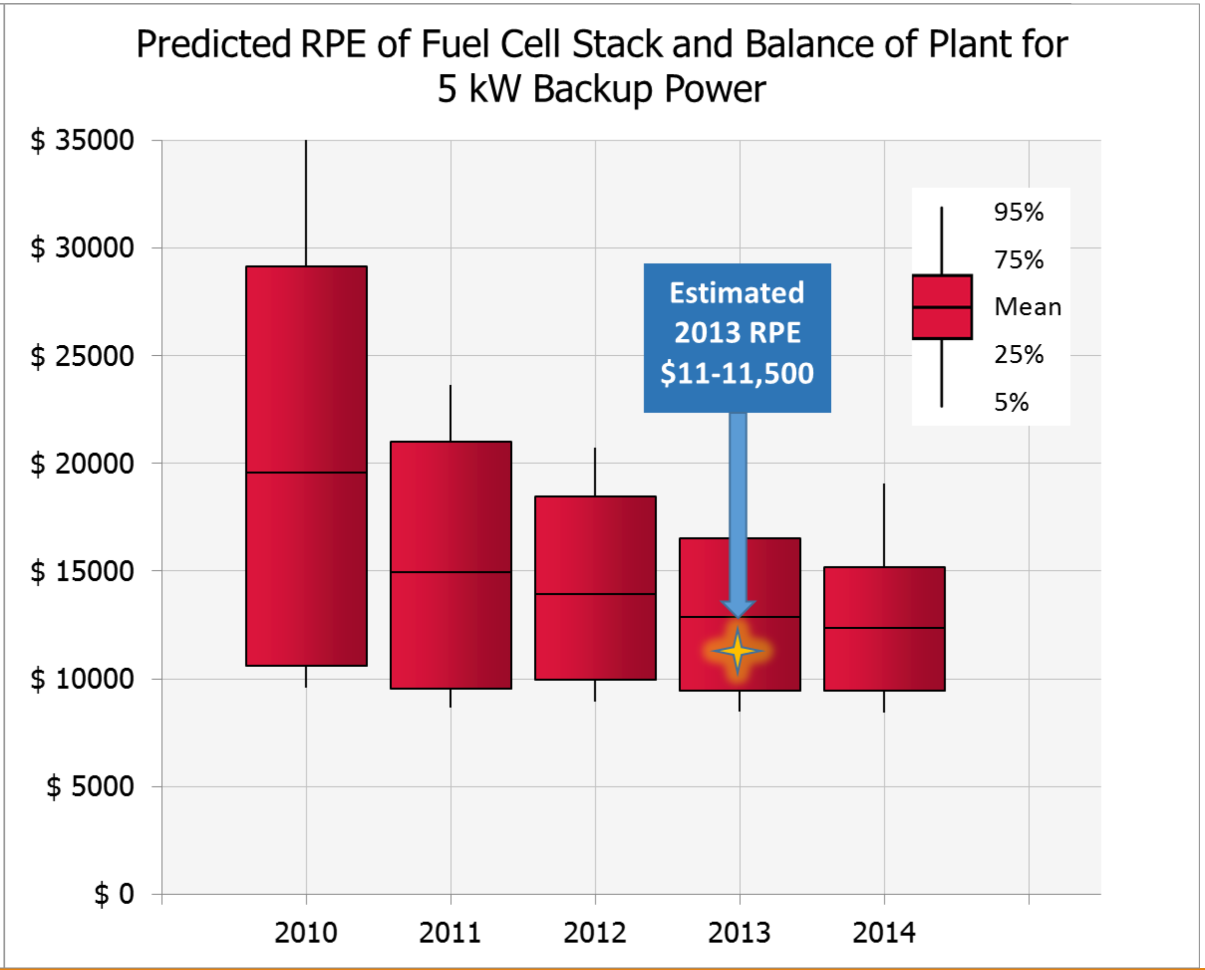
- Are there free riders?
- Is there a bandwagon effect?
- Did the ARRA prevent shut downs?

Although all of the effects are likely, we assumed none (or, offsetting effects).

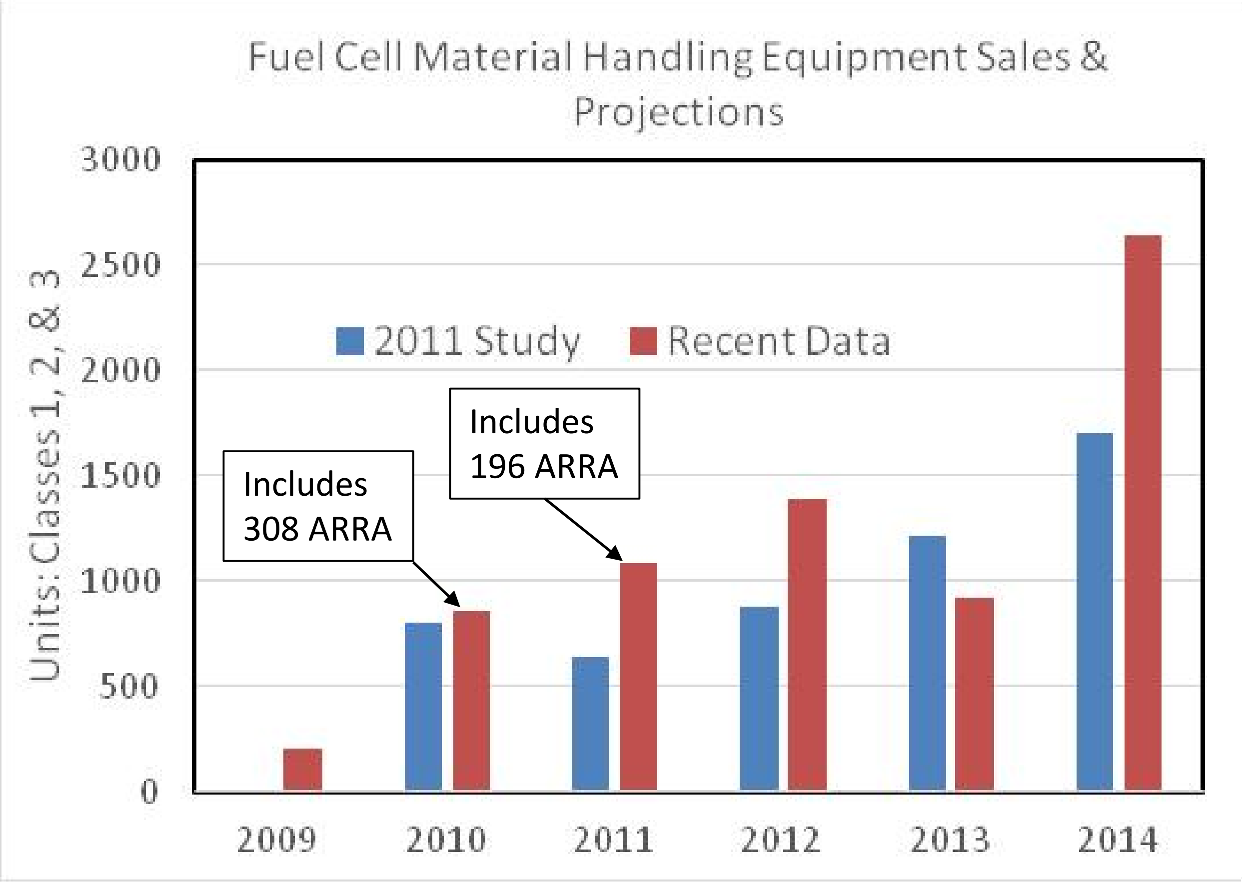
- Recalibrate choice model to exactly predict (Total Sales – ARRA Sales) *with ARRA sales included*.
- Assumes that, given the ARRA purchases, the market is responsible for the other sales.
- Subtract ARRA Sales
- Calculate change in current and future production costs through 2025
- Calculate losses of current and future sales through 2025

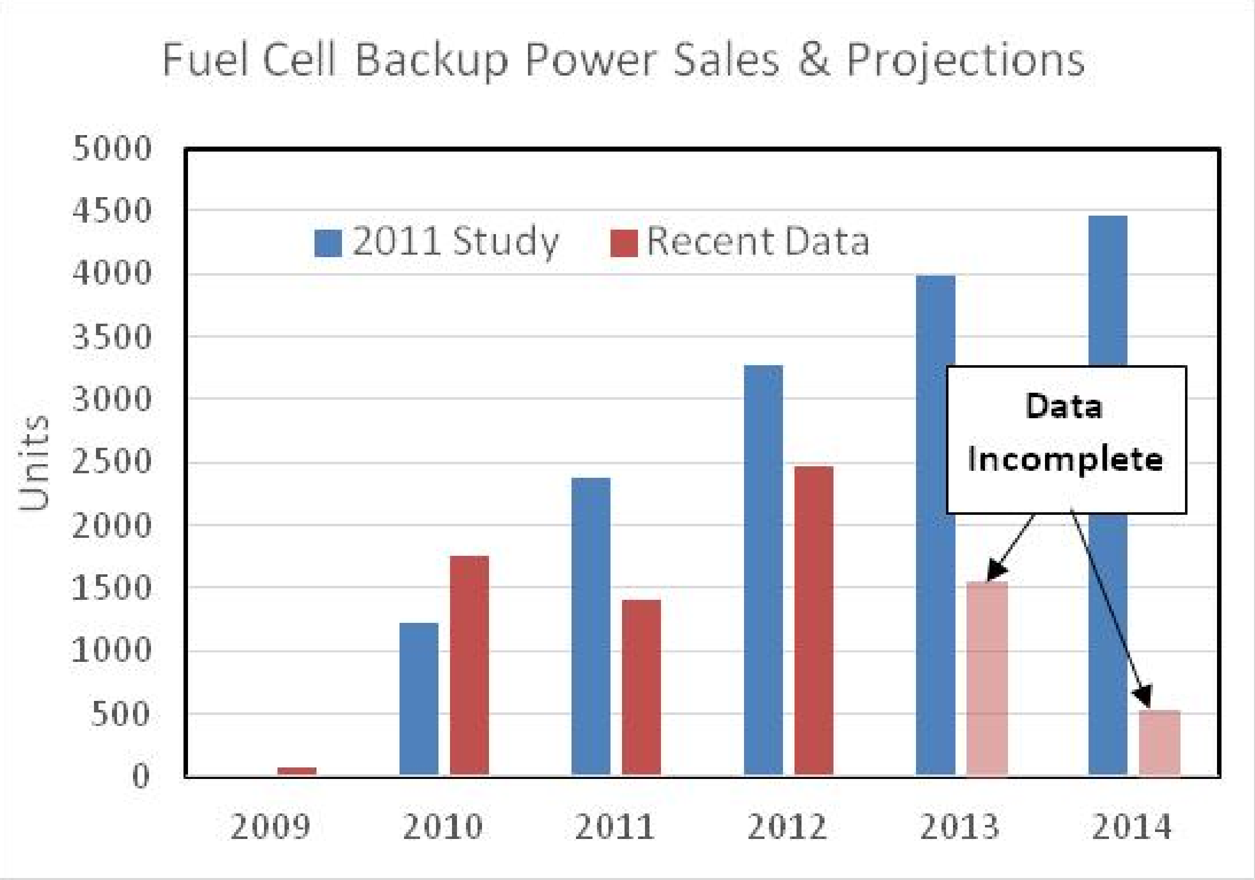
# The fuel cell BuP and MHE industries have made major progress in performance and cost.



# Sales projections for 2012-14 were reasonable for MHE but high for BuP. Sales data included ARRA sales and are also estimates based on publicly available information.



# Our estimates of scale economies were too high.

The 2011 study assumed uniform scale elasticities of -0.2 for both stacks and BoP, for MHE and BuP.

A ten-fold increase in production would reduce costs by 37%.

Discussions with OEMs indicates scale elasticities in the range of -0.07 to -0.1 for stacks.

Battelle's MHE cost analysis indicates that scale effects are different for stacks vs.BoP

- Stacks: 100 to 1,000 ε = -0.04; 1,000 to 10,000 ε = -0.07
- BoP: 100 to 1,000 ε = -0.11; 1,000 to 10,000 ε = -0.07

An analysis of 50 kW PEM backup power units by Berkeley Lab and U.C. Berkeley implies:

- 100 to 1,000 units: ε = -0.2
- 1,000 to 10,000 units: ε = -0.07
- 10,000 to 50,000 units: ε = -0.04

At a scale elasticity of -0.15 a ten-fold increase in production would reduce costs by only 29%

# On the other hand, our estimates of technological progress were too pessimistic.

We assumed a rate of cost reduction of 1%/year for PEM fuel cell stacks, in general.

We assumed a rate of technology-based cost reduction of 2%/year for MHE and Backup Power fuel cell systems.

For fuel cell stacks, OEMs estimate 10-15% per year cost reductions per product generation, with a new generation appearing every 3-5 years.

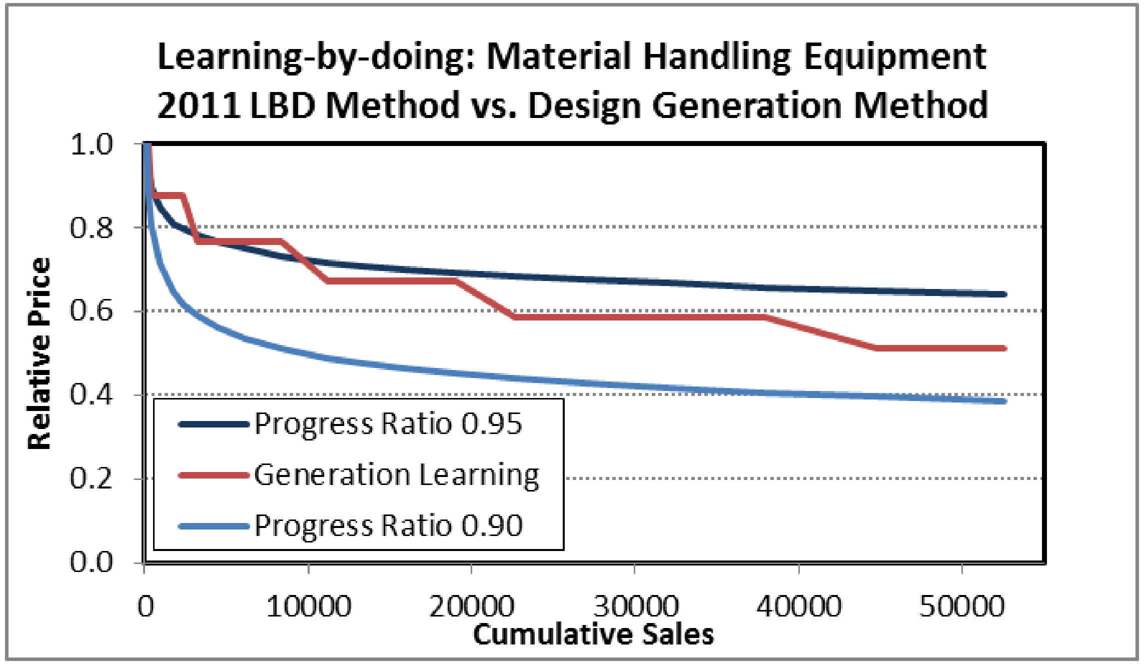
This implies annual progress at about 3% per year.

Technological progress for BoP is believed to be slower.

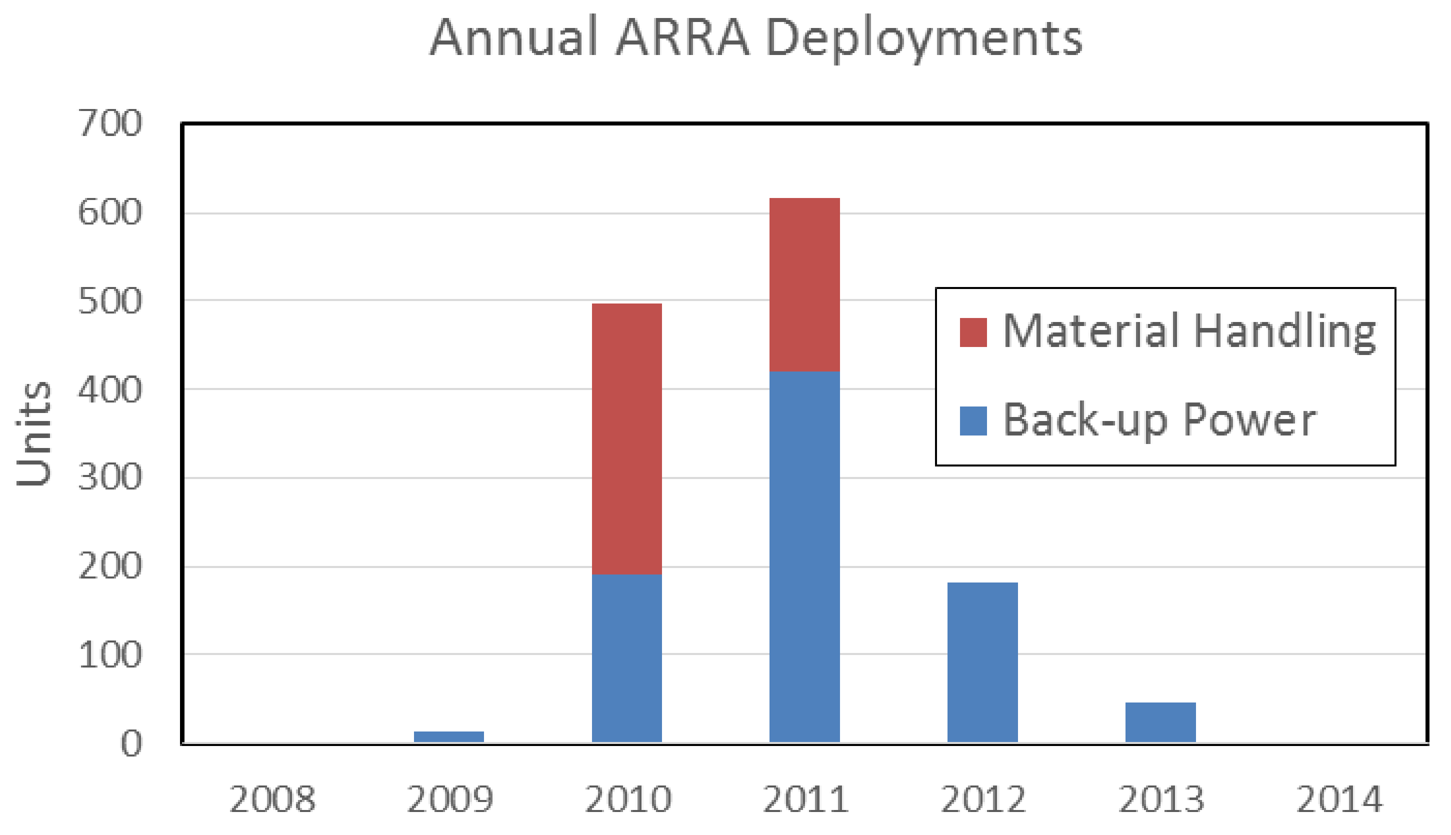
# Our learning rates also appear to have been be too fast.

Following the traditional learning-by-doing method, we assumed cost reduction was a function of cumulative volume: $P/P_0 = (Q/Q_0)^{\alpha}$ ; $\alpha = -0.15$ implying a Progress Ratio of 0.90.

OEMs see cost reduction as a step function. New generations are introduced every 35 years with cost reductions of 10-15% due to learning and 10-15% due to technological advances.

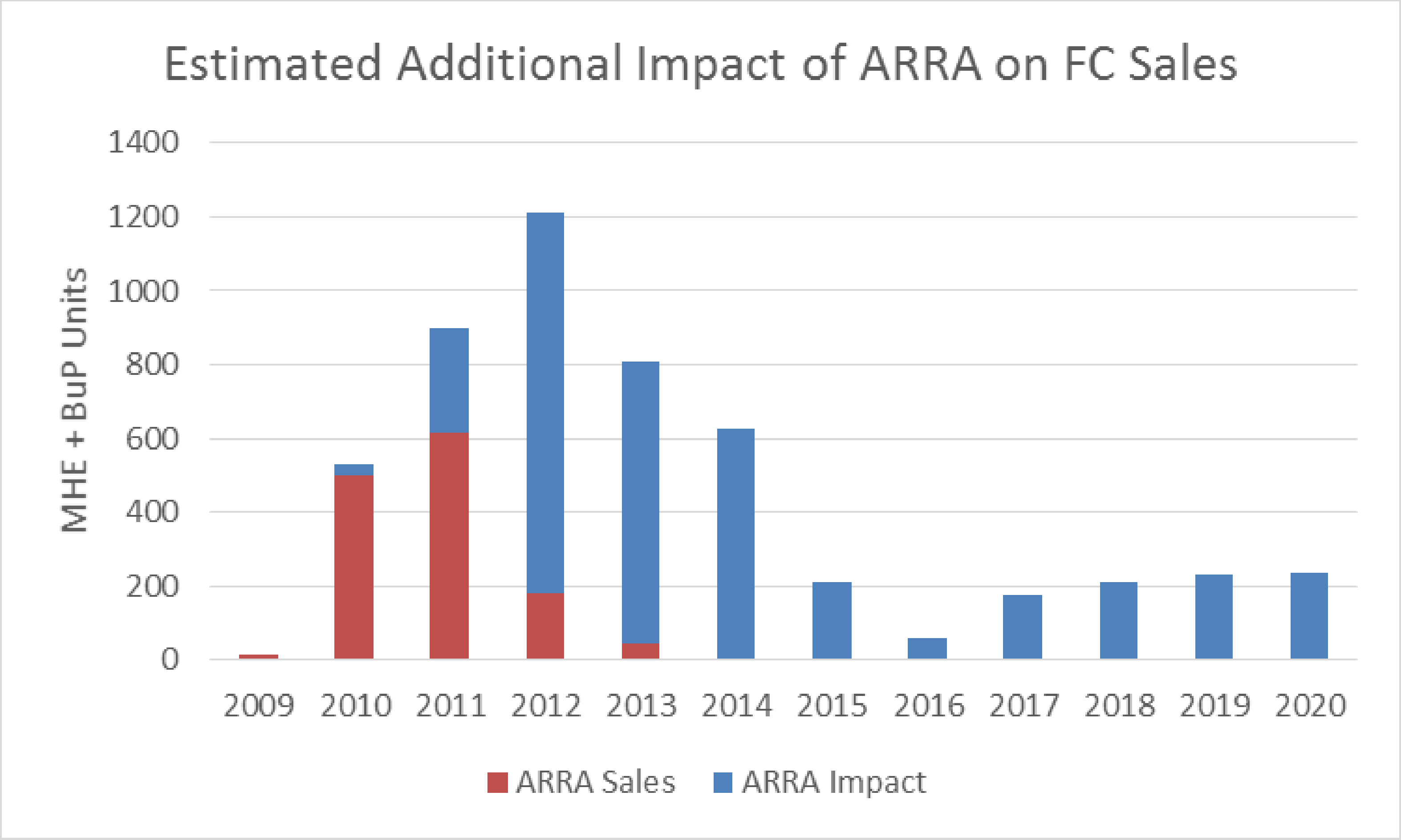


# ARRA-assisted purchases reduced costs via economies of scale and learning-by-doing *up to* an estimated $350 of *annualized cost* per unit for both BuP and MHE.

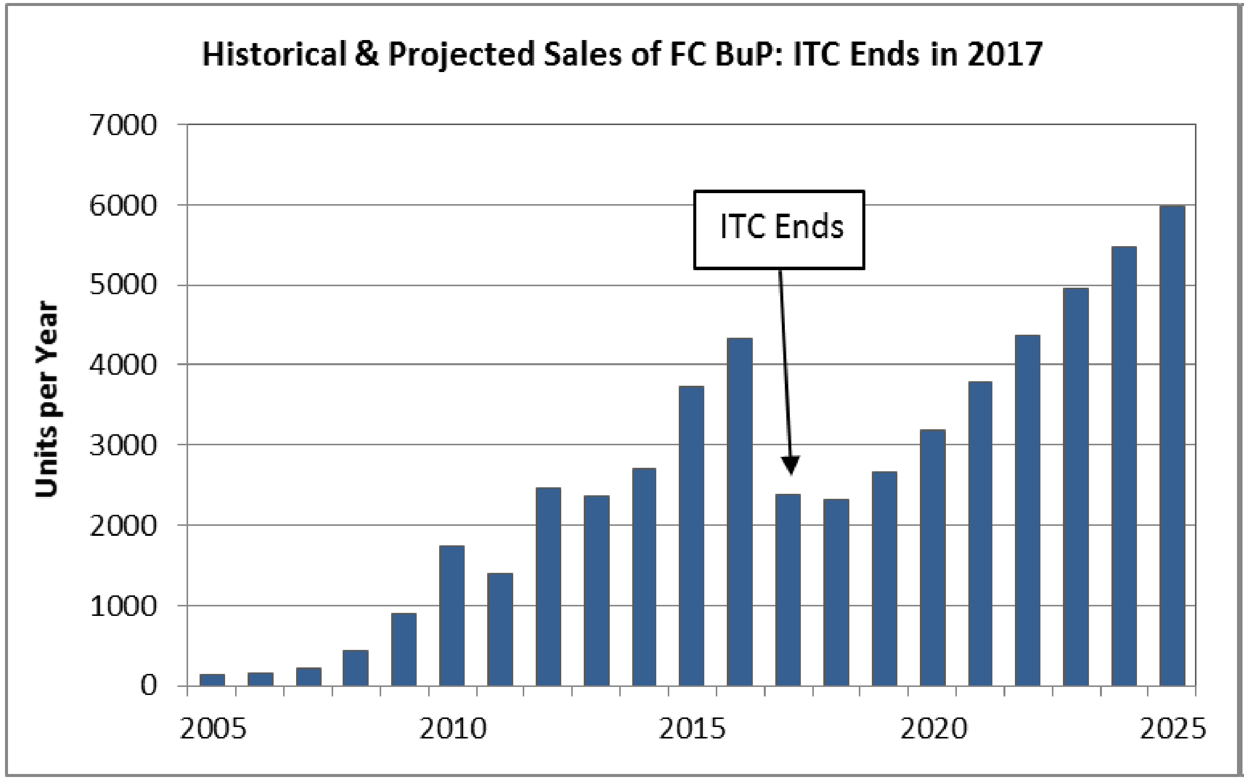


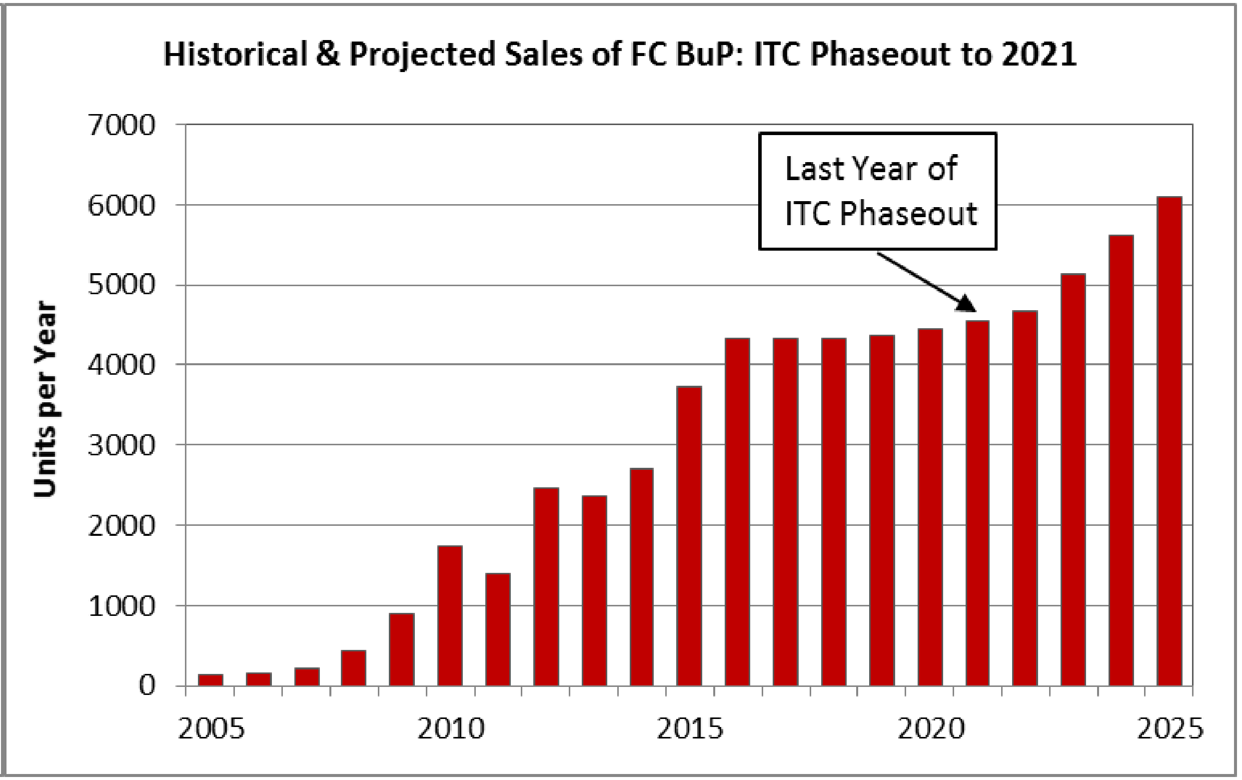

Sources: NREL/TP-5400-62130 & 62025, June 2014

# The 504 ARRA MHE deployments induce an estimated 1,500 additional sales and the 852 ARRA BuP deployments induce an estimated 3,000 additional BuP unit sales through 2025.

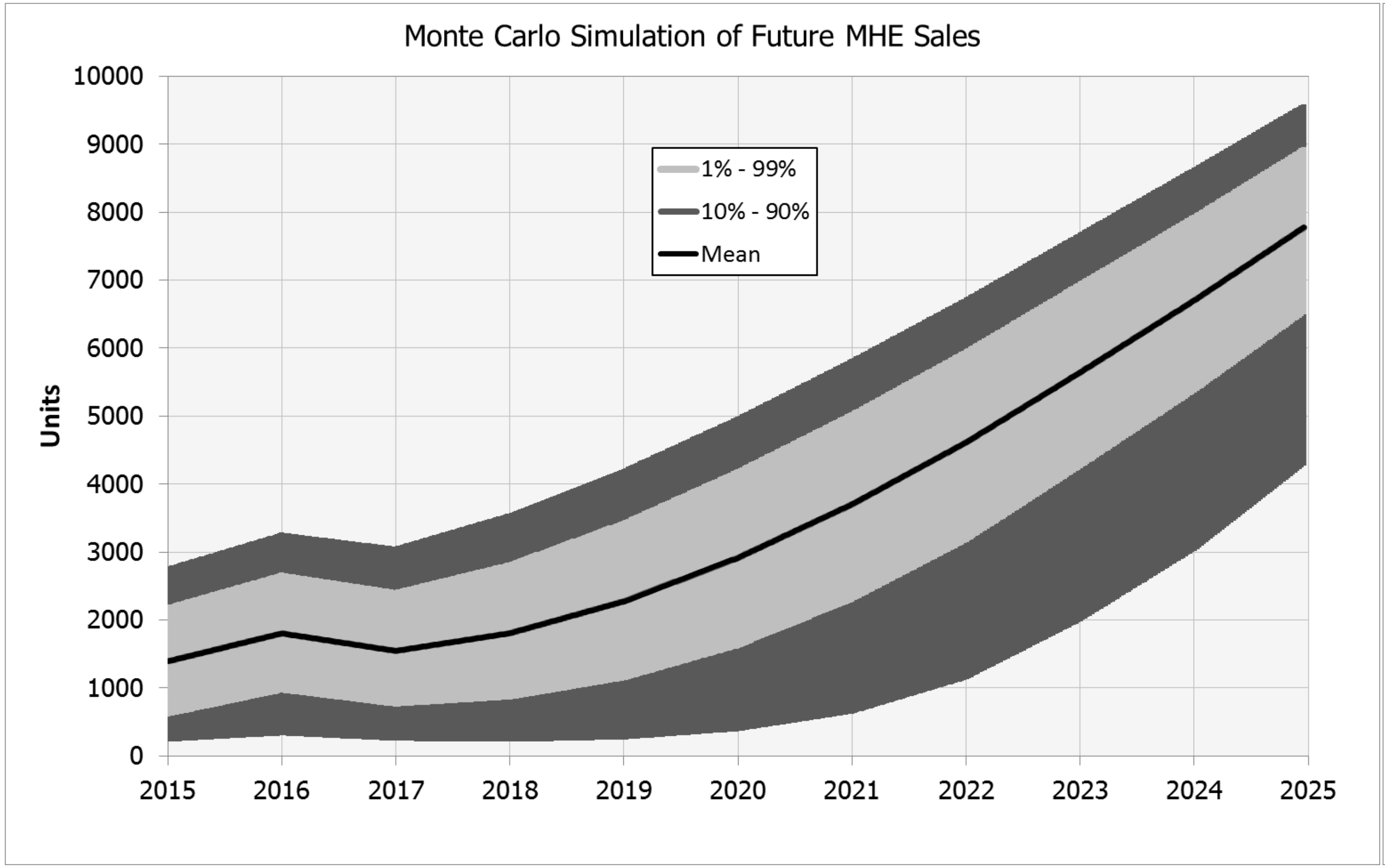


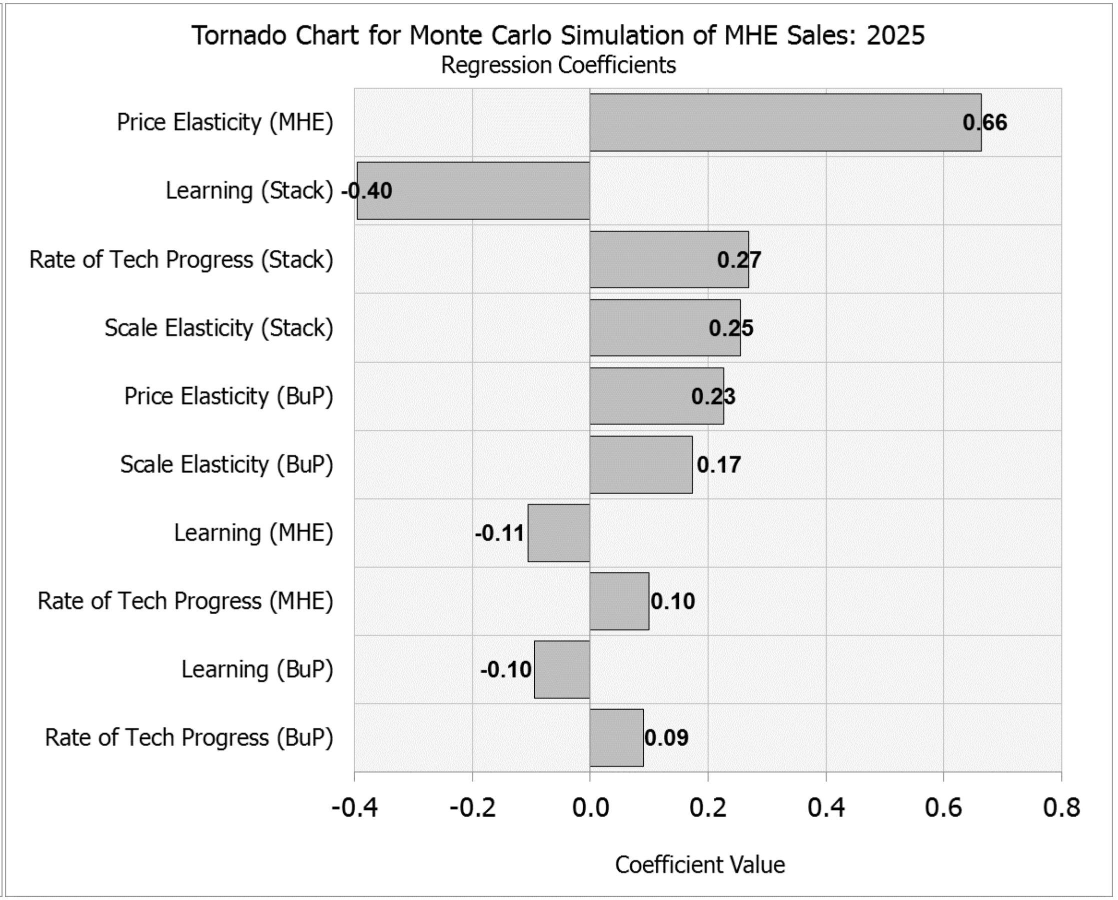
# Ending the ITC abruptly after 2016 is likely to have a disruptive effect. A gradual phase out through 2021 would likely be less disruptive.



# The uncertainty in our projections is large.  Our Monte Carlo simulations do not fully describe it.



# This small project would not have been possible without the help of others.

OEMs provided shared their experience, data and insights.

- Ballard Power Systems
- Nuvera
- Altergy

K.G. Duleep: HD Systems (contractor to ORNL)

- Conducted interviews with OEMs alone and in collaboration with UT staff.

Girish Upreti: PhD candidate, Dept. of Industrial Engineering, U. of Tennessee

- Developing a more complete model with guidance from D. Greene.
- Shared data and literature review.
- Shared results of MHE customer survey.

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# Thanks to NREL, Battelle and others there is a great deal more data and analysis than in 2009-10. Still, important challenges remain.

Difficulty of acquiring accurate historical production data hinders model calibration.

Lack of data with which to calibrate customer choice model raises questions about model validation.

Greater market segmentation detail should also improve model accuracy.

Greater supply chain details would likely improve model accuracy.

Most importantly, adding a realistic representation of export markets and foreign competition would expand the analytical capabilities of the model.

# Our model is simple and could be improved in several ways.

Continue to make projections, re-assess and revise. ("Try, and err.")

More detailed market segmentation

- MHE classes 1,2 & 3; number of shifts/day, etc.
- Telecom towers 4G & later vs. earlier; location.

Improve demand side modeling

- Survey customers
- Econometric analysis

Add more realistic representation of global industry

- Export markets
- Foreign competition
- Global supply chain

Model shut down/acquisition decisions by OEMs

# For this project, technology transfer consists of publishing data, methods, model and results.

Publish Baker Center white paper.

Submit article to peer-reviewed journal.

Make model conveniently available to interested researchers.

# The non-automotive PEM fuel cell industry has come a long way in the four years since our 2011 study.

OEMs have achieved large reductions in cost and improvements in durability and performance.

The accuracy of our past projections has been mixed.

- Correctly estimated cost reductions in MHE, overestimated for BuP
- Learning-by-doing & scale economies overestimated
- Technological progress underestimated

The ARRA had substantial, beneficial effects on the viability of the MHE and BuP industries.

- Induced meaningful cost reductions via scale and learning effects
- Additionally induced sales equal to approximately 3X ARRA deployments

Continuation of the ITC beyond 2016, possibly with a phase-out to zero in 2022 may be important to insure continuity in market demand for the industry's products.