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Economic Impact of Fuel Cell Deployment in Forklifts and for Backup Power under the American Recovery and Reinvestment Act

Energy Systems Division

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TABLE OF CONTENTS

FIGURES

FIGURES (Cont.)

TABLES

TABLES (Cont.)

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SUMMARY

Through the American Recovery and Reinvestment Act (the Recovery Act or ARRA), the United States Department of Energy (DOE) funded several projects to deploy polymer electrolyte membrane (PEM) fuel cells in forklift and backup power applications. DOE invested $9.7 million to deploy fuel cells in forklifts and an additional $11.8 million was contributed through industry cost shares, for a total investment of $21.5 million in forklift projects. DOE invested $18.5 million to deploy fuel cells in backup power projects and an additional $30.8 million was contributed through industry cost shares, for a total investment of $49.3 million in backup power projects.

In the interest of evaluating the success of those projects, DOE's Fuel Cell Technologies (FCT) Office commissioned Argonne National Laboratory (Argonne) and RCF Economic and Financial Consultants (RCF) to estimate the economic impact of those investments. This report summarizes the results of that effort. It presents estimates of total employment, earnings, and economic output attributable to expenditures for fuel cell projects funded under the Recovery Act. Estimates were developed using the JOBS and economic impacts of Fuel Cells (JOBS FC) model, developed by Argonne/RCF for DOE's FCT Office, supplemented as needed with calculations that capture expenditures unique to the ARRA program that are not modeled in JOBS FC. Such ARRA-related expenditures included administrative expenses, coordination, and research, the effects of which were computed separately using Regional Input-Output Modeling System (RIMS) multipliers (which also underlie JOBS FC), and added to JOBS FC results. Economic impacts from private-sector expenditures for hydrogen fuel and maintenance following the conclusion of the ARRA-supported program were calculated separately and are presented on an annual basis.

Results indicate that ARRA-supported fuel cell deployments in forklift applications are associated with approximately 350 job-years of employment,[1] $16 million in earnings, and $57 million in economic output over the timeframe of the Recovery Act projects (2009–2012). Similarly, ARRA-funded fuel cell deployments in backup power projects are associated with approximately 960 job-years of employment, $44 million in earnings, and $142 million in economic output over the Recovery Act timeframe (2009–2012). These totals include direct, indirect, and induced effects. Direct effects arise from the production, installation, operation, and fueling of the fuel cells and associated infrastructure deployed under the program. Indirect effects arise from the production or sourcing of components and other inputs. The sum of direct

[1] A job-year is defined as one year of work for one person. Thus, for example, five job-years can be five years of work by one person, one year of work by five persons, or any person × year product equal to five. Since all economic calculations in the models used for this analysis assume a time dimension (generally one year), employment is also calculated on an annual (i.e., job-year) basis with an associated dollar value.

and indirect effects is referred to as the "industry supply chain" effect. Because of technical issues associated with distinguishing between in-house fabrication versus the assembly of outsourced components, direct and indirect effects are often reported under the broader category of "industry supply chain" effects, a convention that is followed in this analysis. Induced or "ripple" effects occur as a result of the re-spending of dollars in the economy and are reported separately in this analysis.

The additional economic impacts (not covered by Recovery Act funding) attributable to the continued operation of the forklift fuel cells and associated hydrogen fueling infrastructure deployed under the ARRA program (i.e., impacts associated with fuel and maintenance expenditures both during and after completion of the program) are estimated to produce approximately 27 job-years, $1.2 million in earnings, and $4.2 million in economic output annually. The additional economic impacts (not covered by ARRA funding) associated with continued operation of the backup power fuel cells deployed with Recovery Act funds (i.e., those associated with fuel and maintenance expenditures both during and after completion of the program) are estimated to yield approximately 7 job-years, $0.3 million in earnings, and $0.9 million in economic output annually. Again, these totals include industry supply chain (i.e., direct + indirect) and induced effects of the program.

In all, the $70.8 million of total ARRA-related expenditures considered in this study generated or supported approximately 1,300 job-years of employment, which is over 18 job-years per million dollars (2010$), or $54,000 per job-year.

1 INTRODUCTION

This report presents estimates of economic impacts associated with expenditures under the American Recovery and Reinvestment Act (ARRA), also known as the Recovery Act, by the United States Department of Energy (DOE) for the deployment of fuel cells in forklift and backup power applications. Under ARRA, DOE invested $9.7 million and industry contributed an additional $11.8 million, for a total of $21.5 million, to support fuel cell deployment in forklift projects (DOE 2012a,b). DOE invested an additional $18.5 million and industry contributed an additional $30.8 million, for a total of $49.3 million, to support fuel cell deployment in backup power projects (DOE 2012b).

Commonly referred to as the "stimulus package," the Recovery Act was passed by Congress and signed into law by President Obama in 2009 to jump-start the economy and to create and save jobs. The Recovery Act specified appropriations for a wide range of federal programs and increased or extended certain entitlement programs. The 28 federal agencies that received Recovery Act funds developed specific plans for spending the money (Recovery.gov undated). Within DOE, the Fuel Cell Technologies (FCT) Office oversaw the deployment of 1,238 fuel cells in forklift and backup power applications under seven ARRA awards.

As part of their reporting requirements, recipients of Recovery Act funds calculated the number of jobs created or saved by taking the total number of ARRA-funded hours worked in a quarter, and dividing it by the number of hours in a full-time schedule in that quarter as defined by the recipient. Thus, if two full-time employees each worked 520 hours (1,040 hours) for the quarter and another half-time employee worked 260 hours, the total hours for the three employees would be 1300 (520 + 520 + 260 = 1300). Dividing that number by 520 equals 2.5 full-time equivalent (FTE) jobs funded. Recipients were only required to report job numbers by quarter. Those numbers could not be totaled across quarters because some of the jobs spanned multiple quarters (so they would be counted more than once), while others were reported for only the first quarter in which they occurred (since some recipients mistakenly believed that they did not have to report the same job in subsequent quarters) (Recovery.gov undated). Thus, it is difficult to estimate jobs created or retained under the Recovery Act either *in toto* or for any individual program like FCT's fuel cell deployment program.

This analysis addresses part of that data gap. It does so by examining total expenditures for deploying fuel cell over the life of the ARRA-supported program and estimating "job-years" attributable to those expenditures. Note that job-years do not differentiate between full- and part-time jobs. A job-year is simply a year of work by one person. Thus, the estimates obtained in this analysis cannot be compared with other estimates that are based on different definitions (e.g., FTE jobs) and potentially incomplete reporting.

In this report, the discussion of projects deploying fuel cells in "forklift" or "lift truck" applications refers to all materials handling–related fuel cell projects outlined in DOE's Program Record 11017 (DOE 2012a), while the discussion of "backup power" applications refers to all projects outlined in DOE's Program Record 12013 (DOE 2012b). Most of the fuel cell systems for backup power applications described in Program Record 12013 were deployed at cell phone towers; approximately 20 systems were deployed at military bases.

Information on total DOE and industry cost share expenditures over the term of the Recovery Act fuel cell program was provided by staff of the FCT Office. For purposes of calculating total economic impacts, this analysis assumed that ARRA expenditures occurred over the same timeframe as ARRA deployments (2009–2012). Thus, the impact of total ARRA expenditures was captured whether or not they occurred precisely within the 2009–2012 time period.

2 THE RECOVERY ACT FUEL CELL PROGRAM

The ARRA was one of the largest economic stimulus programs in U.S. history. Over $800 billion in government spending was authorized under the Act, $28.4 billion of which was awarded by the DOE across more than 24,000 projects. Of that total, $28.2 million was spent on new deployments of fuel cell technologies. As with other portions of the Act, a major objective of fuel cell deployments was to create new jobs, save existing jobs, and spur economic activity and investment over the long term.

Specifically, the seven fuel cell projects funded under the Recovery Act were intended to stimulate economic activity and advance the long-term market success of fuel cells by

- Creating jobs in the design, production, installation, and commissioning of fuel cell power units, hydrogen storage and fueling equipment, and hydrogen delivery;
- Training lift truck operators and maintenance personnel in hydrogen safety, fueling procedures, and fuel cell operation and maintenance;
- Increasing the commercial availability of fuel cell systems by generating volume in the fuel cell industry supply chain, creating and deploying novel storage and delivery options, and expanding practical user experiences; and
- Advancing perceptions of the reliability and durability of fuel cell systems and related equipment by validating performance, demonstrating safe and reliable operation, and quantifying costs associated with operation and maintenance (O&M) of all equipment.

2.1 Fuel Cell Deployments under the Recovery Act

Four of the projects funded under the Recovery Act supported the installation and operation of fuel cells in materials handling (i.e., for forklifts or lift trucks), while three supported the installation and operation of fuel cell systems for backup power. Table 1 summarizes the four awards to deploy fuel cells for materials handling.

TABLE 1 Recovery Act Awards Supporting Fuel Cell Deployments in Lift Trucks

Award Recipient	Fuel Cell Deployment Site	Fuel Cell System Supplier
FedEx Freight East	FedEx, Springfield, MO	Ballard Power Systems
Genco	Coca Cola, NC	Hydrogenics
	Kimberly-Clark, SC	Nuvera Fuel Cells
	Sysco Philadelphia, PA	Oorja Protonics
	Wegmans, PA	Plug Power, Inc.
	Whole Foods Market, MD	
Nuvera	H-E-B Grocery, TX	
Sysco Houston	Sysco Houston, TX	

Sources: DOE (2012a,c–f)

Under the ARRA awards, fuel cells were installed in Class 1, 2, and 3 lift trucks. Lift trucks typically are operated under different duty cycles with different power demands. Class 1–3 lift trucks are generally operated indoors using industrial lead-acid batteries for motive power and transistor motor controllers to control travel and hoist functions. Class 1 lift trucks, often called rider trucks, typically range from 4 to 20 kW in power and may be either sit-down or stand-up style. Class 2 lift trucks have similar power demands but are designed to operate in narrower aisles. Class 3 lift trucks, often called hand-pallet jacks, are typically smaller, stand-up units with power demands in the range of 1–4 kW. The four awards were intended to support the deployment of up to 500 fuel cells in all three classes of lift trucks.

Table 2 shows the number of fuel cells that were anticipated to be deployed in lift trucks by location, as reported by award recipients in 2011. Ultimately, nearly 500 fuel cells were deployed, with 484 still in service at year end 2012 (DOE 2012b). Note that fuel cell units were deployed for different lengths of time (some early in the program, others much later) and that some units were retired before the final units were deployed. In addition, some units were temporary rental units, others were deployed in harsh environments (i.e., sub-freezing temperatures), and still others utilized novel fueling and on-site fuel production processes. Thus, analyses conducted at different times during the course of the program could reflect different mixes of lift trucks operating under different conditions, which would likely produce different results. This issue is compounded by the fact that the timing of expenditures cannot be associated with any certainty to the timing of actual deployments. To avoid these problems, this analysis characterized the entirety of forklift deployments under the Recovery Act and adopted methodologies to describe their overall operation both during the time of the program and thereafter. This issue is discussed further in Section 3.

TABLE 2 Planned Deployments of ARRA-Supported Fuel Cells in Lift Trucks

Facility Name and Location	Total
Wegmans – Pottsville, PA	136
Whole Foods – Landover, MD	61
Coca-Cola – Charlotte, NC	40
Sysco – Philadelphia, PA	95
Kimberly-Clark – Graniteville, SC	25
Sysco – Houston, TX	79
FedEx – Springfield, MO	35
H-E-B – Various locations, TX	14
TOTAL	485

Sources: DOE (2012c–f)

Table 3 summarizes the three Recovery Act awards under which fuel cells were deployed for backup power. A total of 451 potential sites were initially proposed for fuel cell installation. However, due to a variety of site issues (primarily insufficient space to accommodate the fuel cell unit, fuel cabinet, and associated hardware, or difficulties in delivering hydrogen fuel to the site), a number of the sites that were initially investigated were later withdrawn from consideration. Thus, fuel cells were actually installed at 356 sites. Depending on the power requirements of the site, one, two, or three fuel cells were installed (DOE 2012g). Ultimately, a total of 734 fuel cells were deployed to provide backup power at 356 sites (DOE 2012b).

TABLE 3 Recovery Act Awards Supporting Fuel Cell Deployments for Backup Power

Award Recipient	Proposed Fuel Cell Systems/Sites	Fuel Cell System Supplier
ReliOn	189 AT&T and PG&E sites (CA, UT, CO, AZ, NM, MI, IN, FL)	Altergy Hydrogenics
Sprint Nextel	260 Sprint sites (CA, CT, NJ, NY, LA, TX, MS, NC)	IdaTech Plug Power, Inc.
Plug Power	Warner Robins Air Force Base (CA) Fort Irwin (GA)	ReliOn

Sources: DOE (2012b,g,h, 2013)

Figure 1 shows the 20 states where fuel cells were deployed to provide backup power, to power forklifts, or to serve both applications with support from the Recovery Act. In these states, employment impacts occurred as a result of expenditures associated with the installation and maintenance of fuel cells and associated infrastructure. Employment impacts also occurred as a result of expenditures associated with the industry supply chain for these activities, and for the production of fuel cells, fueling infrastructure, and hydrogen fuel. Beyond a handful of obvious

examples where individual fuel cell producers have a large presence (e.g., California, Massachusetts, Oregon), the granularity of the data is insufficient to identify the states in which these broader impacts occurred.

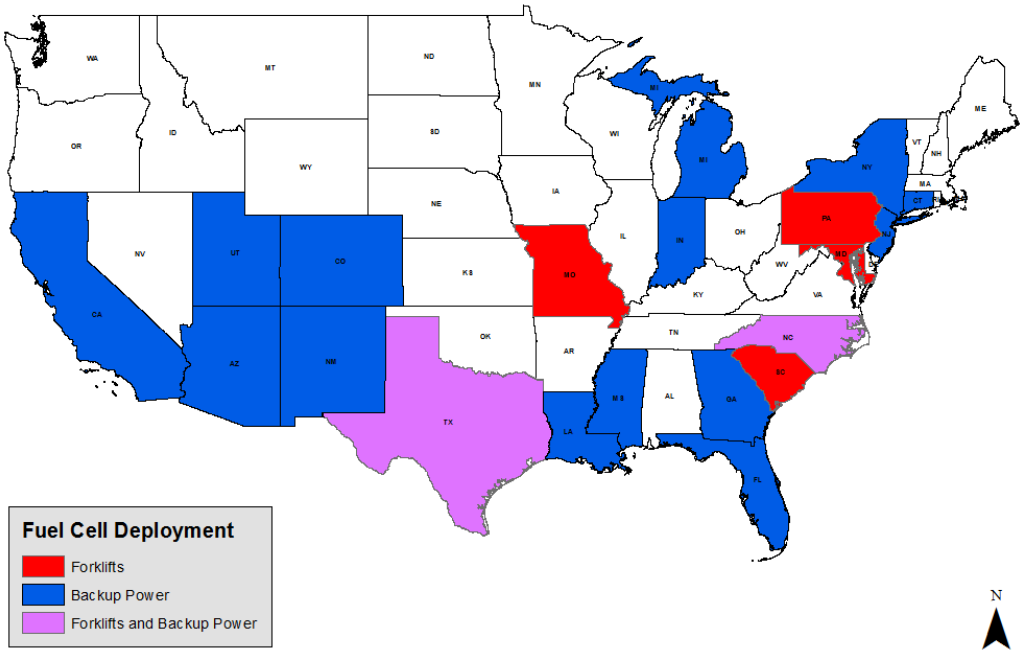

FIGURE 1 States Where Fuel Cells Were Deployed with Recovery Act Funds

3 METHODOLOGY

This effort uses input-output analysis to examine economic impacts from expenditures associated with ARRA-supported fuel cell deployments. Those impacts go beyond the limited number of workers directly involved in manufacturing, installing, or servicing the fuel cells and related infrastructure deployed under the program and the wages and benefits earned by those workers. As noted earlier, reporting requirements for ARRA award recipients were limited to those types of direct activities, and the associated job estimates were, in effect, "snapshots" for individual quarters during the program, not overall estimates for the program. This incomplete picture misses (a) significant numbers of workers employed further up the fuel cell and hydrogen infrastructure industry supply chains, as well as (b) the changing dynamics of employment supported by the program, which at different times could include vastly different proportions of workers involved in the production or installation of the fuel cells and fueling infrastructure, or in the operation of the units themselves.

Input-output analysis is uniquely suited to capturing impacts from spending as it moves up the industry supply chain and out into the broader economy. Because the underlying transactions are based on annual data, it is also able to provide a broader perspective on spending and resulting impacts over time. For this analysis, two input-output based tools were used to estimate economic impacts – the JOBS and economic impacts of Fuel Cells (JOBS FC) model and the Regional Input-Output Modeling System (RIMS).

3.1 JOBS FC

JOBS FC is a spreadsheet-based tool designed to estimate U.S. economic impacts from the manufacture and use of select types of fuel cells. It was developed by Argonne National Laboratory (Argonne), with assistance from RCF Economic & Financial Consulting, Inc., and support from the FCT Office within DOE's Office of Energy Efficiency and Renewable Energy. JOBS FC uses input-output analysis to estimate economic impacts associated with changes in industry expenditures and calculates the ripple effects of those changes throughout the economy. It uses relationships from the Regional Input-Output Modeling System (RIMS), an input-output model developed by the U.S. Department of Commerce's Bureau of Economic Analysis, which is discussed in Section 3.1.2.

Figure 2 provides an overview of the geographic detail, scope, and economic output of JOBS FC. The tool has been designed to be as flexible as possible, and to allow users with diverse interests to estimate economic impacts. JOBS FC is based in Microsoft® Excel 2010 with spreadsheet tabs for inputs and results.

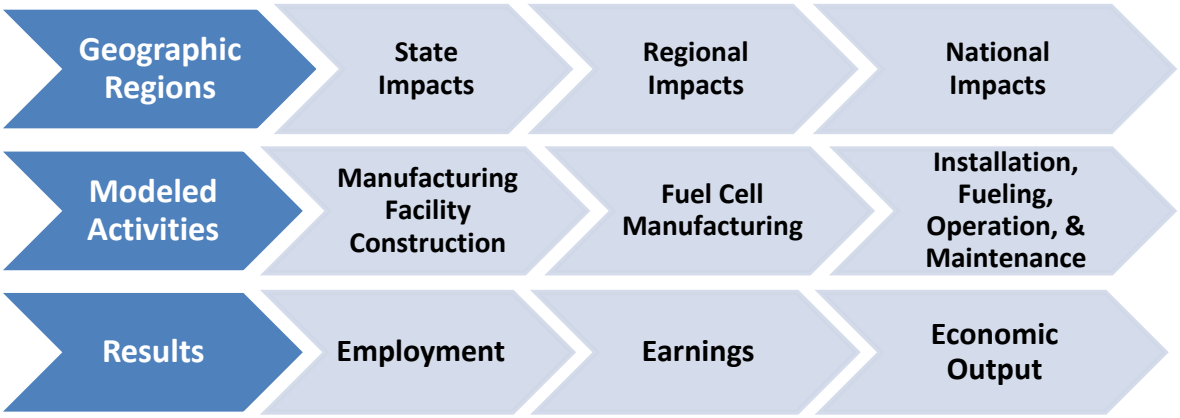

FIGURE 2 Overview of JOBS FC

JOBS FC models the application of fuel cells to the following markets: forklifts (utilizing Proton Exchange Membrane (PEM) technology), telecommunications back-up power (also using PEM technology), and prime power replacement (using either Molten Carbonate (MCFC) or Phosphoric Acid Fuel Cell (PAFC) technologies). Default values, where provided, are based on information derived from the technical literature, from industry sources, and from other researchers. Detailed breakdowns of fuel cell component costs are a key feature of the model. These breakdowns are based on FCT-supported research at Battelle Memorial Institute (2011) and Oak Ridge National Laboratory (Warren et al. 2012). Note that JOBS FC may be used to estimate the impacts of utilizing the same type of fuel cell in other applications by specifying customized inputs in place of default values, provided that the user has a thorough understanding of the implications of using the tool for the intended customized fuel cell application.

JOBS FC may be run at the state, regional, or national level. Figure 3 shows the 60 possible geographies (i.e., all 50 states, the nine federal census regions, and the U.S. as a whole)[2] that users may select for a given analysis. Note that results will vary based on geography due to differences in concentrations of industries, wage rates, and sectors of the economy. While the user is free to select whatever geography is most appropriate for his/her analysis, it should be noted that results based on one geography should not be combined with those based on a higher-order geography (e.g., state results should not be subtracted from national results to estimate out-of-state results) since the underlying multipliers apply only to the specific geography for which they have been calculated. For the ARRA analysis, JOBS FC was run at the national level, supplemented with additional calculations as needed.

[2] Alaska and Hawaii are part of the Pacific census region.

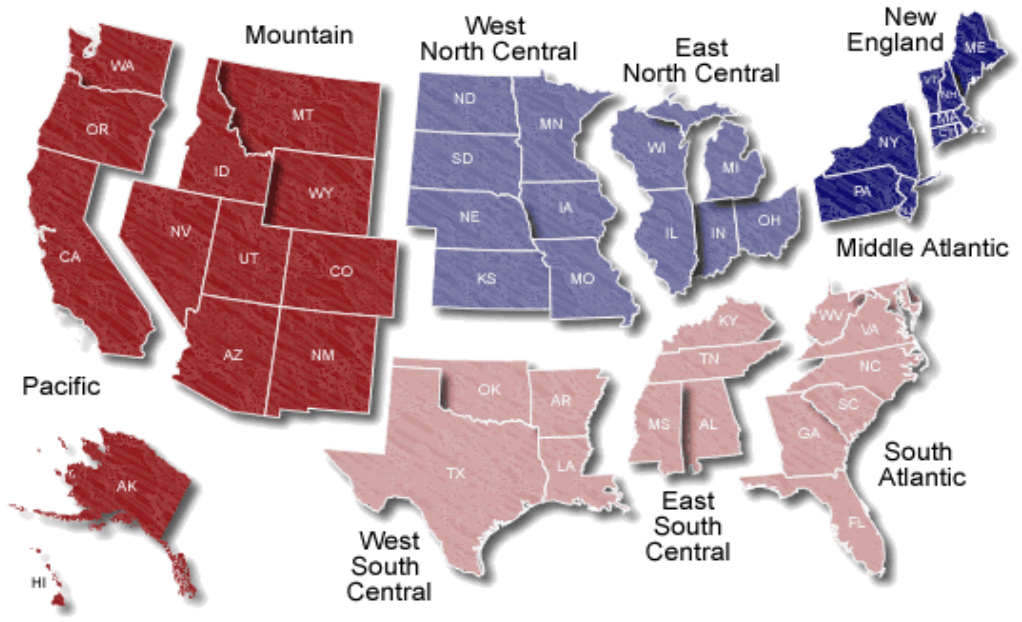

FIGURE 3 Geographies Modeled by JOBS FC: States and U.S. Census Regions

Note that JOBS FC can estimate either gross or net economic impacts. Net impacts account for those economic impacts that are displaced by spending on one activity in lieu of another. In most cases fuel cells used in lift trucks displace batteries and fuel cell backup power units displace batteries and/or generator sets. Thus, in a net analysis, the foregone impacts from spending on batteries and generator sets would be deducted from gross impacts associated with fuel cell spending. For the Recovery Act, however, expenditures were intended to *stimulate* the economy, not displace other investments. Thus, it is assumed for this analysis that fuel cells were not deployed in lieu of incumbent technologies and it is assumed they did not displace expenditures that otherwise would have occurred. Thus, the economic analysis and all results reported in this document are *gross* totals.

Further information on JOBS FC, along with a User's Guide and downloadable copy of release 1.1 of the model, is available from Mintz et al. (2012) and at http://jobsfc.es.anl.gov.

3.2 RIMS

As mentioned above, JOBS FC is based on an input-output model of the U.S. economy and is applicable to 60 geographic regions. The model incorporates 60 sets of multipliers (one for each geographic region) to allocate expenditures to the economic sectors associated with fuel cell production, installation, and use, as well as for the expenditures associated with constructing and equipping the facility to produce those fuel cells. Multipliers were obtained from RIMS, a 406-

sector input-output model of the U.S. economy, which has been developed and is maintained by the Bureau of Economic Analysis (BEA) at the U.S. Department of Commerce. Multipliers are based on the 2002 U.S. Benchmark Input-Output Table for national and 2008 regional data. Further information about input-output modeling in general, and RIMS in particular, may be obtained at the BEA's RIMS website (BEA undated).

3.3 Expenditures Analyzed

It should be noted that there are important differences between the scope of expenditures modeled in JOBS FC and the scope of Recovery Act expenditures. Certain expenditures, for example capital expenses involved in constructing or expanding a facility to produce the fuel cell, are beyond the scope of Recovery Act funding. ARRA guidelines assume that these expenditures have already occurred and thus are not attributable to the program. On the other hand, expenditures for activities like program administration, research, and reporting, which tend to be common for demonstration and pilot programs like those supported by ARRA (but not for commercial installations), are not part of JOBS FC. Economic impacts of these latter expenditures had to be calculated outside JOBS FC. In order to maintain consistency with calculations from JOBS FC, multipliers from the same underlying input-output model of the U.S. economy (RIMS) were used for these calculations.

Figure 4 illustrates three types of expenditures and associated calculations: those modeled in JOBS FC but not within the scope of ARRA (shown in the left-hand portion of the figure), those "in scope" of ARRA reporting but not modeled in JOBS FC (shown in the right-hand portion of the figure), and those common to both (shown in the center). This report discusses these expenditures and calculations separately for each of the two fuel cell applications funded under the Recovery Act. In other words, for forklifts and then for backup power, the following discussion is organized as follows:

1. ARRA "in scope" impacts. An initial discussion of impacts associated with the black ARRA "in scope" circle in Figure 4 (excluding impacts associated with expenditures shown to the far left in the figure).

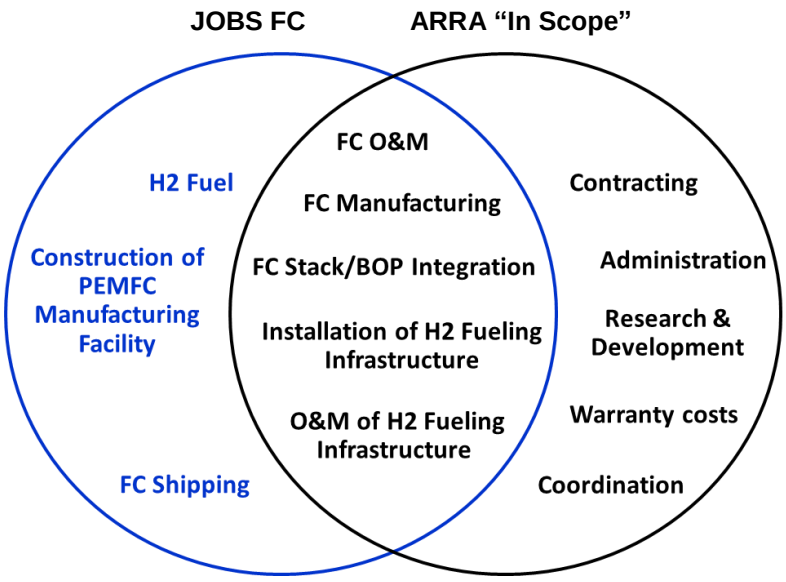

FIGURE 4 Types of Fuel Cell Expenditures Included in JOBS FC and ARRA "In Scope" Categories

2. Annual, ongoing impacts. Estimates of annual economic impacts associated with continued fueling and maintenance expenditures that are "out-of-scope" of the ARRA program. These expenditures and the effort to capture their impact are discussed below.

Table 4 further categorizes the three types of spending associated with the Recovery Act-supported fuel cell program. These categories dictated how expenditures were treated in this analysis.

TABLE 4 Expenditures Analyzed

Expenditure Type	Timeframe of Impact	Grouping of Economic Impact (Nomenclature in Sec. 4)
Expenditure types included in JOBS FC and identified as being covered by Recovery Act funding	2009–2012	Total over timeframe (ARRA in Scope Impacts)
Expenditure types outside the scope of JOBS FC but identified as being covered by Recovery Act funding	2009–2012	Total over timeframe (ARRA in Scope Impacts)
Annual fuel and maintenance expenditures associated with ARRA deployments but not covered by Recovery Act funding	Post–2012	Annual (Annual, Ongoing Impacts)

1. Expenditures belonging to the first category (those in JOBS FC and identified as being covered by Recovery Act funding)[3] – including the purchase of the fuel cell (fuel cell manufacturing, development, and sales), the purchase and installation of the on-site hydrogen fueling equipment, and maintenance-related expenditures – were allocated to appropriate expenditure sub-categories within JOBS FC.

2. Expenditures from the second category (those outside the scope of JOBS FC but identified as being covered by Recovery Act funding)[4] – were allocated among different RIMS sectors to represent activities such as program administration, research, coordination, and other indirect costs.

3. Expenditures for the third category (those for hydrogen fuel during and following the conclusion of the ARRA program, and for continued maintenance of the fuel cell and associated infrastructure after conclusion of the ARRA program) were treated somewhat differently since they not only are outside the scope of Recovery Act funding, but are recurring expenses (with recurring impacts). Most of the fuel cells deployed under the ARRA program are expected to continue to be operated after completion of the program. Thus, impacts associated with their annual fuel and maintenance expenses (which are not covered by Recovery Act funding) were calculated with JOBS FC. Results are reported separately (following results for category one and category two expenditures) in Section 4 on a per-year basis.

Note that this analysis assumes all assembly, manufacturing, non-manufacturing, and associated labor for fabricating fuel cell *systems* occurred in the United States. Assumptions about the location (domestic or foreign) of stack and balance-of-plant activities and materials are based on conversations with industry experts. Those expenditures deemed to occur outside the United States are excluded from the results reported here. Indirect and induced impacts utilize import assumptions embedded within RIMS multipliers.

Note also that ARRA-specific expenditures (the first and second categories in Table 4) included in this analysis occurred over a multi-year time period. Due to reporting limitations, these expenditures cannot be allocated with any certainty to a single year. Thus, expenditures and associated impacts are calculated *in toto* and only total impacts associated with total expenditures are reported here.

[3] These expenditures are used to calculate ARRA in-scope impacts as discussed above.
[4] These expenditures are also used to calculate ARRA in-scope impacts.

3.4 Comparison with Earlier Analysis

A preliminary economic impact analysis of fuel cell deployments under the Recovery Act was presented at the FCT Office's 2012 Annual Merit Review.[5] That analysis was intended to illustrate how the JOBS FC model could be used to estimate economic impacts. It employed a bottom-up approach to estimate expenditures because complete information on actual expenditures was not yet available. It looked solely at fuel cell deployments through December 2011 and incorporated many preliminary assumptions on operational parameters and fuel expenses based on early, incomplete data. While it provided a means to test the model, it could not generate a complete picture of the economic impact of fuel cell deployment under the Recovery Act-supported program.

The analysis reported here differs in several important ways from that earlier effort:

- This analysis used a top-down approach, based on official records of total reported expenditures, to calculate impacts by category (fuel cell production, installation, program-related expenses, and some maintenance).

- Both government expenditures and industry cost shares are included in this analysis.

- All expenditures in this analysis reflect Recovery Act reporting guidelines.

- Only domestic impacts are reported here. These were estimated using industry input on domestic versus foreign sourcing of key stack and balance-of-plant components.

This last difference is a particularly important distinction between the two efforts. It required a separate analysis of component sourcing, which can vary from one project to another. Some materials and components (e.g., platinum catalysts, end plates) are almost universally imported while others may or may not be (e.g., stacks, bipolar plates), and still others are largely supplied by domestic manufacturers (e.g., membranes, tie rods). This type of analysis is beyond the scope of the current JOBS FC model and necessitated direct industry input.

A further difference between this and the earlier effort concerns the timing of expenditures impacts. Fuel cell deployment under the Recovery Act occurred over several years. Because of variability in the number of fuel cells in operation at any given time, and where and

[5] See http://www.hydrogen.energy.gov/pdfs/review12/an029_mintz_2012_o.pdf.

how they were operated, it was not possible to model the entire program as the sum of individual units or even individual projects. Rather, a "top-down" approach was used to examine the overall impact of the program. This is especially important since the ARRA fuel cell deployment program (like other stimulus projects) had a broad impact, reaching beyond readily visible effects within the fuel cell industry supply chain to infrastructure, installation and maintenance suppliers, and their respective supply chains as well as producing ripple effects in the broader economy.

In short, the current analysis reflects the official scope and magnitude of DOE's ARRA-funded fuel cell deployment program, is consistent with Recovery Act reporting guidelines, and provides the granularity needed to estimate *domestic* economic impacts with the best available information.

3.5 Economic Concepts and Types of Impacts

The economic impacts presented in this report are estimates of gross employment, earnings, and economic output associated with DOE and industry expenditures under the ARRA-supported program to deploy fuel cells in materials handling equipment and for backup power. As mentioned earlier, this analysis assumed that the Recovery Act *added spending* to the economy. That spending would not have occurred in the absence of the program and thus, other spending was not displaced. Therefore, a gross analysis was performed.

Several key concepts that are used to describe the analysis and the results obtained (as reported in Section 4). They include:

- **Gross employment** is measured in job-years and includes employment created or supported by expenditures under the Recovery Act fuel cell program. It includes both full-time and part-time employment.

- A **job-year**, as noted earlier, is defined as one year of work (full-time or part-time) for one person. Thus, for example, five job-years can be five years of work by one person, one year of work by five persons, or any person × year product equal to five. It is important to note that employment estimated from this analysis is measured in total job-years.

- **Gross earnings** consist of wages, salaries, and proprietors' income.[6]

[6] All dollar values – including all expenditures and estimated economic impacts – are assumed to be in 2010 dollars.

- **Gross economic output** is an economic concept that represents the total value of sales by producing enterprises including the value of the intermediate goods used in production. Gross domestic product is different from gross economic output because it does not include the value of the intermediate goods used in production (Bess and Ambargis 2011).

The economic impacts estimated in this analysis are broken down into two distinct categories**:**

1. **Industry supply chain impacts** are those impacts directly associated with DOE and industry cost share expenditures for fuel cells and fuel cell–related activities such as for manufacturing, installation of fueling infrastructure, and maintenance. Expenditures also include the upstream purchases made by those industries, such as input materials.[7] In this analysis, industry supply chain impacts include what are often referred to as direct and indirect impacts of expenditures.

2. **Induced impacts** account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.[8]

[7] Industry supply chain impacts are equivalent to what BEA refers to as RIMS' Type I impacts.
[8] Industry supply chain plus induced impacts are equivalent to what BEA refers to as RIMS' Type II impacts.

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4 RESULTS

4.1 Forklift Projects

4.1.1 ARRA In-Scope Impacts

As noted earlier, DOE invested $9.7 million in forklift fuel cell projects under the Recovery Act and an additional $11.8 million was contributed through industry cost shares, for a total investment of $21.5 million. These expenditures resulted in the deployment of 504 fuel cell-powered forklifts in three projects.

Expenditures for the deployment of fuel cells in forklifts are associated with total impacts over the course of the Recovery Act program (i.e., industry supply chain plus induced impacts) of approximately 350 job-years of employment, over $16 million in earnings, and over $57 million in economic output. Figure 5 shows the breakdown between industry supply chain and induced impacts for those 350 job-years of employment by expenditure category.

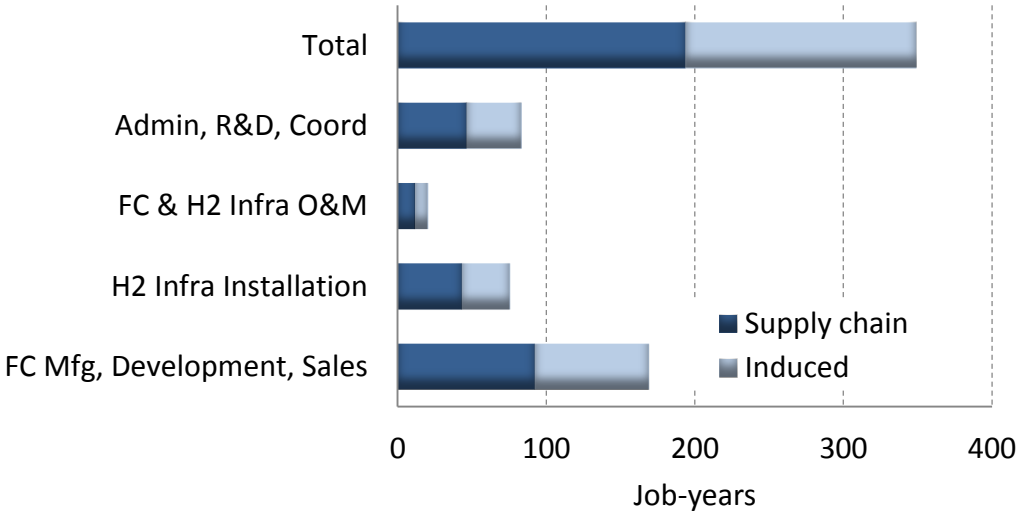

FIGURE 5 Domestic Employment from Recovery Act-Supported Deployment of Fuel Cells in Forklifts (ARRA In Scope Impacts)

Tables 5–7 summarize program impacts in terms of industry supply chain and induced employment, earnings, and economic output. Note that for Figure 5 and Tables 5–7 industry supply chain impacts include direct and indirect impacts of expenditures. Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

TABLE 5 Domestic Employment Associated with ARRA-Supported Deployment of Fuel Cells in Lift Trucks (job-years[a])

Expenditure Category	Industry Supply Chain[b]	Induced[c]	Total
Forklift Fuel Cell Manufacturing, Development, Sales	92	77	169
Installation of On-Site Hydrogen Fueling Infrastructure	43	33	76
Non-Fuel O&M of Fuel Cell and Hydrogen Infrastructure	12	9	21
Program Administration, Research, Coordination	46	37	83
Total	194	155	349

[a] A job-year is one year of work (full- or part-time) for one person.

[b] Industry supply chain impacts include direct and indirect impacts of expenditures.

[c] Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

TABLE 6 Domestic Earnings Associated with ARRA-Supported Deployment of Fuel Cells in Lift Trucks (thousands 2010$)

Expenditure Category	Industry Supply Chain[a]	Induced[b]	Total
Forklift Fuel Cell Manufacturing, Development, Sales	$4,908	$2,922	$7,830
Installation of On-Site Hydrogen Fueling Infrastructure	$2,231	$1,241	$3,472
Non-Fuel O&M of Fuel Cell and Hydrogen Infrastructure	$599	$333	$932
Program Administration, Research, Coordination	$2,527	$1,406	$3,933
Total	$10,266	$5,902	$16,168

[a] Industry supply chain impacts include direct and indirect impacts of expenditures.

[b] Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

TABLE 7 Domestic Economic Output Associated with ARRA-Supported Deployment of Fuel Cells in Lift Trucks (thousands 2010$)

Expenditure Category	Industry Supply Chain[a]	Induced[b]	Total
Forklift Fuel Cell Manufacturing, Development, Sales	$20,973	$10,415	$31,387
Installation of On-Site Hydrogen Fueling Infrastructure	$7,491	$4,423	$11,913
Non-Fuel O&M of Fuel Cell and Hydrogen Infrastructure	$1,759	$1,188	$2,947
Program Administration, Research, Coordination	$6,114	$5,010	$11,124
Total	$36,337	$21,034	$57,371

[a] Industry supply chain impacts include direct and indirect impacts of expenditures.

[b] Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

4.1.2 Annual, Ongoing Impacts

These impacts are not directly related to Recovery Act expenditures since Recovery Act funds could not be used for these purposes (e.g., hydrogen fuel during or after the conclusion of the ARRA program, and maintenance expenses after the conclusion of the program). Thus, they are called "out-of-scope" or "annual, ongoing" impacts in this analysis. Nevertheless, fuel and maintenance expenses (and their associated impacts) may be expected to occur over the lifetime of the fuel cells deployed under ARRA. For this reason, they are included in this analysis. Unlike the in-scope impacts presented above, these impacts cannot be calculated from reported expenditures. Rather, they are based primarily on the default values in JOBS FC, which, in turn, are based on a variety of published sources and stakeholder input to characterize operations parameters and maintenance expenditures for fuel cells of varying sizes. The National Renewable Energy Laboratory (NREL) has issued a series of summary reports or "composite data products" providing detail on fuel cell-powered lift trucks deployed under the Recovery Act program (NREL 2012b). These reports are the source for the number of fuel cell deployments and deployment locations shown in Table 8.

While somewhat more units were deployed initially, by the end of 2012 approximately 226 fuel cells were in operation in Class 1 or 2 lift trucks. An additional 258 fuel cells were in operation in Class 3 lift trucks as of that date. These units are assumed to continue to operate for the foreseeable future. Table 8 below summarizes the key assumptions used in JOBS FC to estimate the annual economic impact of fueling and maintaining those units and their associated infrastructure.

TABLE 8 Key Assumptions for Calculating Ongoing Economic Impacts of ARRA-Supported Fuel Cell Deployment in Lift Trucks

Variable	Class 1 and 2	Class 3
Forklift fuel cells in operation at year end 2012, that were deployed under ARRA program	226 (estimated)	258
Average fuel cell unit size (kW/fuel cell unit)	8	2
Average annual H2 fuel expense ($/FC unit)	$2,750	$320
Average annual fuel cell maintenance expense ($/fuel cell unit)	$1,600	$1,200
Number of hydrogen fuel infrastructure sites	8[a]	
Average annual hydrogen fueling infrastructure maintenance expenses ($/site)	$27,000	

[a] Fuel cell-powered lift trucks were deployed under four ARRA awards. Some of the award recipients deployed fuel cells at multiple sites.

Approximately 27 annual job-years (industry supply chain and induced) are associated with the ongoing operation of fuel cell-powered lift trucks deployed under the Recovery Act program. Table 9 displays employment impacts associated with fuel purchases; Table 10 shows employment impacts associated with maintenance expenses for the fuel cells and their fueling infrastructure.

TABLE 9 Domestic Annual Economic Impacts Associated with Hydrogen Fuel Expenditures from ARRA Deployment of Forklift Fuel Cells

Category	Industry Supply Chain[a]	Induced[b]	Total
Employment (job-years)	7	5	12
Earnings (thousands 2010$)	$342	$190	$532
Economic Output (thousands 2010$)	$1,332	$678	$2,010

[a] Industry supply chain impacts include direct and indirect impacts of expenditures.

[b] Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

TABLE 10 Domestic Annual Economic Impacts Associated with Maintenance Expenditures from ARRA Deployment of Forklift Fuel Cells and Associated Hydrogen Fueling Infrastructure

Category	Industry Supply Chain[a]	Induced[b]	Total
Employment (job-years)	9	6	15
Earnings (thousands 2010$)	$443	$246	$689
Economic Output (thousands 2010$)	$1,301	$878	$2,179

[a] Industry supply chain impacts include direct and indirect impacts of expenditures.

[b] Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

4.2 Backup Power Projects

4.2.1 ARRA In-Scope Impacts

As noted earlier, DOE invested $18.5 million in fuel cell deployment for backup power projects and an additional $30.8 million was contributed through industry cost shares, for a total of $49.3 million. These investments resulted in the deployment of over 700 fuel cells for backup power under three Recovery Act awards. Two of the awards supported the deployment of fuel cells for backup power at cell phone towers. The third supported the deployment of 20 fuel cells for backup power at military bases.

Recovery Act spending for backup power fuel cells is associated with approximately 960 job-years of employment (including induced impacts), over $43 million in earnings, and over $142 million in economic output. Figure 6 shows estimated industry supply chain and induced employment by expenditure category.

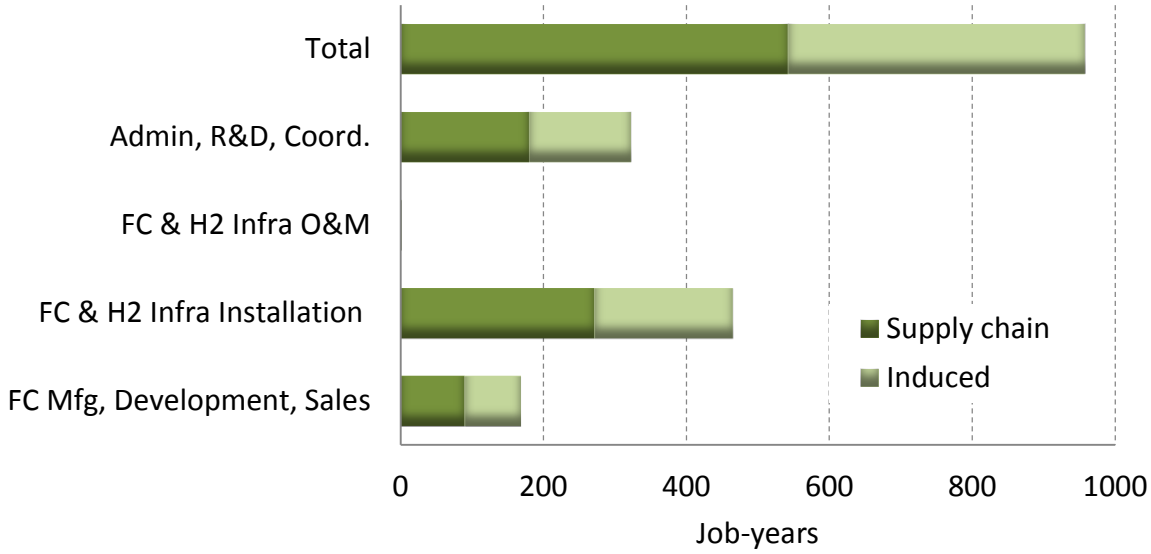

FIGURE 6 Domestic Employment from ARRA-Supported Deployment of Fuel Cells for Backup Power (ARRA In Scope Impacts)

Tables 11–13 summarize program impacts in terms of industry supply chain and induced employment, earnings, and economic output. Note that for Figure 6 and Tables 11–13, industry supply chain impacts include direct and indirect impacts of expenditures. Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

TABLE 11 Domestic Employment from ARRA-Supported Deployment of Backup Power Fuel Cells (ARRA In Scope Impacts) (job-years[a])

Expenditure Category	Industry Supply Chain[b]	Induced[c]	Total
Backup Power Fuel Cell Manufacturing, Development, Sales	90	79	168
Backup Power Fuel Cell Installation and Fuel Storage	271	193	465
Backup Power Fuel Cell and Site Maintenance	1	1	2
Program Administration, Research, Coordination	180	143	323
Total	542	416	958

[a] A job-year is one year of work (full- or part-time) for one person.

[b] Industry supply chain impacts include direct and indirect impacts of expenditures.

[c] Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

TABLE 12 Domestic Earnings from ARRA-Supported Deployment of Fuel Cells in Backup Power (ARRA In Scope Impacts) (thousands 2010$)

Expenditure Category	Industry Supply Chain[a]	Induced[b]	Total
Backup Power Fuel Cell Manufacturing, Development, Sales	$4,788	$2,987	$7,775
Backup Power Fuel Cell Installation and Fuel Storage	$13,222	$7,351	$20,573
Backup Power Fuel Cell and Site Maintenance	$50	$28	$78
Program Administration, Research, Coordination	$9,777	$5,438	$15,215
Total	$27,837	$15,803	$43,639

[a] Industry supply chain impacts include direct and indirect impacts of expenditures.

[b] Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

TABLE 13 Domestic Economic Output from ARRA-Supported Deployment of Fuel Cells in Backup Power (ARRA In Scope Impacts) (thousands 2010$)

Expenditure Category	Industry Supply Chain[a]	Induced[b]	Total
Backup Power Fuel Cell Manufacturing, Development, Sales	$19,478	$10,644	$30,122
Backup Power Fuel Cell Installation and Fuel Storage	$43,048	$26,204	$69,253
Backup Power Fuel Cell and Site Maintenance	$147	$99	$246
Program Administration, Research, Coordination	$23,652	$19,379	$43,031
Total	$86,325	$56,326	$142,651

[a] Industry supply chain impacts include direct and indirect impacts of expenditures.

[b] Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

4.2.2 Annual, Ongoing Impacts

As discussed in Section 4.1.2, ongoing impacts are not directly related to Recovery Act expenditures since they result from activities outside the scope of the program (e.g., hydrogen fuel during or after the conclusion of the ARRA program, and maintenance expenses after the conclusion of the program). Nevertheless, fuel and maintenance expenses (and their associated impacts) may be expected to occur over the life of the fuel cells as they continue to operate. For this reason, they are included in this analysis. Unlike the in-scope impacts presented above, these impacts cannot be calculated from reported expenditures. Rather, they are based primarily on the default values in JOBS FC. As noted earlier, those values incorporate information from a variety

of published and industry sources to estimate operations parameters that are then used to estimate fuel and maintenance expenditures for fuel cells of varying sizes. One key data source is the NREL-issued series of summary reports or "composite data products" providing detail on fuel cells for backup power deployed under the Recovery Act (NREL 2012a, NREL 2012c). These reports are the source for the values shown in Table 14 for the number of fuel cells deployed, the number of sites at which they were deployed, and average fuel cell unit size.

TABLE 14 Key Assumptions for Calculating Ongoing Economic Impacts of Fuel Cell Deployment for Backup Power

Variable	Value
Backup power fuel cells deployed under ARRA program	734
Number of sites	356
Average fuel cell unit size (kW/unit)	2.2
Average annual hydrogen fuel expense ($/fuel cell unit)	$62
Average annual maintenance expense ($/fuel cell unit)	$450

Based on the assumptions in Table 14, this analysis estimates that approximately 7 annual job-years (industry supply chain and induced) are associated with the ongoing operation (including fueling and maintaining) of the fuel cells for backup power that were deployed under the Recovery Act. Estimates of ongoing employment, earnings, and economic output associated with hydrogen fuel expenses are shown in Table 15. Comparable estimates associated with expenses for fuel cell maintenance are shown in Table 16.

TABLE 15 Domestic Annual Economic Impacts from Hydrogen Fuel Expenditures Resulting from ARRA Deployment of Backup Power Fuel Cells

Category	Industry Supply Chain[a]	Induced[b]	Total
Employment (job-years)	1	0	1
Earnings (thousands 2010$)	$26	$14	$40
Economic Output (thousands 2010$)	$84	$51	$135

[a] Industry supply chain impacts include direct and indirect impacts of expenditures.

[b] Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

TABLE 16 Domestic Annual Economic Impacts from Maintenance Expenditures Resulting from ARRA Deployment of Backup Power Fuel Cells

Category	Industry Supply Chain[a]	Induced[b]	Total
Employment (job-years)	3	2	6
Earnings (thousands 2010$)	$165	$92	$257
Economic Output (thousands 2010$)	$484	$327	$811

[a] Industry supply chain impacts include direct and indirect impacts of expenditures.

[b] Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

4.3 Total Economic Impacts

4.3.1 ARRA In-Scope Impacts

Tables 17–19 summarize the employment, earnings, and economic output impacts associated with total DOE and industry cost-share expenditures under the Recovery Act. The $70.8 million of expenditures analyzed in this report generated or supported approximately 18 job-years per million dollars, or $54,000 per job-year. Approximately $60 million in domestic earnings and $200 million in domestic economic output resulted from the total DOE and industry cost share investment in fuel cells under ARRA.

TABLE 17 Domestic Employment from ARRA-Supported Deployment of Fuel Cells in Forklifts and for Backup Power (job-years[a])

Expenditure Category	Industry Supply Chain[b]	Induced[c]	Total
Employment associated with fuel cell-powered forklifts	194	155	349
Employment associated with fuel cell backup power units	542	416	958
Total fuel cell-related employment	736	571	1,307

[a] A job-year is one year of work (full- or part-time) for one person.

[b] Industry supply chain impacts include direct and indirect impacts of expenditures.

[c] Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

TABLE 18 Domestic Earnings from ARRA-Supported Deployment of Fuel Cells in Forklifts and for Backup Power (thousands 2010$)

Expenditure Category	Industry Supply Chain[a]	Induced[b]	Total
Earnings associated with fuel cell-powered forklifts	$10,266	$5,902	$16,168
Earnings associated with fuel cell backup power units	$27,837	$15,803	$43,639
Total fuel cell-related earnings	$38,103	$21,705	$59,807

[a] Industry supply chain impacts include direct and indirect impacts of expenditures.

[b] Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

TABLE 19 Domestic Economic Output from ARRA-Supported Deployment of Fuel Cells in Forklifts and for Backup Power (thousands 2010$)

Expenditure Category	Industry Supply Chain[a]	Induced[b]	Total
Economic output associated with fuel cell-powered forklifts	$36,337	$21,034	$57,371
Economic output associated with fuel cell backup power units	$86,325	$56,326	$142,651
Total fuel cell-related economic output	$122,662	$77,360	$200,022

[a] Industry supply chain impacts include direct and indirect impacts of expenditures.

[b] Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

4.3.2 Annual, Ongoing Impacts

The following tables summarize annual employment, earnings, and economic output impacts from fuel and maintenance expenditures associated with fuel cells deployed under the Recovery Act. They summarize the separate estimates for fuel cell–powered lift trucks and backup power units presented earlier. As shown in Tables 20–22, including both industry supply chain and induced effects, an additional 34 job-years, $1.5 million in domestic annual earnings, and $5.1 million in domestic annual economic output are generated from annual fuel and maintenance expenditures associated with fuel cell deployments under the Recovery Act.

TABLE 20 Domestic Annual Employment from Fuel and Maintenance Expenditures Resulting from ARRA Deployment of Fuel Cells in Forklifts and for Backup Power (job-years[a])

Expenditure Category	Industry Supply Chain[b]	Induced[c]	Total
Employment associated with fuel cell-powered forklifts	16	11	27
Employment associated with fuel cell backup power units	4	3	7
Total fuel cell-related employment	20	14	34

[a] A job-year is one year of work (full- or part-time) for one person.

[b] Industry supply chain impacts include direct and indirect impacts of expenditures.

[c] Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

TABLE 21 Domestic Annual Earnings from Fuel and Maintenance Expenditures Resulting from ARRA-Supported Deployment of Fuel Cells in Forklifts and fro Backup Power (thousands 2010$)

Expenditure Category	Industry Supply Chain[a]	Induced[b]	Total
Earnings associated with fuel cell-powered forklifts	$785	$436	$1,222
Earnings associated with fuel cell backup power units	$191	$106	$297
Total fuel cell-related earnings	$976	$542	$1,519

[a] Industry supply chain impacts include direct and indirect impacts of expenditures.

[b] Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

TABLE 22 Domestic Annual Economic Output from Fuel and Maintenance Expenditures Resulting from ARRA-Supported Deployment of Fuel Cells in Forklifts and for Backup Power (thousands 2010$)

Expenditure Category	Industry Supply Chain[a]	Induced[b]	Total
Economic output associated with fuel cell-powered forklifts	$2,633	$1,556	$4,189
Economic output associated with fuel cell backup power units	$568	$378	$946
Total fuel cell-related economic output	$3,201	$1,934	$5,135

[a] Industry supply chain impacts include direct and indirect impacts of expenditures.

[b] Induced impacts account for the additional expenditures made by households as recipients of income that is then re-spent throughout the economy.

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ACRONYMS

ARRA	American Recovery and Reinvestment Act
BEA	Bureau of Economic Analysis
DOE	U.S. Department of Energy
FCT	Fuel Cell Technologies Office
FTE	Full-time equivalent
H2	Hydrogen
JOBS FC	JOBS and Economic Impacts of Fuel Cells model
kW	kilowatt
MCFC	Molten carbonate fuel cell
O&M	Operations and maintenance
PAFC	Phosphoric acid fuel cell
PEM	Polymer electrolyte membrane
R&D	Research & Development
RIMS	Regional Input-Output Modeling System

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