

# Fuel Cell Combined Heat and Power Industrial Demonstration

*Authors: W. Colella (PI), R. Timme, M. Rinker (PM, Presenter)*

*Contributors: J. Willett, J. Holladay*

*Pacific Northwest National Laboratory (PNNL)*

United States (U.S.) Department of Energy (DOE)  
Fuel Cell Technology (FCT) Program  
Annual Merit Review

Washington, DC  
May 9-13, 2011

Market Transformation & Technology Development Manager: Peter Devlin



U.S. Department of Energy

Energy Efficiency and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

*This presentation does not contain any proprietary, confidential, or otherwise restricted information*



*Proudly Operated by Battelle Since 1965*

# Overview

## ▶ Timeline

- Project start date: Q4, FY10
- Project end date: Q4, FY16
- Percent complete: 5%

## ▶ Budget

- FY 10 Funding: \$3,000k
  - DOE share: \$3,000k
  - Round One
    - Contractor share: \$1,962k (non-DOE cost share)
    - PNNL cost share: \$1,213k
  - Round Two
    - Contractor share: TBD
  - *Contractors supply 50% or greater cost share.*
- FY11 Funding: \$0k

## ▶ Barriers

- Technical and Economic issues preventing full commercialization of fuel cell systems (FCSs)
- Lack of long term validated performance data for 5 kilowatt electric (kWe) to 100 kWe FCS
  - Energy performance
  - Durability
  - Reliability
  - Installation, operations, and maintenance costs

## ▶ Partners

- Project Lead: PNNL
- Round One Sub-contractors: An industrial fuel cell manufacturer and ten commercial, non-profit, and community partners
- Round Two Contract: TBD

## **PNNL project supports Fuel Cell Technology (FCT) Program goal of addressing technical and economic barriers to commercialization.**

- ▶ Objective: ***To demonstrate combined heat and power (CHP) FCSs, objectively assess their performance, and analyze their market viability in commercial buildings.***
- ▶ PNNL is analyzing continuously-measured data from CHP FCSs installed in light commercial buildings to independently assess technical and economic barriers that are currently preventing full commercialization of CHP FCSs.
- ▶ PNNL is analyzing engineering, economic, and environmental performance data from CHP FCSs in the field so as to reveal commercialization “bottlenecks” -- where industry needs to spend the greatest effort to achieve high market penetration.



# **PNNL project addresses FCT program goal of validating performance data for 5 to 100 kWe CHP FCS over the long term.**

- ▶ The project will provide continuously-monitored performance data sampled every second from CHP FCSs installed in light commercial buildings over the project's five year lifetime.
- ▶ Monitored CHP FCSs will be installed in arrays ranging in size from 5 to 100 kWe.
- ▶ Measured data includes
  - Energy performance
  - Durability
  - Reliability
  - Installation, operations, and maintenance costs
- ▶ Measured performance data will be used to inform the development of future FCT program technical targets.



# PNNL is deploying CHP FCS via partnerships with FCS manufacturers and end users.

- ▶ Build a high-caliber PNNL expert team from subject matter experts(SME)
  - Capitalize upon PNNL's existing world-renowned expertise both in fuel cells and in building energy technologies.
- ▶ Establish baseline model to evaluate cost and technical performance of CHP FCSs.
  - Provides DOE and PNNL with a common basis with which to evaluate both proposed systems and systems that will be deployed.
- ▶ Acquire CHP FCSs for demonstration
  - Acquisitions through open competition
  - Both United States (U.S.) and foreign companies solicited
  - Manufacturers and end-users expected to team
- ▶ Monitor demonstration systems
  - Remote monitoring of key parameters
- ▶ Analyze and document performance data
  - Performance and overall cost data analyzed and recommendations will be documented and provided to DOE.

## **PNNL has established baseline models of FCS cost and technical performance.**

- ▶ Key data requested from FCS makers and included in model input
  - Engineering Performance
    - Individual FCS [example (exp): heat recovery efficiencies]
    - Cooling cycle for combined cooling, heat, and electrical power (CCHP) FCSs (if applicable)
    - Arrays of FCS installed
    - Building installation site energy use and in-use energy efficiencies
    - Past FCS performance [exp: mean time before failure (MTBF)]
  - Financial Performance
    - Individual FCS cost
    - Project level finance [exp: internal rate of return (IRR); payback]
  - Environmental Performance
    - Original feedstock energy source
    - Greenhouse gas (GHG) emissions
    - Air pollution emissions
    - End of life decommissioning plans



# PNNL is acquiring CHP FCSs for demonstration A final contract has been issued.

- ▶ Acquisitions through open competition
  - Solicitation was circulated to manufacturers, suppliers, researchers, and others around the U.S., Europe, and Asia
- ▶ Both U.S. and foreign companies were solicited
  - No restrictions on foreign manufacturer participation at full cost share
  - All deployments required to occur in the U.S.
- ▶ FCS manufacturers and commercial end-users expected to team for procurement
  - Fifty percent cost-share (minimum) required by applicants
  - Manufacturer can use their business model for system integration
  - Input data for technical performance models compared with objective criteria to down-select the most competitive partners
  - Install and commission CHP FCSs.



# **PNNL will remotely monitor key parameters every second, for five years, including**

- ▶ Instantaneous and cumulative power generation
- ▶ Grid voltage at the inverter
- ▶ Exported grid current
- ▶ Internal cabinet temperatures
- ▶ Heating and Cooling temperatures of water
- ▶ Water flow rates
- ▶ Heat exchanger cooling fan speeds
- ▶ Fuel inlet flow rate and cumulative fuel use
- ▶ Exhaust temperature
- ▶ Heat generation rate and cumulative heat generated
- ▶ Cumulative system time on load
- ▶ System availability

Engineering, environmental, and economic performance will be analyzed and benchmarked against FCT program goals. Recommendations will be provided to DOE.



# **PNNL has established baseline performance models, down-selected the most competitive projects and issued a final contract.**

- ▶ PNNL conducted site visits and telephone calls with many FCS manufacturers
  - PNNL created an open dialog with manufacturers regarding overall requirements for the Request for Proposals (RFP)
- ▶ PNNL finalized Technical Requirements and Evaluation Criteria documents
  - Technical Proposal (60%); Cost Proposal (40%)
- ▶ Released RFP in December, proposals due in February
- ▶ PNNL has established models of FCS cost and technical performance
- ▶ Decision to negotiate award with single vendor in March
  - Ten deployment sites
    - Five sites in Northern California
    - Four sites in Southern California
    - One site in Oregon
  - Total of 38 CHP FCSs to be deployed
  - Wide variety of industrial locations: Supermarket, Greenhouse/Nursery, Manufacturer, Community Center, Fitness, Hotel, Education, Multi family housing

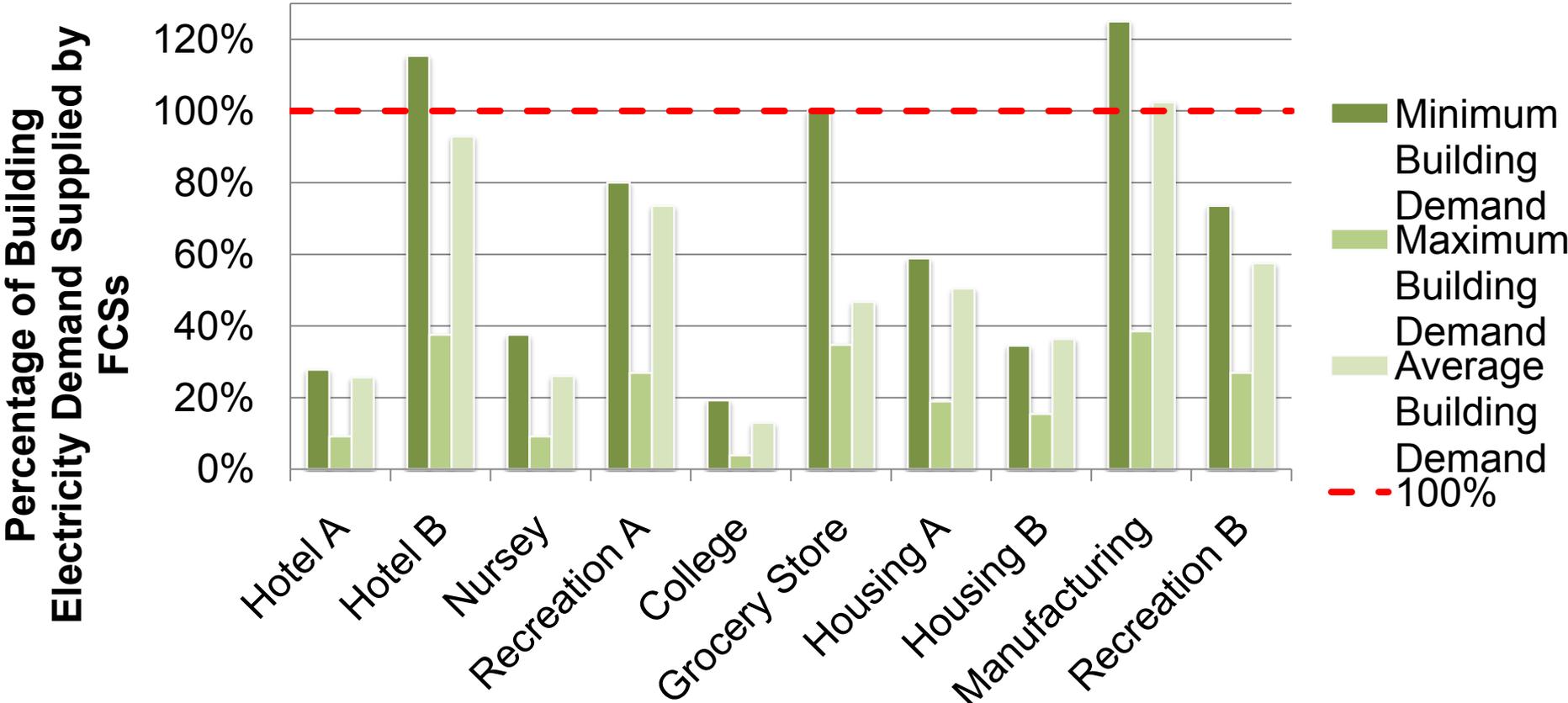
# Gantt chart delineates key technical accomplishments to date for FY 11.

Task Name	Qtr 1, 2011			Qtr 2, 2011			Qtr 3, 2011		
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	
Analyze CHP FCS Market	[Bar]								
Developing Solicitation		[Bar]							
Supporting Released Solicitation			[Bar]						
Review Technical Proposals				[Bar]					
Negotiate Contracts with Suppliers							[Bar]		
Publishing Peer-Reviewed Journal Publications	[Bar with orange diamonds at Nov and Feb]								
Publishing Peer-Reviewed Conference Proceedings	[Bar with red diamonds at Nov, Dec, and Apr]								

PNNL objectively reviewed and analyzed proposals from industry for technical and economic performance. PNNL’s analysis of manufacturer data is documented in peer-reviewed journal publications and conference proceedings.



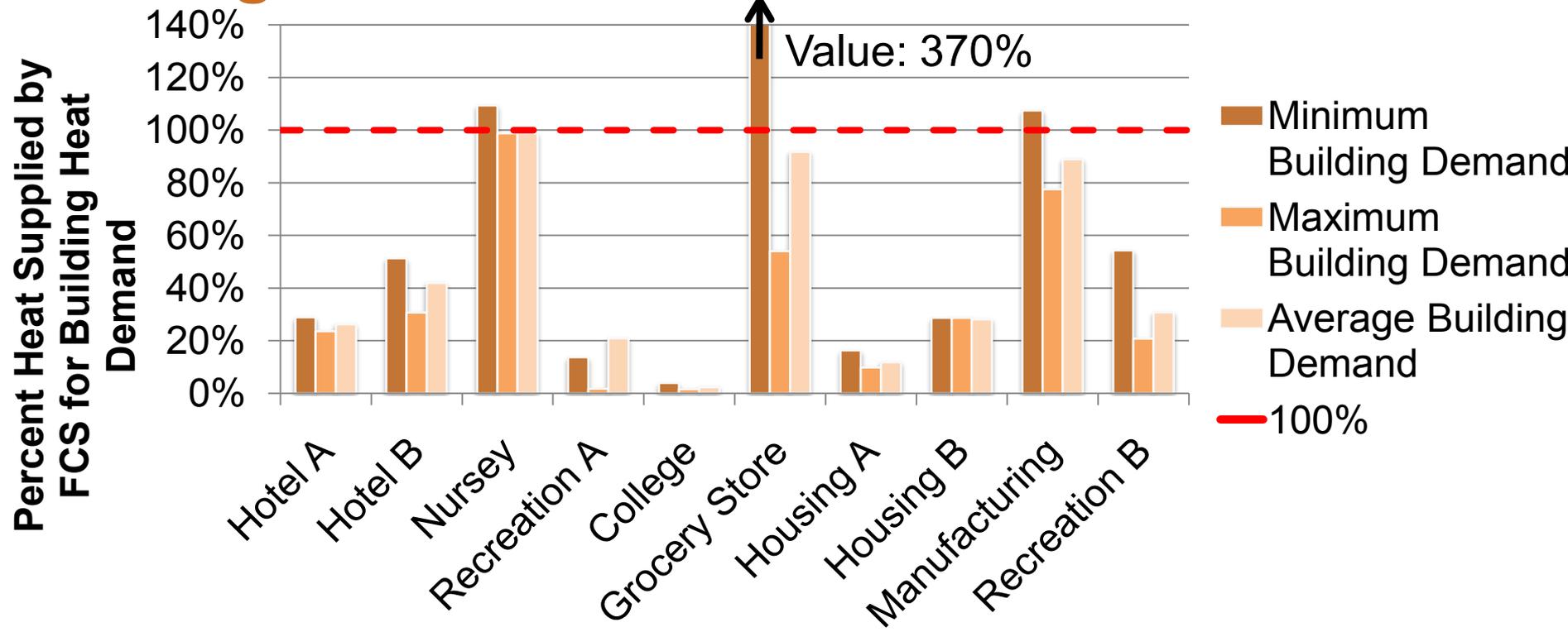
# Installation sites have been down-selected such that the majority of electricity supplied by the fuel cell systems meets building demands.



Excess electricity can be sold back to the utility company for a credit because FCSS will be grid-connected.



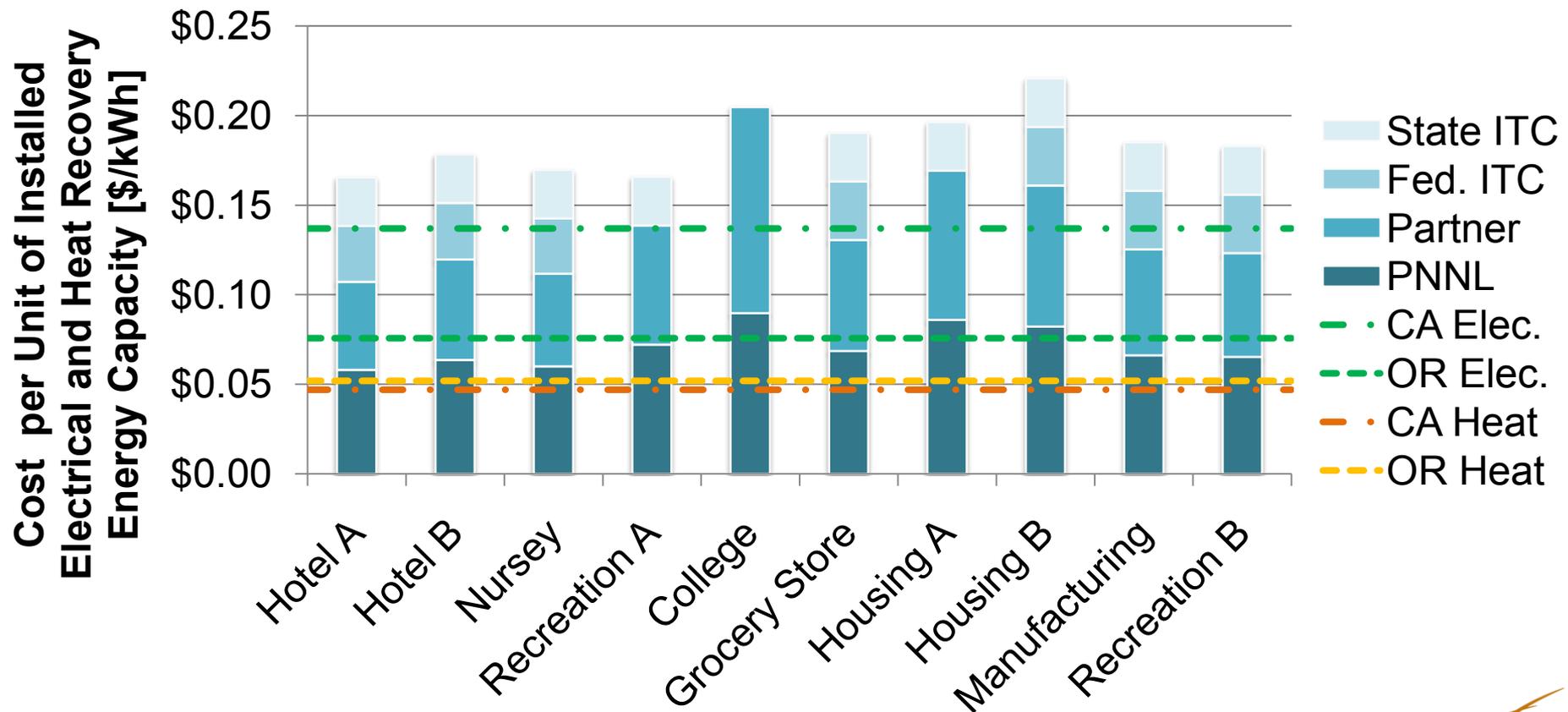
# Installation sites have been down-selected such that all FCS recoverable heat is consumed by building heat demand in most instances.



In a few cases, FCS heat supply is above building heat demand, but only at southern installation locations during the summer. When CHP FCSs are installed so that they have a high heat utilization, PNNL computer models indicate that they are more economical and more environmentally benign.



**About 1/3<sup>rd</sup> of project costs are generally covered by PNNL, our industrial partners, and combined state and federal incentive tax credits (ITCs).**



Both state and federal incentives are typically needed to make FCSs cost competitive with CA power.

## Collaborations

**FCS company provides all FCSs. Commercial entities and communities host installation sites.**

Partner	Description	Sector	Cost Share [\$]	Cost Share [%]
FCS Manufacturer	FCS Provider	Industry	\$1,128k	36%
Recreation A	Community Center	Local Gov.	\$245k	40%
Grocery Store	Grocery Store	Commercial	\$143k	33%
Manufacturing	Manufacturing	Commercial	\$136k	32%
Recreation B	Swim/Tennis Club	Commercial	\$133k	32%
College	College	Local Gov.	\$106k	56%
Housing A	Real Estate Investment Trust	Commercial	\$77k	42%
Hotel B	Hotel	Commercial	\$77k	31%
Housing B	Affordable Housing	Non-profit	\$72k	36%
Nursery	Nursery	Commercial	\$71k	30%
Hotel A	Hotel	Commercial	\$68k	30%

Collaborators include successful organizations operating hotels, retail, recreation, education, real estate, manufacturing, and community buildings.



*Proudly Operated by Battelle Since 1965*

# Remaining FY 11 Activities

- ▶ Award contract in May to FCS manufacturer
  - Attend kick-off meetings with installation site partners
  - Fuel cell systems become operational in September
- ▶ Review additional proposals and develop more contracts
- ▶ Prepare for data acquisition and analysis
  - Design data acquisition methodology and process
  - Develop data analysis models
    - Analyze CHP FCS operational performance (i.e. electricity and recoverable heat outputs)
    - Employ Energy Network Optimization (ENO), AspenPlus™
- ▶ Present preliminary analysis at fuel cell conferences
  - European Fuel Cell Forum – Lucerne, Switz., June
  - ASME Fuel Cell Conference – Washington DC, Aug.



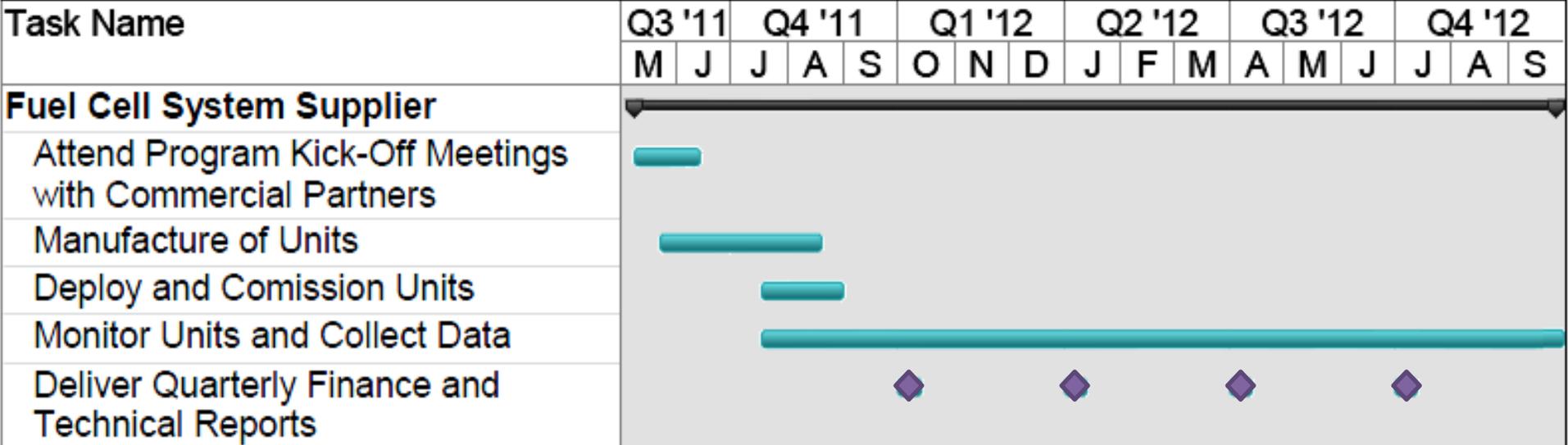
### Activities for FY 12

- ▶ Provide critical analysis of CHP FCS performance
  - Publish peer-reviewed journal articles, reports
- ▶ Objectively measure and report evaluation of engineering, economic, and environmental criteria
  - Engineering: electrical and heat recovery efficiencies, electricity and heat capacity utilization, availability, mean time to failure (MTTF), mean time between failures (MTBF), etc.
  - Economic: net present value (NPV), internal rate of return (IRR), payback, energy costs to customer, operating and maintenance costs, etc.
  - Environmental: GHG and air pollution emissions, GHG mitigation costs, human health costs due to air pollution, etc.
- ▶ Continually update and improve data analysis models
- ▶ Present results at fuel cell conferences
  - Fuel Cell Seminar & Expo. – Orlando, FL, Oct.
  - Piero Lunghi Conference – Rome, Italy, Dec.



Proposed Future Work

**Gantt chart shows FCS manufacture's FY11 and FY12 tasks. They will deploy and commission FCSs at installation sites by the end of FY11.**

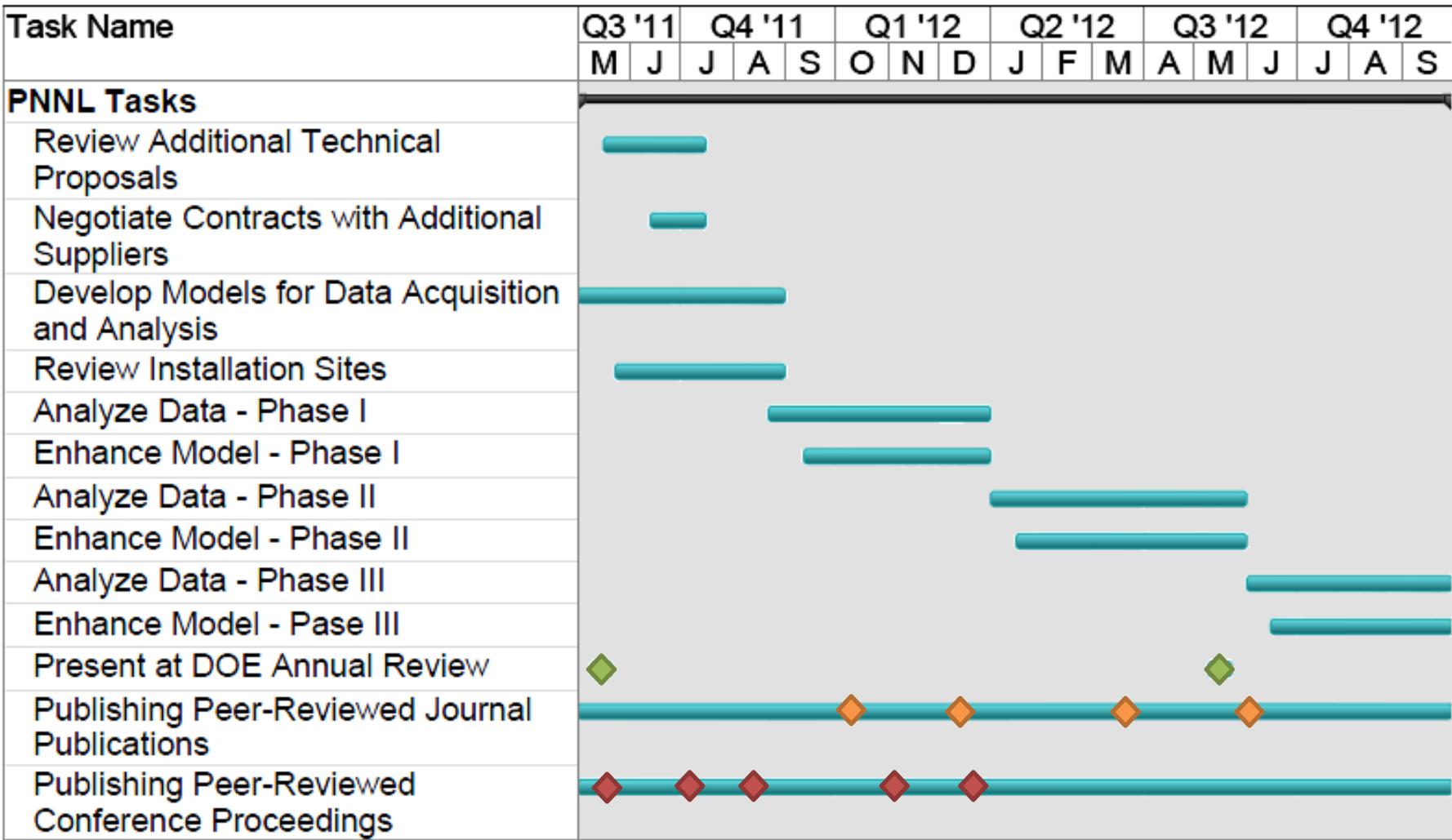


Upon contract completion in May FY11, project meetings with installation site owners begin.



# Proposed Future Work

## Gantt chart shows PNNL FY11 and FY12 tasks.



PNNL is now preparing models for analysis of manufacturer data. Before FCSs are operational at the end of FY11, PNNL will have completed the first phase of these models. In FY12, PNNL will continually update these models in second and third phases.



18 ◆ European FC Forum, ASME FC Conf., FC Seminar, Piero Lunghi Conf.

## Milestones and Deliverables Status

- ▶ Baseline Model Input Completion (Q4, FY10)
  - Status: **Completed in Q1, FY11**
- ▶ Completion of detailed CHP FCS Program Plan (Q4, FY10)
  - Status: **Complete**
- ▶ Go/No-Go decision based upon detailed program plan cost estimate (Q1, FY11)
  - Status: **Complete – Available funding commensurate with project cost estimates**
- ▶ Complete acquisition of CHP FCSs (Q3, FY11)
  - Status: **Upcoming**
- ▶ Install and commission Combined Heat and Power Fuel Cell Systems (Q4, FY11)
  - Status: **Upcoming**
- ▶ Complete monitoring of systems (Q4, FY16)
- ▶ Issue final documentation of demonstration (Q4, FY16)

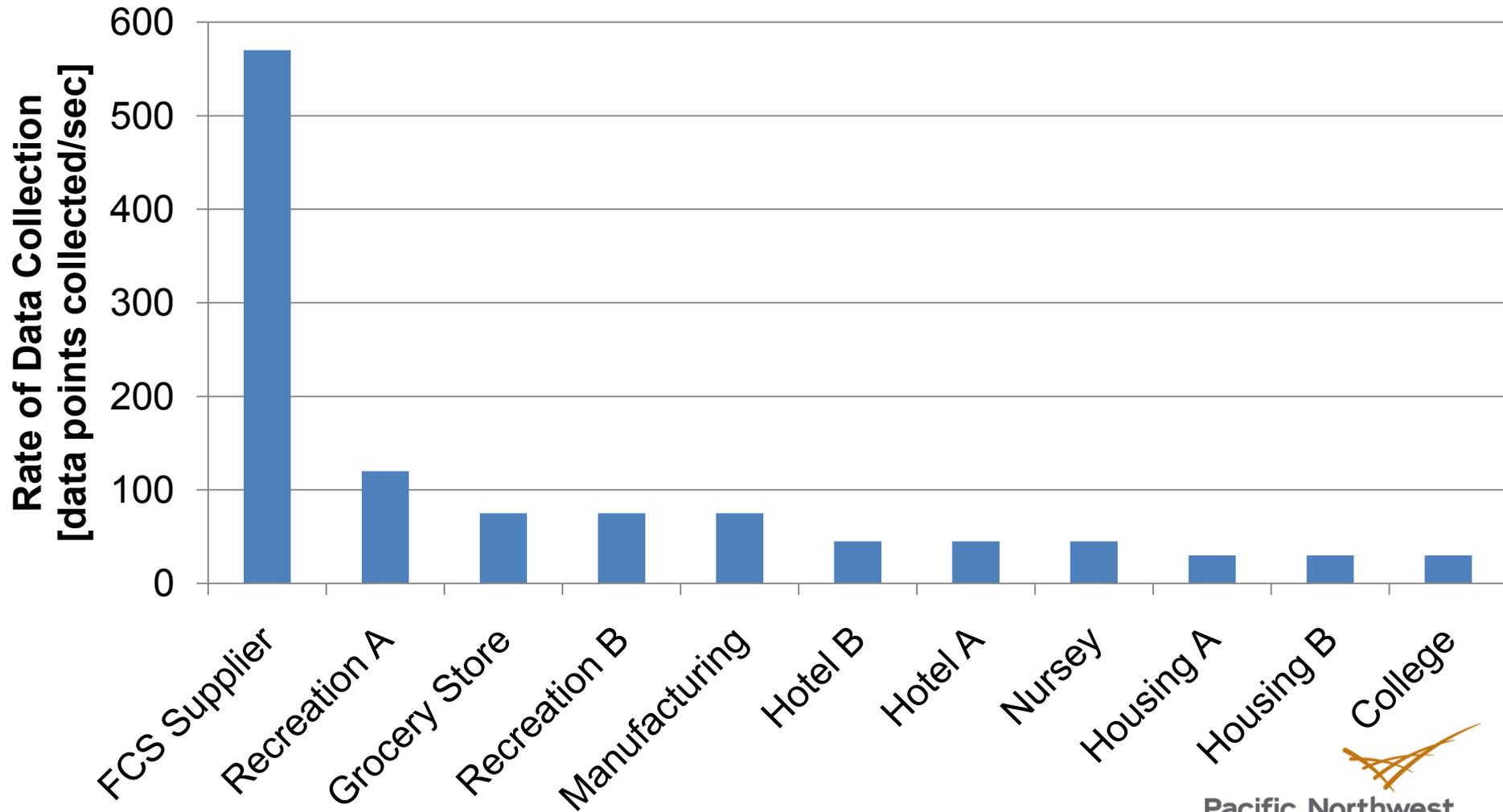


# **This project will demonstrate and objectively assess combined heat and power (CHP) fuel cell systems (FCSs) in commercial buildings.**

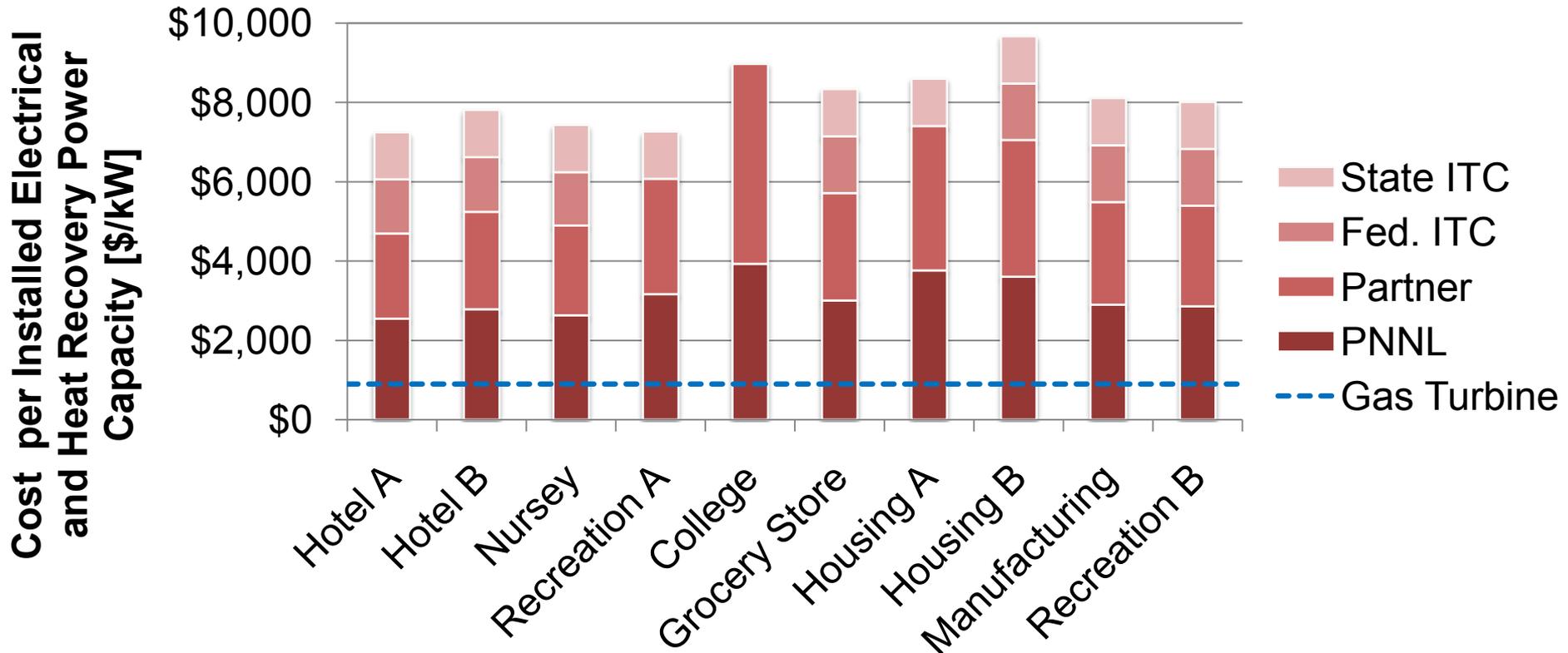
- ▶ The fuel cell manufacturer and commercial partners have been down-selected. A contract was issued in May FY11.
- ▶ CHP FCSs will be deployed and operational by FY11 end.
- ▶ PNNL will initiate data collection and analysis in FY11.
- ▶ PNNL will independently assess CHP FCS engineering, economic, and environmental performance.
- ▶ PNNL will compare stated manufacturer performance data against measured data from field installations that are continuously monitored.
- ▶ PNNL will benchmark measured performance data against current DOE FCT Program technical targets and estimates of technical potential so as to guide development of new ones.

# Technical Back-Up Slides

**PNNL will collect operating data from every FCS installed, in real-time, at one second intervals.**



# Cost per installed power capacity quantifies the economic barriers between fuel cell technologies and existing power generation.



Gas turbine cost includes capital and installation costs but not fuel and maintenance costs, or electricity transmission, distribution, and supply costs.



# FSCs have a higher combined capital and installation cost per unit of installed capacity compared to gas turbines.

