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Innovation for Our Energy Future

Adapting the H2A Hydrogen Production Cost Analysis Model to Stationary Applications

Michael Penev

National Renewable Energy Laboratory

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Overview

Timeline

Project start date

– January 2008

Project end date

– H2A Power Model v1.0 Completed Sep. 08

– H2A Power Model v1.1 Complete Sept. 09

Percent complete

– Work on version 1.1 is 85% complete

Barriers

Section 4.5 of the Program's RD&D Plan

B: Stovepiped/siloed analytical capabilities

C: Lack of consistent data, assumptions, and guidelines

E: Unplanned studies and analysis

Budget

Total project funding for version 1.0 and 1.1 of the H2A Power Model

$330K to NREL

Funding received in FY08

$130K

Funding for FY09

$200K

Partners

H2A Team:

DOE

NREL

Directed Technologies, Inc.

Partners/Reviewers:

DOE FE

Fuel Cell Energy

UTC Power

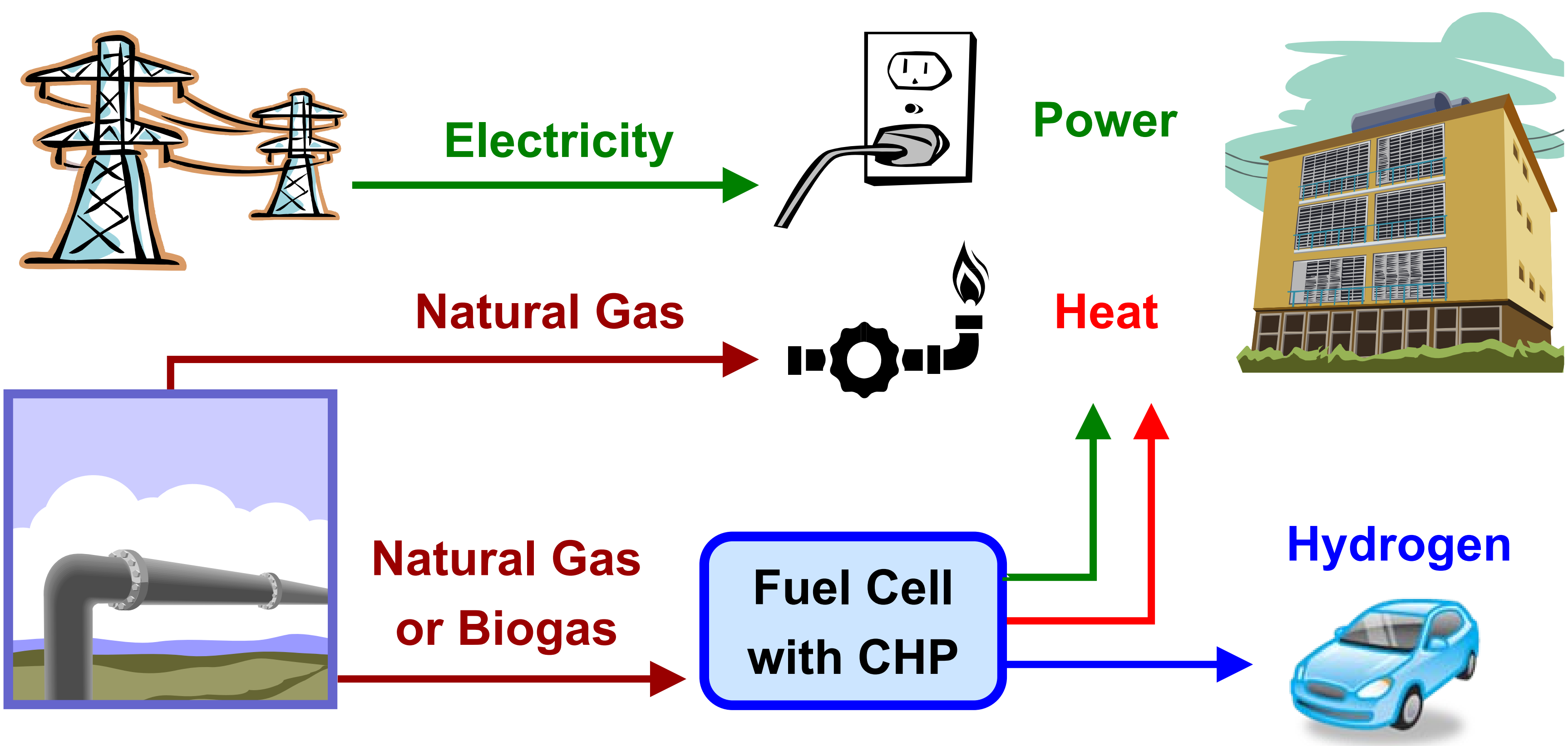
Plug Power

ANL, SNL

Relevance – H2A Power Model Allows Transparent and Consistent Analysis of New Transition Strategies

Hydrogen infrastructure costs for early transition phase are large, and are relatively high risk due to uncertainty of demand

Combining hydrogen production with CHP capability may reduce upfront costs and reduce investment risks



Relevance – Overview of Distributed Tri-Generation Advantages

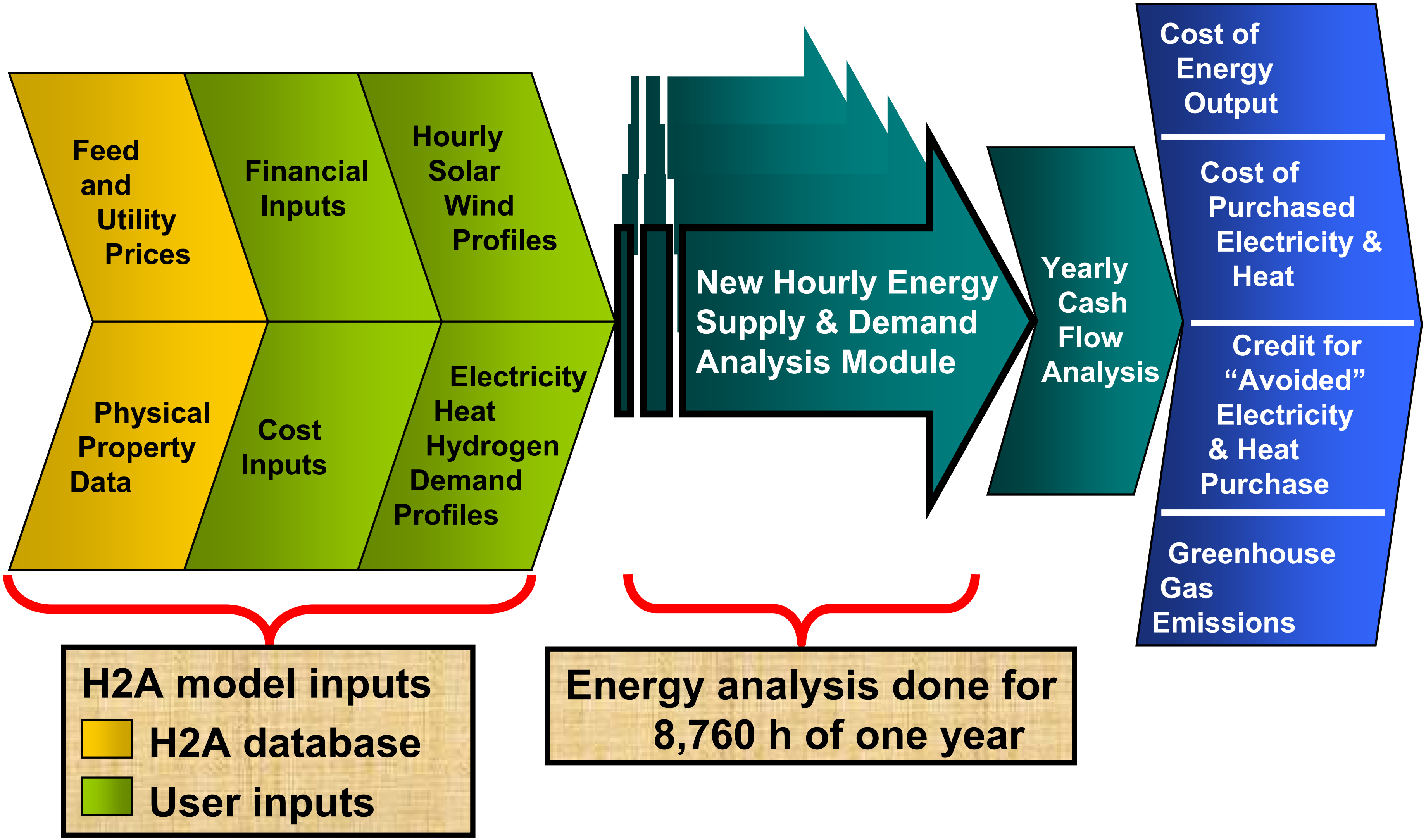
Advantages

- Potential for lower hydrogen production cost
- Inherently distributed hydrogen production
- Lower fossil energy use
- Lower greenhouse gas emissions
- Reduced electricity transmission congestion
- Lower capital investment risk
- Backup power functionality

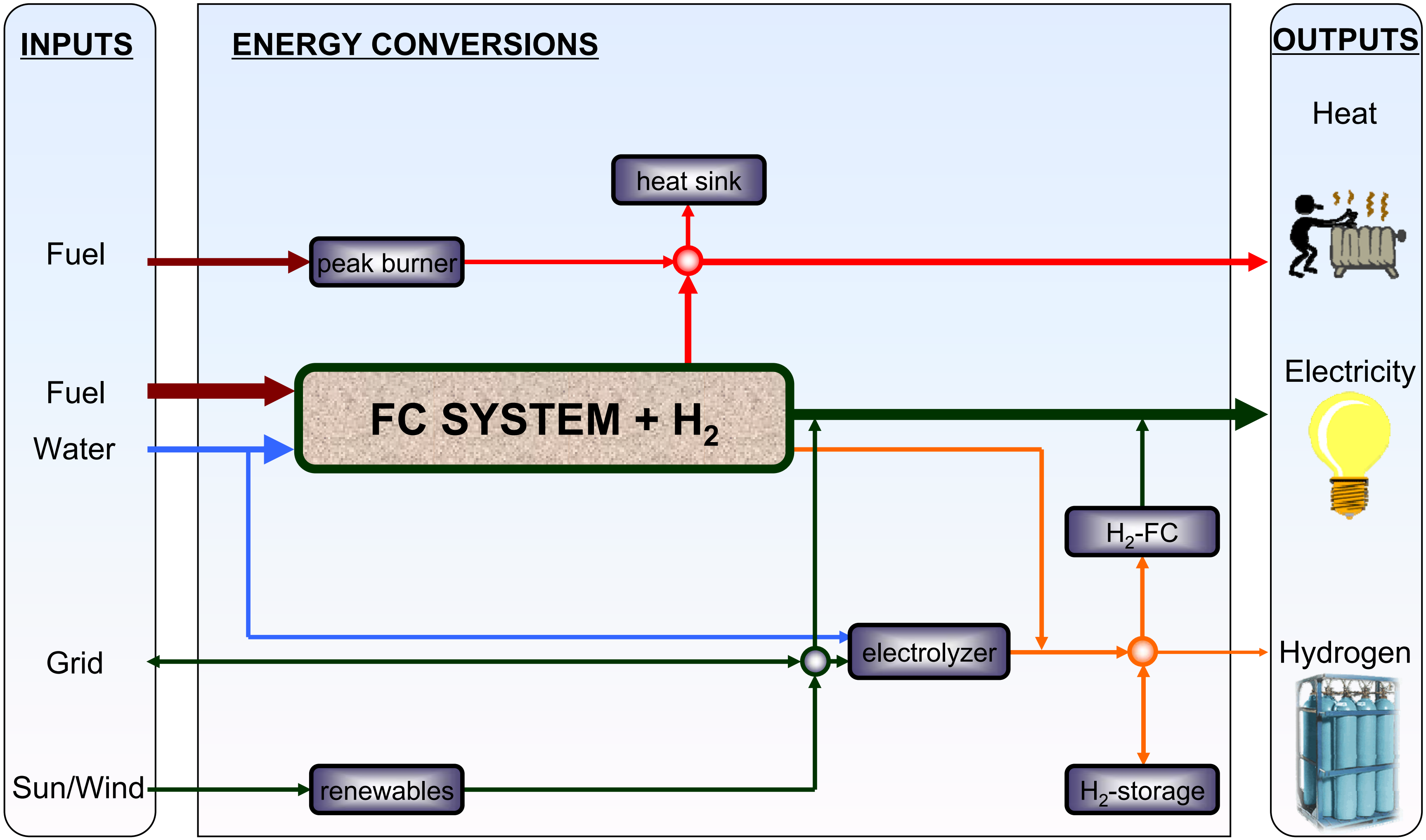
Analysis Requirements

- Above advantages depend on specific building types, locations, utility interaction, economic incentives.
- Capturing these dependencies requires flexible, hourly modeling.

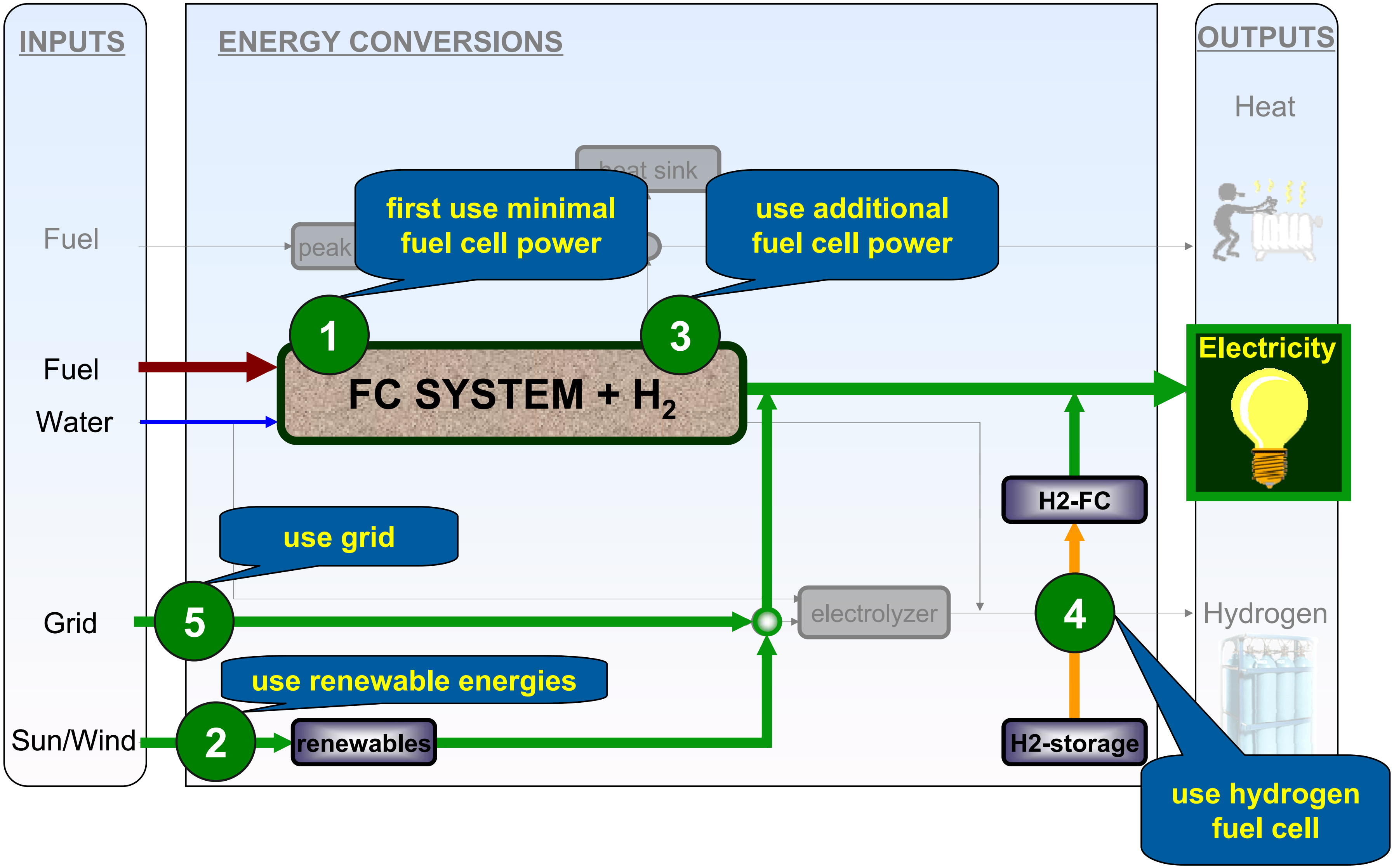
Technical Approach - H2A Power Model Hourly Energy Analysis Module Was Added



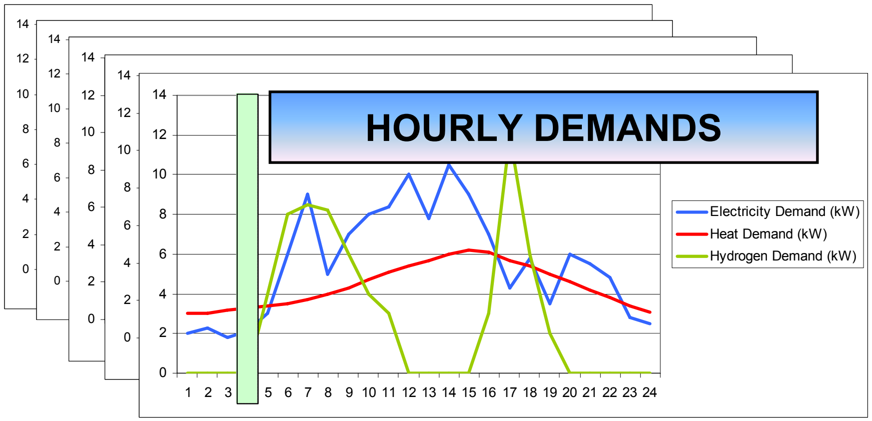
Technical Approach – Technologies Selection for Hourly Energy Analysis



Technical Approach – Example Dispatch Priority Sequence for Electricity Generation



Technical Approach – Integration of Demand Profiles, Renewables Availability, & Grid Cost Structure

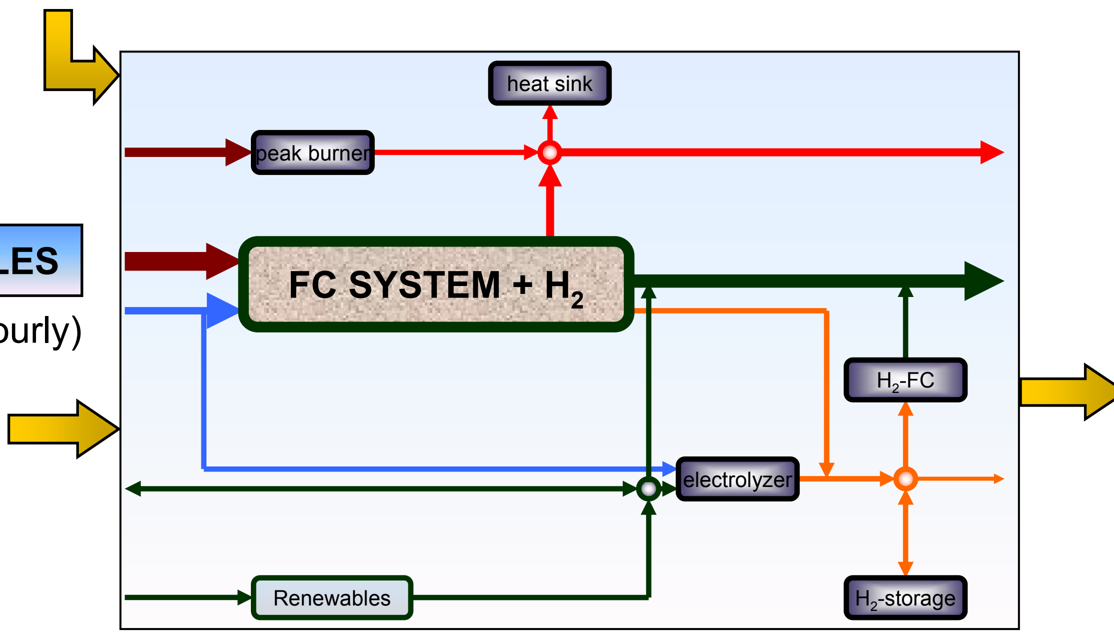


Enter Process Specifications (default values will be provided)

Download or enter hourly demand profiles
Download or enter hourly renewable energy profiles
Enter grid electricity price profile (peaking price structure)
Enter equipment capital costs
Enter equipment capacity, operating parameters and operating costs

PRICE SCHEDULES

- Grid electricity (hourly)
- Fuel prices
- Water price



ENERGY FLOWS ($)

- Delivered electricity
- Delivered heat
- Delivered hydrogen
- Used fuel
- Used grid electricity
- Sales to grid

Technical Accomplishments – Model Features Implemented FY09

H2A Power Model Functionality Enhancements

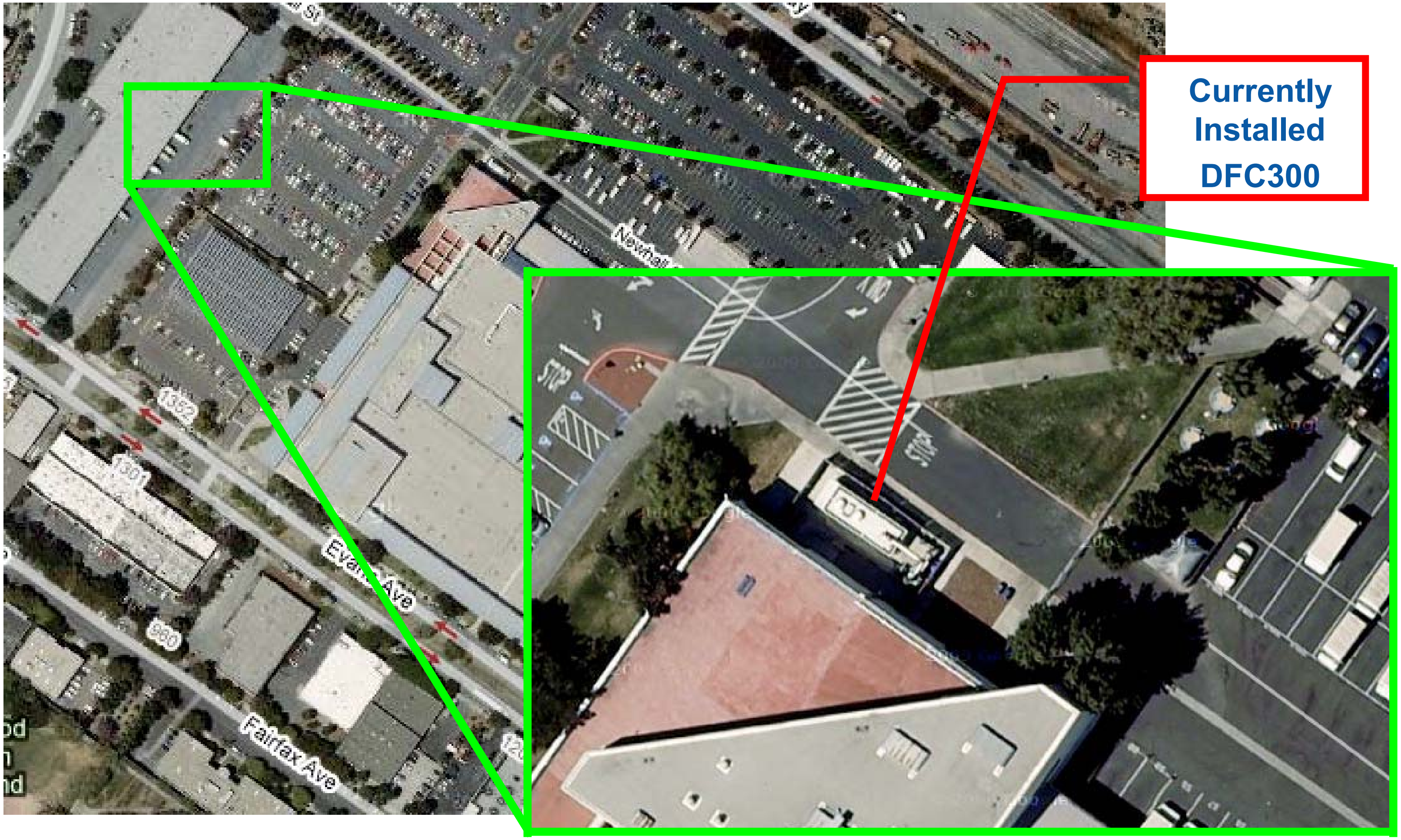
- Standard building load profiles can be imported
- Solar and wind resource data can be imported
- Individual depreciation for all components has been implemented
- Analysis of economic incentives has been incorporated
- Detailed grid power purchase structure is included
- Net metering functionality has been added
- GHG tables from GREET 1.7 have been incorporated
- Financial summary sheet has been added
- Sensitivity / tornado chart capability is available

Technical Accomplishments – Model Enhancements Implemented FY09

H2A Power Model Developments

- Default MCFC fuel cell model based on fuel cell energy systems
- Default PAFC fuel cell model loosely based on UTC
  (H_2 co-generation is not pursued by UTC)
- Users guide generated
- Training provided for initial user group
- Initial peer review performed & model peer feedback incorporated
- Second round of peer evaluation on-going

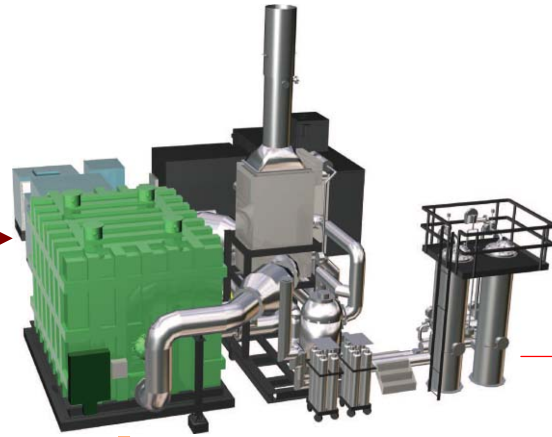
Technical Accomplishments – Hypothetical Case Study USPS San Francisco



- Facility profiles used to evaluate a tri-generation system
- H_2 would be used for forklifts and public dispensing

Technical Accomplishments – Example Case Study – System Configuration Evaluated

Natural Gas



~1.4 MW Electricity

~400 kW Heat

~540 kg/day Hydrogen

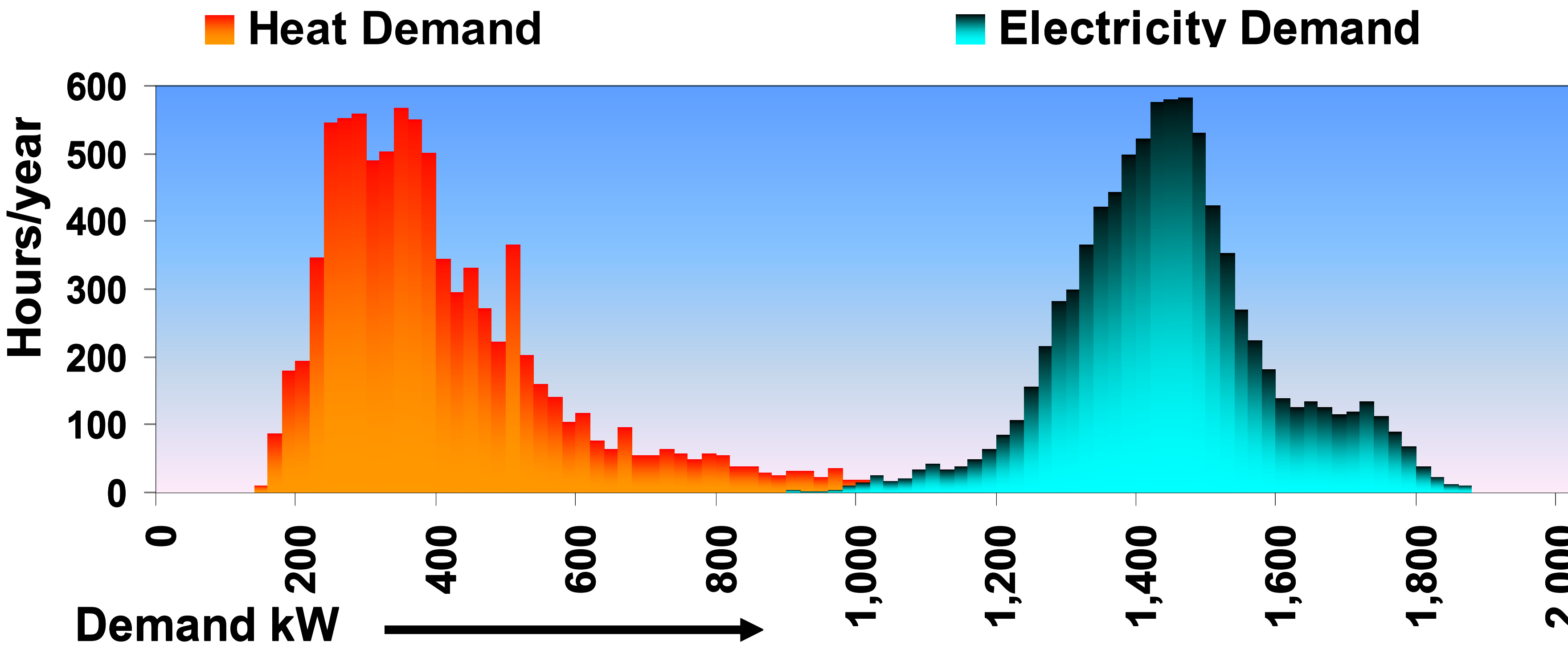
~15 F.C. Forklifts + 15 Tugs

~60 kg/day

~480 kg/day

~1,000 F.C. Vehicles

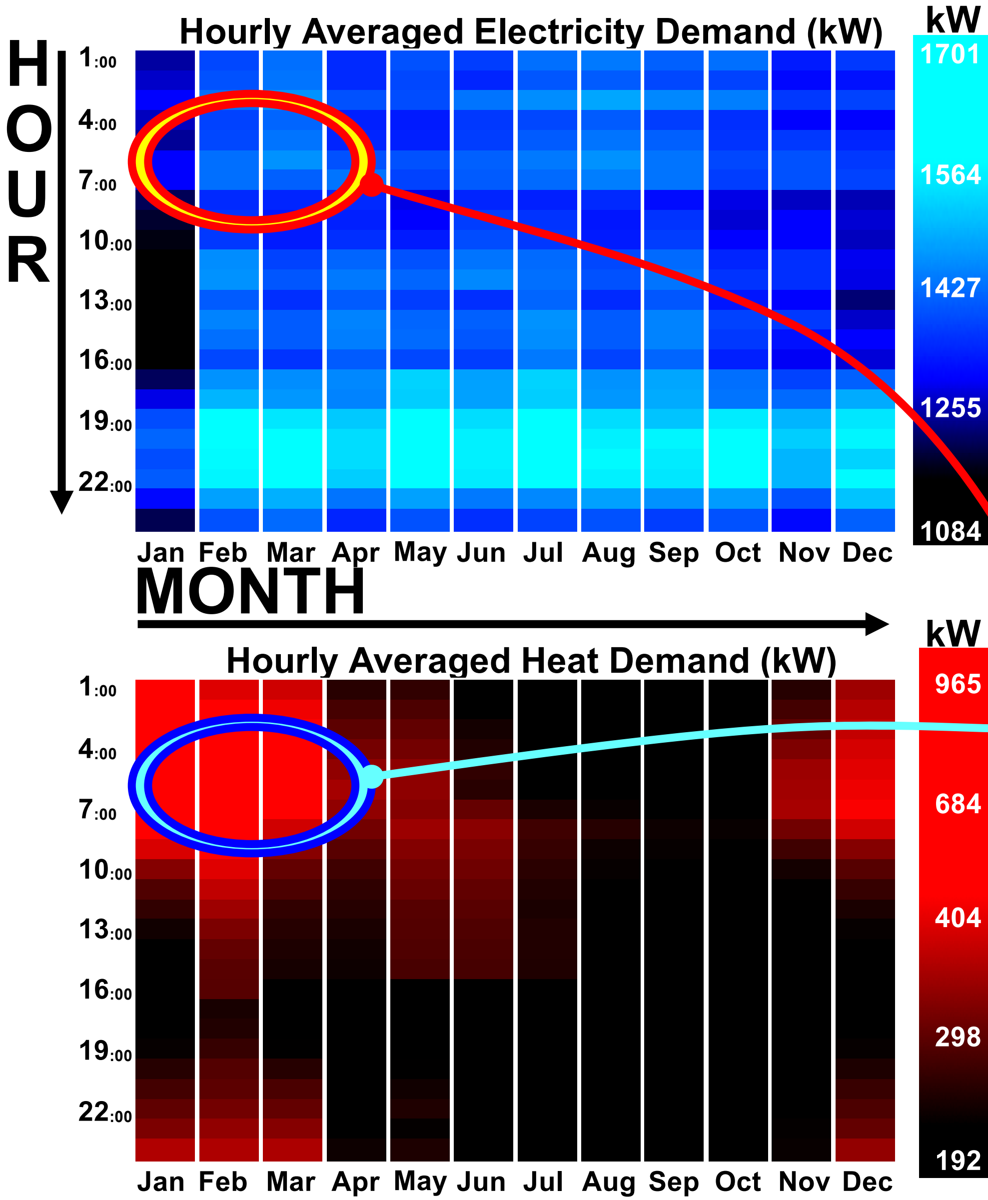
Technical Accomplishments – Example Case Study – Heat and Electricity Demand Distribution



Annual Building Heat & Electricity Demands

- Average heat demand = 400 kW
- Average electric demand = 1,450 kW
- 1.4 MW fuel cell chosen for the case study

Technical Accomplishments – Example Case Study – Annual Heat and Electricity Demand Distribution

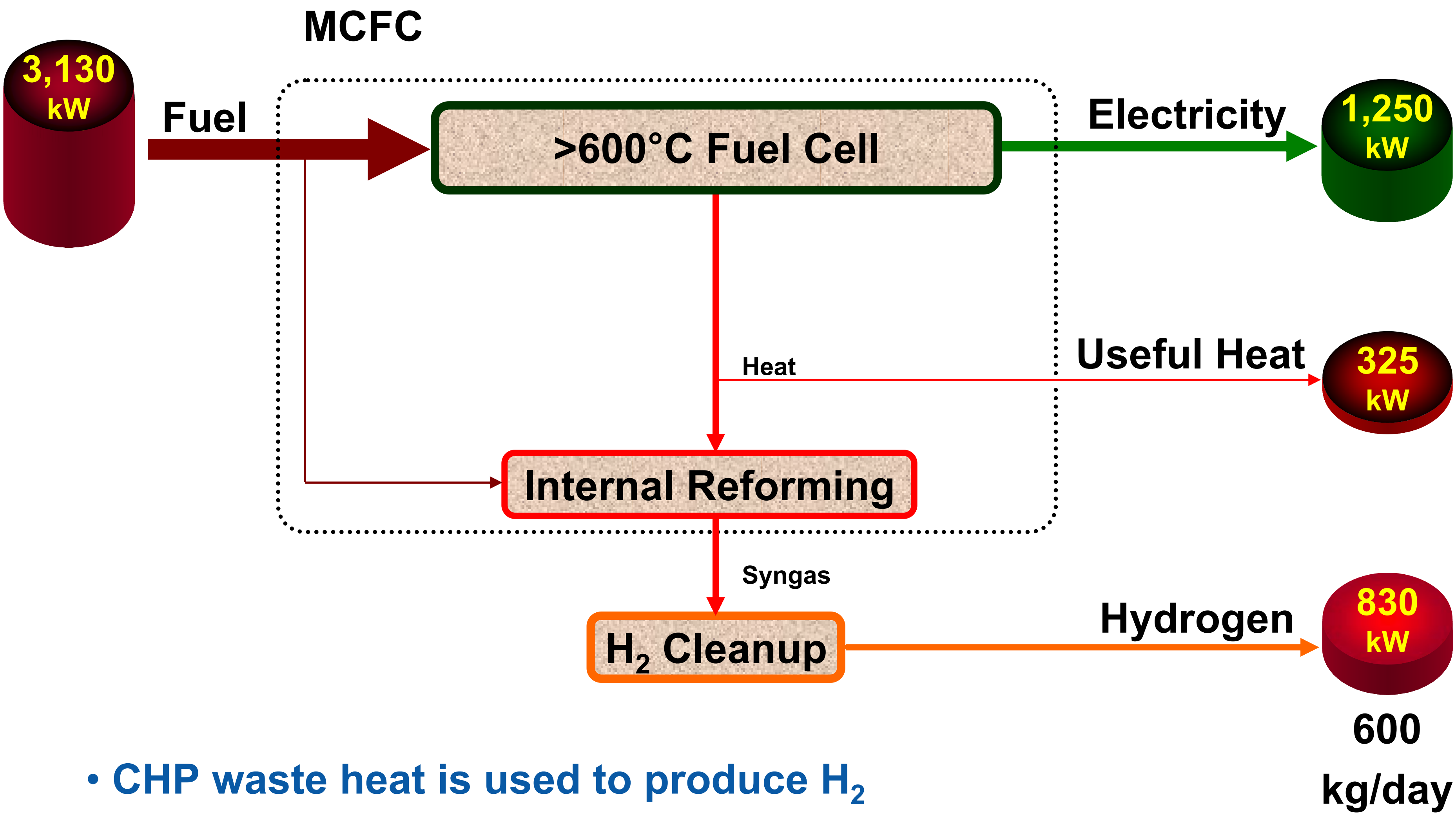


Electricity demand supports 3-shift operation resulting in relatively flat profile.

Heat and electricity demands are mismatched

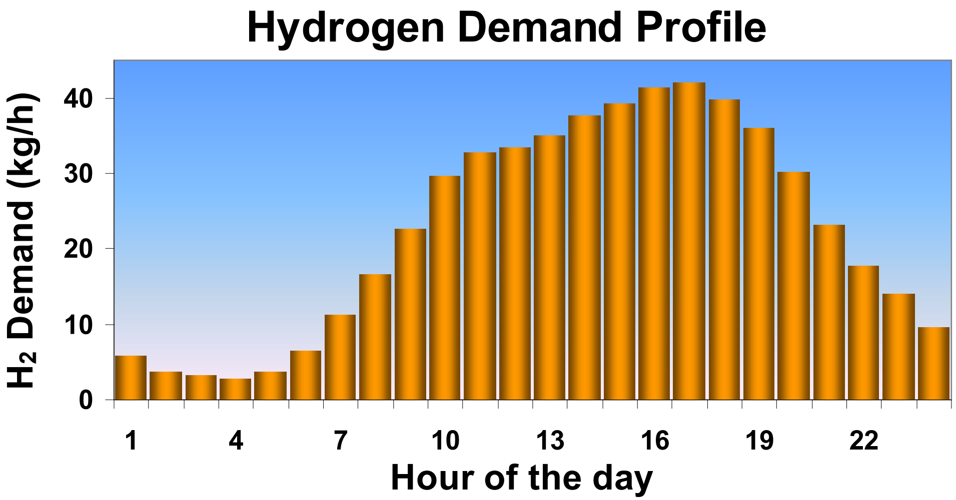
Heating demand is highest during winter mornings.

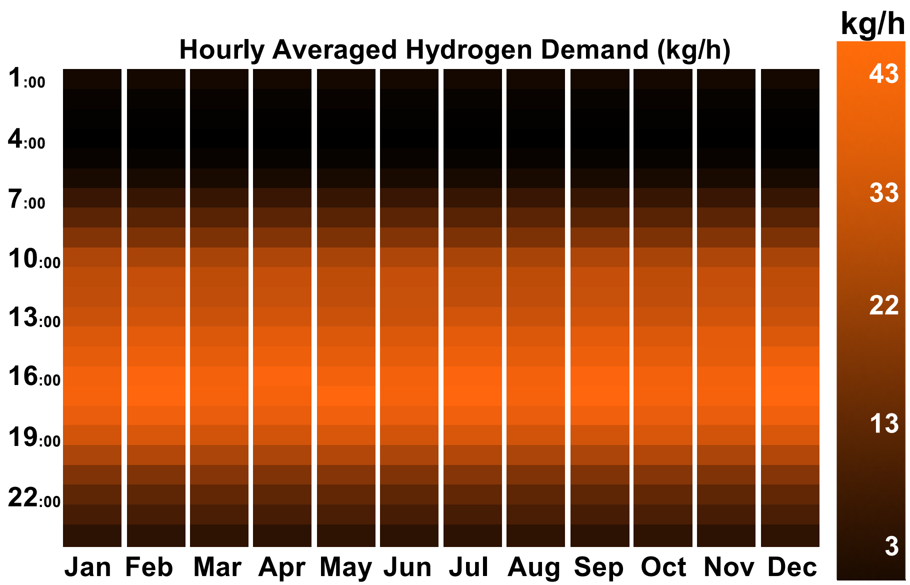
Technical Accomplishments – Example Case Study – Molten Carbonate Fuel Cell H_2 Co-Production



- CHP waste heat is used to produce H_2
- H_2 co-production technology is in the prototype stage

Technical Accomplishments – Example Case Study – Hydrogen Demand Distribution





- H_2 demand profile is used from the H2A distributed generation model
- Demand was scaled to 540 kg/day
- Hydrogen demand profile is a 24h profile repeated throughout the year

Technical Accomplishments – Example Case Study – Analysis Inputs & Assumptions

Fuel Cell System Performance Parameters (FCE Supplied)

• System Electric Efficiency	= 49%	LHV Basis
• System Size	= 1,400	kW
• System H_2 Rating	= 540	kg/day
• Stack Life	= 5	years
• System Life	= 25	years
• Restacking	= 30%	of installed cap cost
• O&M (non-stack)	= 1.5%	of installed cap cost annually
• System Installed Cost	= 2,000 to 5,000 $/kW	
• Tri-gen Module Cost	= 25% of System Installed Cost	

Compression, Storage, Dispensing

• Number of Compressors	= 2	@ 6,250 psig
• Storage amount	= 540	kg
• Number of Dispensers	= 2	@ 5,000 psig
• Total CSD Cost	= 920,000	$

Operation Assumptions

• System operating hours	= 8760	h/year
• Natural Gas Cost	= 10.6	$/mmBTU
• Value of Heat	= 50%	of CHP electricity cost ¢/kWh
• Financing	= 100%	Equity financing

Technical Accomplishments – Example Case Study – Cost Separation For CHP and Hydrogen

First, run model with CHP only

NG

Electricity

Heat

Determine costs of electricity & heat ¢/kWh

Second, run model with H_2

NG

Electricity

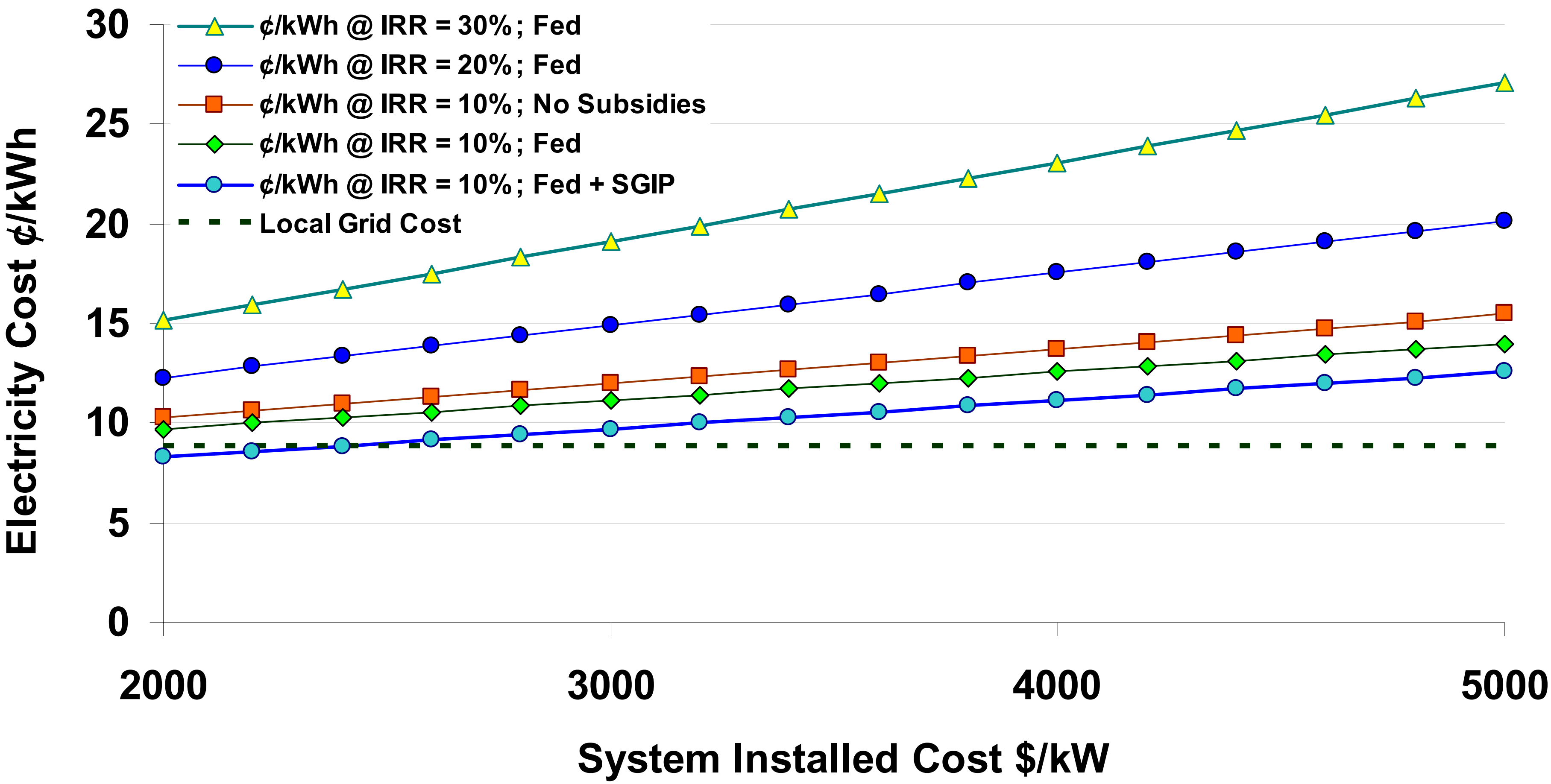
Heat

Hydrogen

Determine marginal cost of hydrogen $/kg

(Cost of electricity and heat is held constant from CHP-only run)

Technical Accomplishments – Example Case Study – Costs of Electricity vs. System Cost, IRR & Incentives

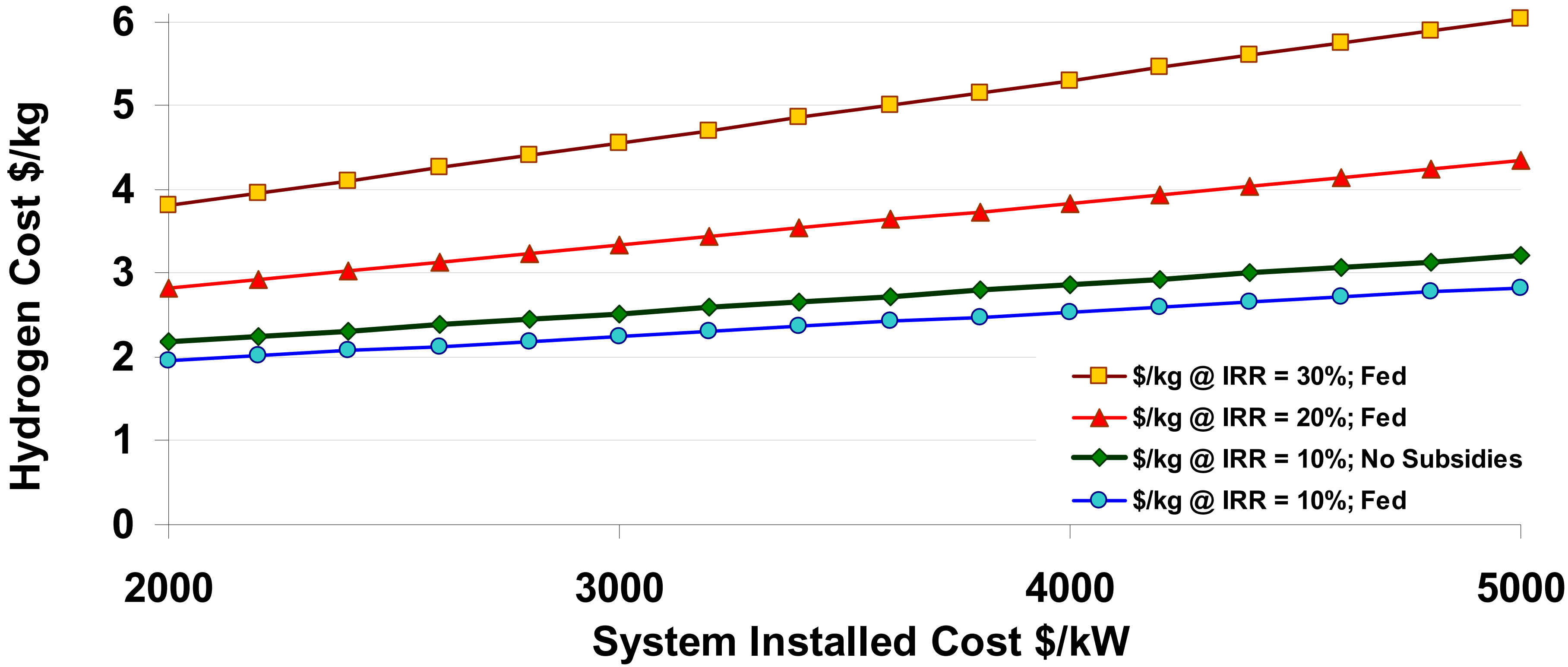


IRR = Real After-Tax Internal Rate of Return

SGIP = Self Generation Incentive Program = 2,500 $/kW

Fed = Federal Incentives = 30% or 3,000 $/kW, whichever is less

Technical Accomplishments – Example Case Study – Costs of Hydrogen vs. Internal Rate of Return & Incentives



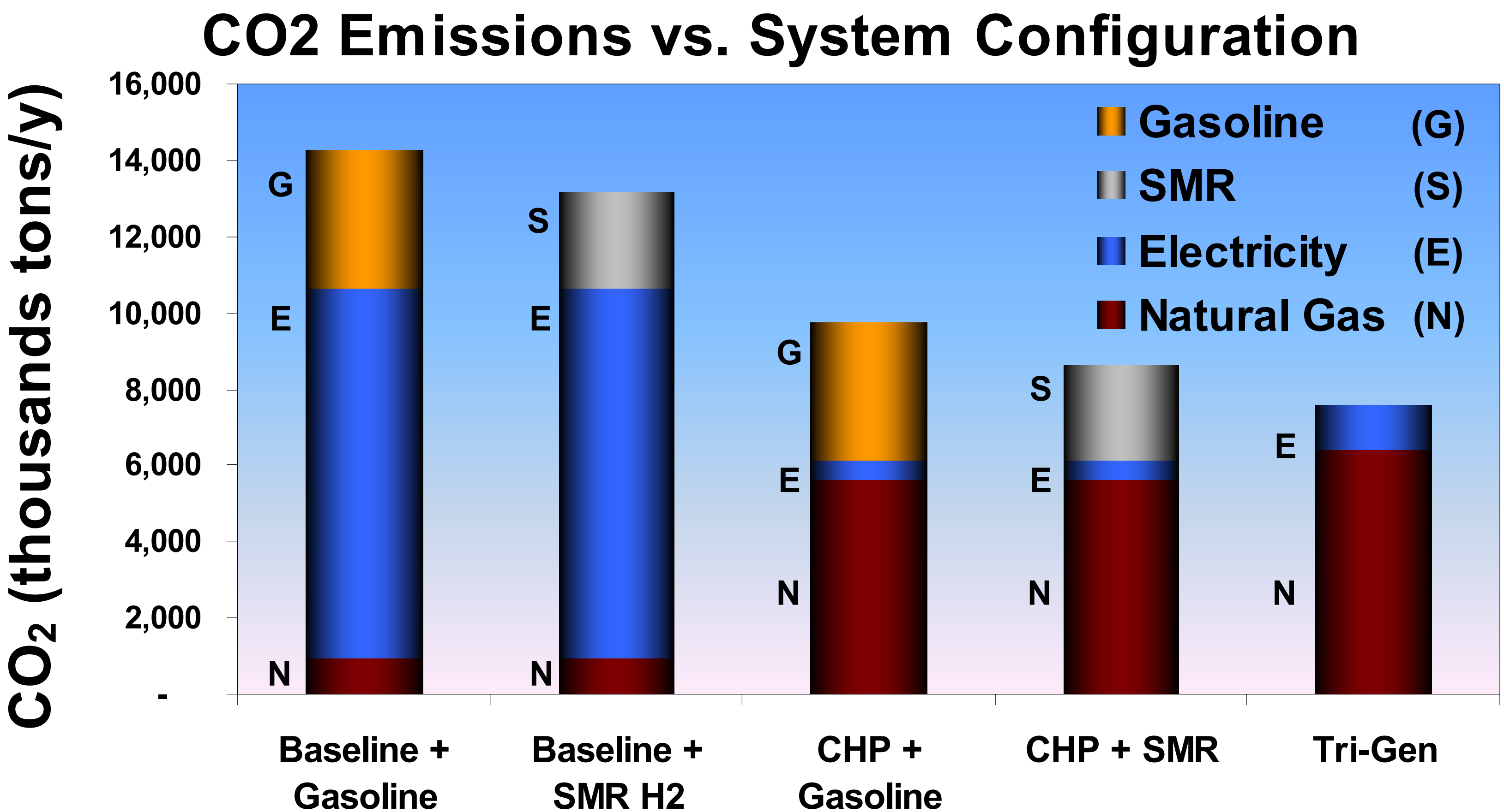
IRR = Real After-Tax Internal Rate of Return

Federal Incentives = 30% or 3,000 $/kW, whichever is less

NOTE: SGIP has no effect on cost of hydrogen

Hydrogen is dispensed locally, and no additional transportation costs incurred

Technical Accomplishments – Example Case Study – Greenhouse Gas Emissions Impact



Assumptions: 1 kg H_2 displaces 2 gal gasoline

SMR = Steam Methane Reformer

Special Thanks to our Collaboration Partners

- Fuel Cell Energy
- UTC Power
- Plug Power
- USPS
- Directed Technologies Inc.
- Sandia National Lab
- Argonne National Lab
- Materials Handling Group
- DOE Market Transformation
- DOE Systems Analysis

Future Work & Model Support

Functionality and model support

- Detailed second-round peer review will be performed
- Absorption chiller capability will be added
- Training and documentation will be made available
- We will support and maintain the model

Model analyses

- Model will support infrastructure analysis
- Use model for support for market transformation
- Model will be integrated with the Macro Systems Model (MSM)

Summary

Relevance

- Model addresses alternative hydrogen production strategies for early market transitions
- Hydrogen co-production appears practical and economical

Approach

- The H2A discounted cash flow model has been modified to perform distributed generation analysis
- Hydrogen can be generated by electrolysis and fuel cell co-generation

Technical Accomplishments and Progress

- Model functionality has been significantly increased
- Model grounding with industry has been established
- First-round peer review has been performed and feedback incorporated
- Transportation and Stationary Power Integration workshop reviewed the concept
- Model guide has been generated

Collaborations

- Key industry and government partners have been engaged

Proposed Future Work

- Model maintenance, support and functionality improvements
- Scenario analysis and model use