National Renewable Energy Laboratory
Innovation for Our Energy Future

Distributed Hydrogen Technologies for Commercial Buildings and Vehicle Refueling

Ali A. Jalalzadeh-Azar

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Premise of Multi-Faceted Analysis

- Energy- and water-resource assessment is important for infrastructure development.

- Effective hydrogen utilization on the demand side can influence the economic and environmental attributes of hydrogen technologies.

- Use of a joint hydrogen production facility for stationary and transportation applications can provide an opportunity for overall cost reduction—a critical criterion for accelerating market acceptance.

Successful implementation of hydrogen technologies requires macro- and micro-level analysis.

Objectives

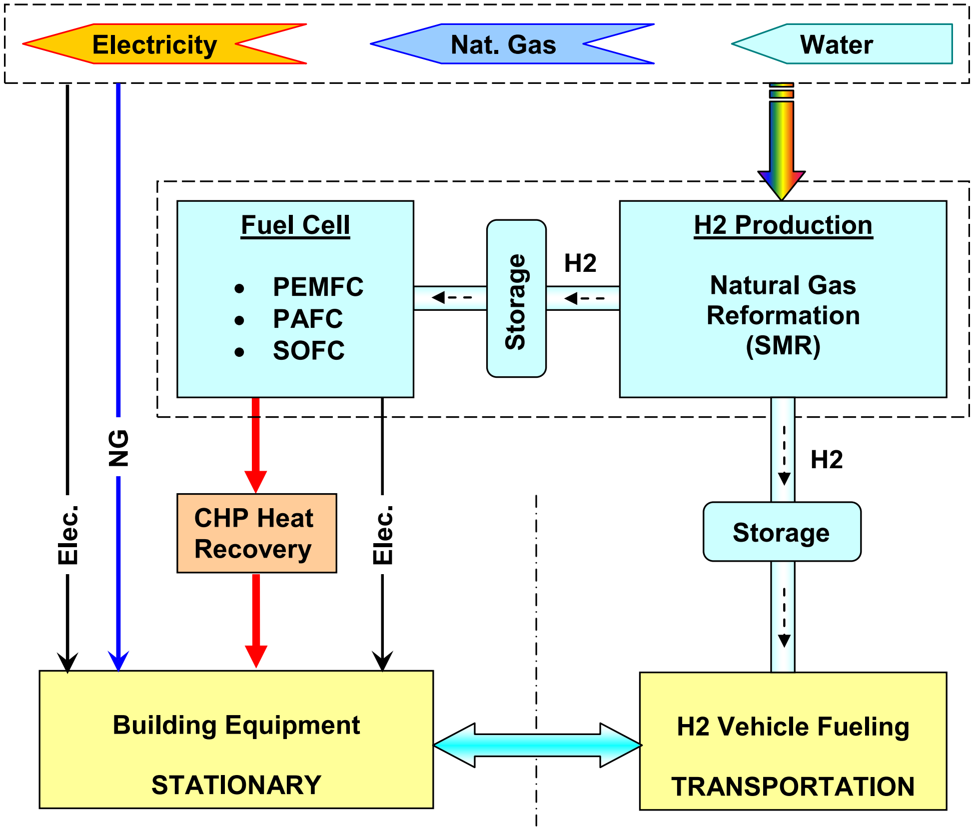
- Perform energy analysis of H2-based DG systems serving commercial buildings

- Address resource requirements—energy and water—for the DG systems.

- Investigate the potential economic benefits of integrated stationary and transportation applications in the context of tri-generation.

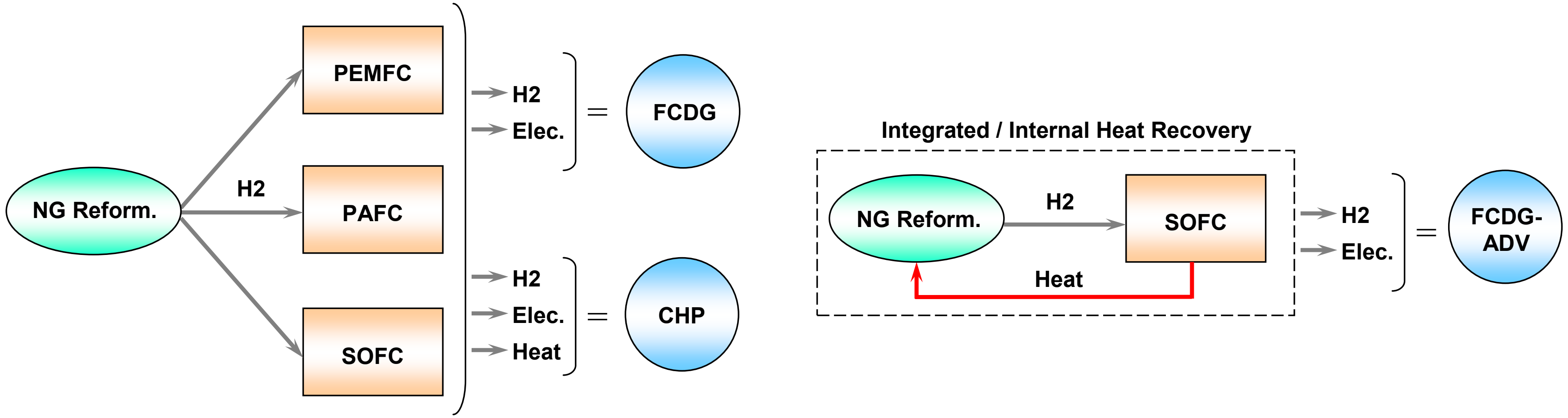
System Characteristics

- Distributed generation (DG) system consists of a steam methane reformer, and a fuel cell system—PEMFC, PAFC, or SOFC.
- DG system generates electricity for commercial buildings; excess H2 is used for refueling.
- Heat recovery from PAFC and SOFC is available for internal and external applications.



Approach

- Perform thermodynamic analysis of the three H2-based DG systems for commercial buildings using the DOE Benchmark Load Profiles:
  - ***FCDG:*** A basic system with no heat recovery—all FC types.
  - ***CHP:*** FCDG plus heat recovery for end-use equipment—PAFC and SOFC.
  - ***FCDG-ADV:*** Advanced system incorporating SOFC and internal heat recovery for H2 production



Approach (cont.)

- Extrapolate the results of system-level analysis for national-level assessment of resource requirements stemming from adoption of DG technologies for commercial buildings using the EIA data.

- Evaluate the primary energy and environmental impact of the DG systems.

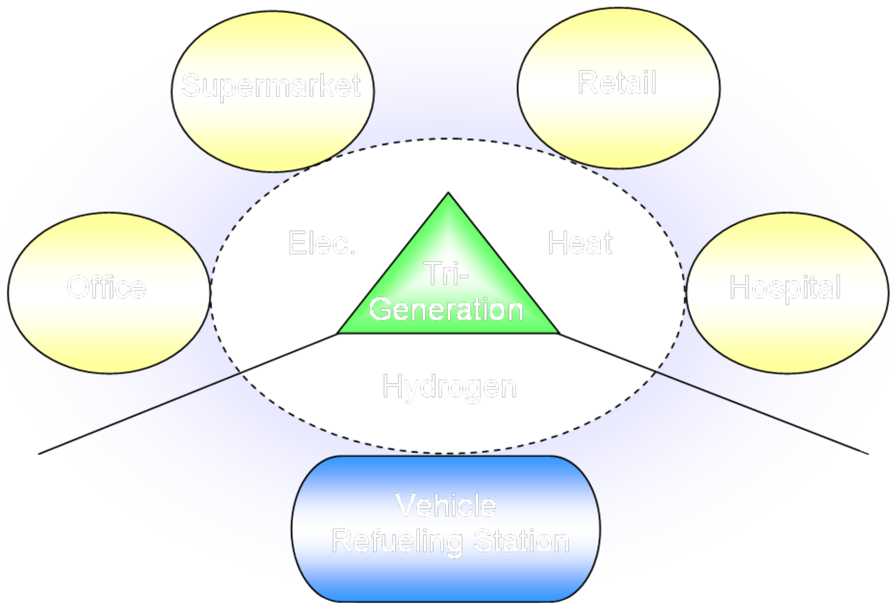
- Investigate the economics of a consolidated H2-production facility serving both stationary & transportation applications in commercial communities consisting of a H2 refueling station and an EIA-based group of buildings—hospitals, supermarkets, offices, and retails.

Approach (cont.)

Two models are conceptualized for integration:

- **Model I:** A properly sized H2 production facility for buildings also supplies the excess hydrogen during the off-peak periods to the community refueling station.

- **Model II:** The FCV refueling station is oversized in H2-production capacity to meet the aggregate demand of the buildings within the community.



Key Assumptions

System Category	Type	Efficiency [1]	Operating Temp. (°C)[1]	Application
Distributed Hydrogen Production	NG Reformer	0.75	N/A	FCDG, FCDG-ADV, and CHP
Distributed Power Generation	PEMFC	0.42	90	FCDG
	PAFC	0.48	190	FCDG and CHP
	SOFC	0.56	600	FCDG, FCDG-ADV, and CHP
End-Use Systems	Electric Cooling	3.0 COP	N/A	Baseline, FCDG, FCDG-ADV, and CHP
	Gas-fired Furnace/ Space Heating[2]	0.80 AFUE	80	Baseline, FCDG, FCDG-ADV, and CHP
	Gas-fired Service Hot-Water Heater[2]	0.62 AFUE	50	Baseline, FCDG, FCDG-ADV, and CHP

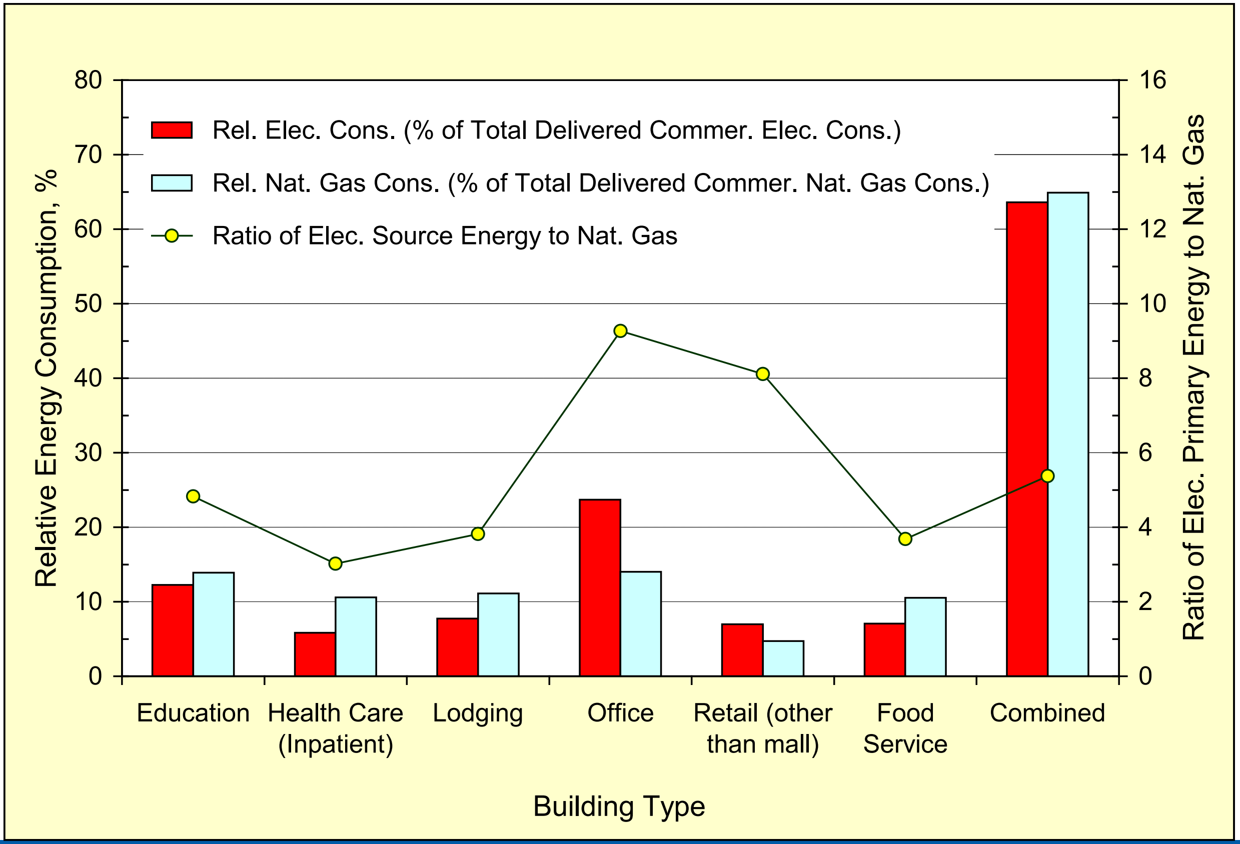
1. Nominal values
2. Gas-fired systems are retrofitted to accept non-combustion heat source in the CHP system

Results and Discussions

- EIA Data
- Resource Assessment
- Vehicle Fueling Capacity
- Energy and Environmental Benefits
- Economic Impact of System Integration

Relative Energy Use of Buildings—EIA Aggregates

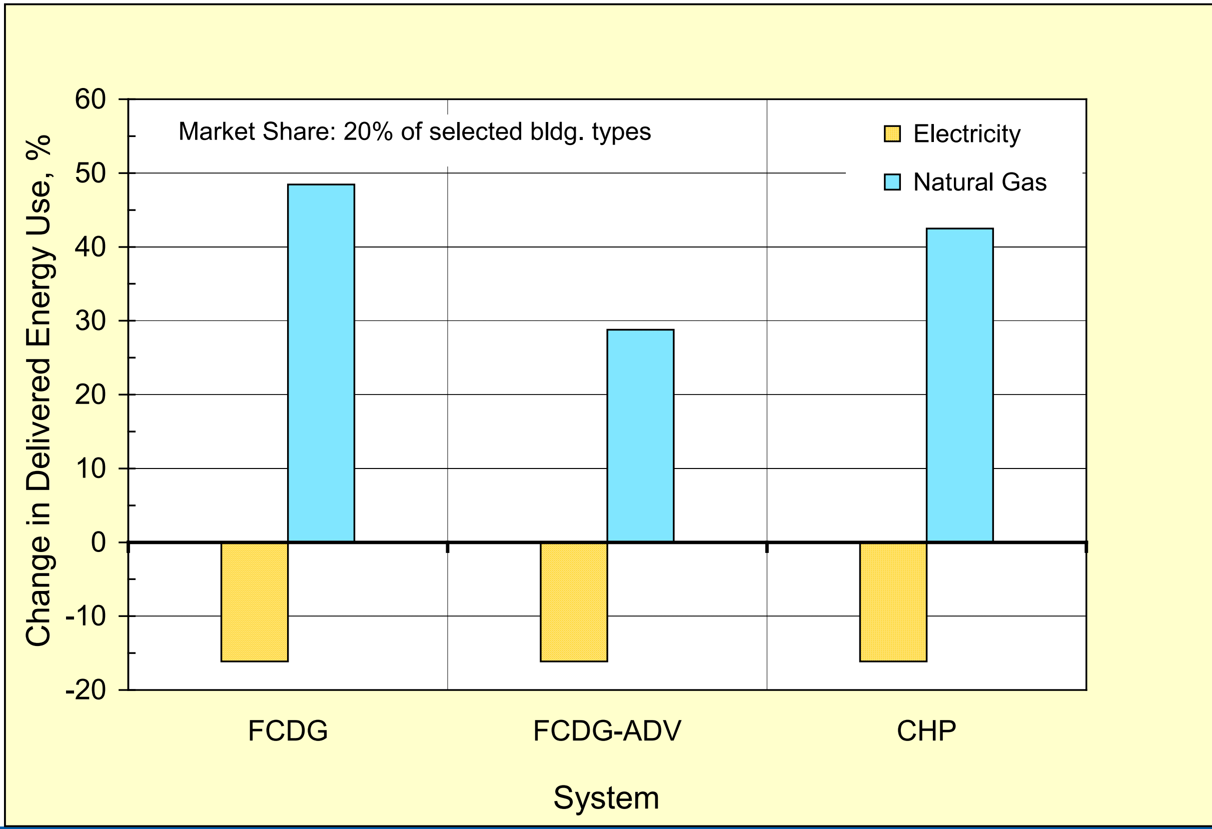
- EIA-aggregated electricity use of office buildings has he highest share—followed by education building type.
- On average, the primary energy for electricity generation is about 5.5 times the natural gas energy for selected building types.



Resource Assessment at 20% Market Share

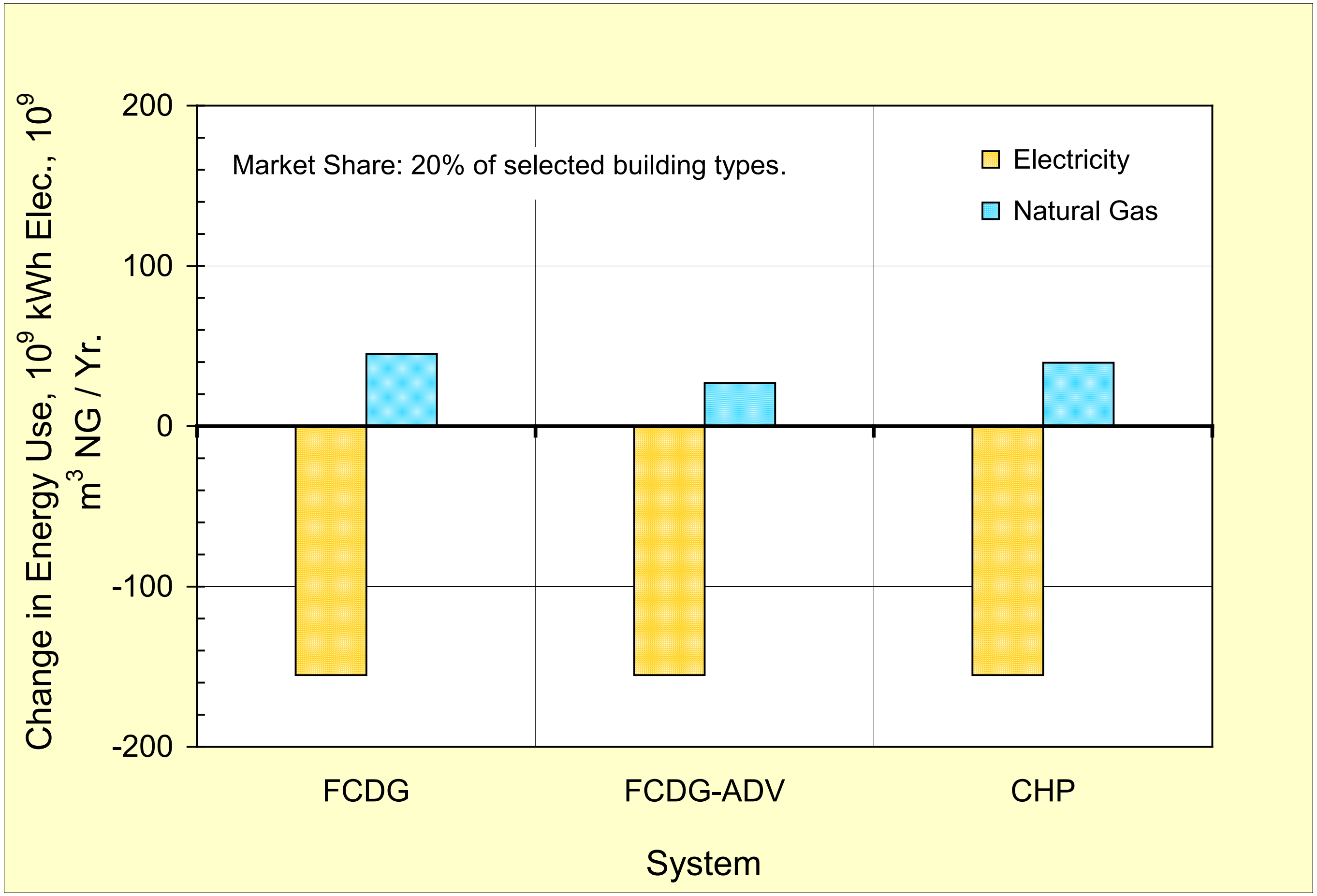
- About 16% reduction in the total grid-electricity use for commercial buildings is expected with any of the DG alternatives.
- Alternative FCDG-ADV requires about 29% more natural gas compared to 43% and 49% for CHP and FCDG, respectively.
- Water consumption increased by less than 3% at the site.

Note: An overall decrease in water usage is possible when considering the water-use displacement at the power plants.



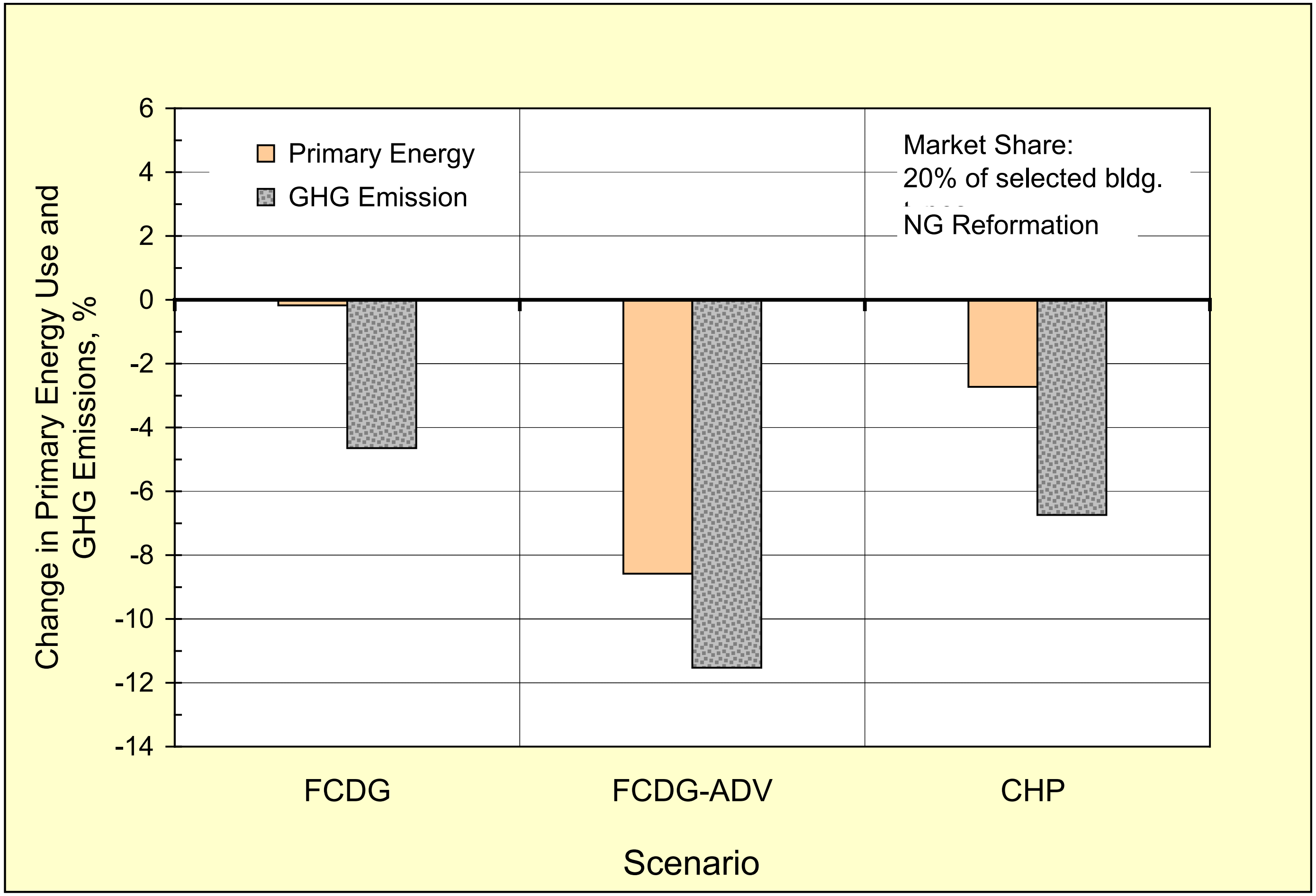
Resource Assessment (cont.)

- Resource requirements—absolute values.



Energy and Environmental Impact at 20% Market Share

- The advanced DG system, FCDG-ADV, offers the greatest reduction in primary energy use and GHG emissions, followed by the CHP system.

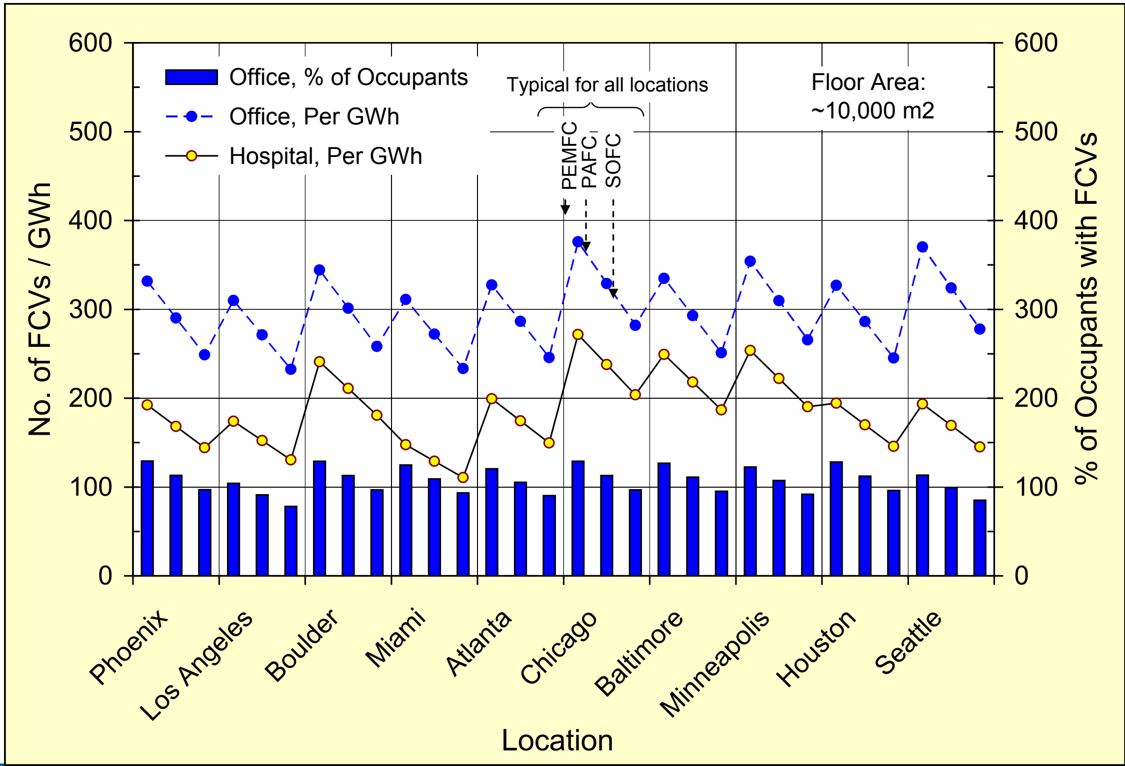


Vehicle Refueling Capacity / Model I—Building Level

- Under Model I integration, excess H2 capacity and the FC efficiency are negatively correlated. (The opposite will be the case for fixed H2 production rate for all FC types.)

- An office building offers a greater refueling capacity per GWh of the annual energy consumption than hospital.

- For office buildings, excess on-site H2 prod. can meet and even surpass the hydrogen demand of the occupants' FCVs (13,000 miles/yr at 50 miles/kg H2), Office occupancy: 1 person per 26 m^2.



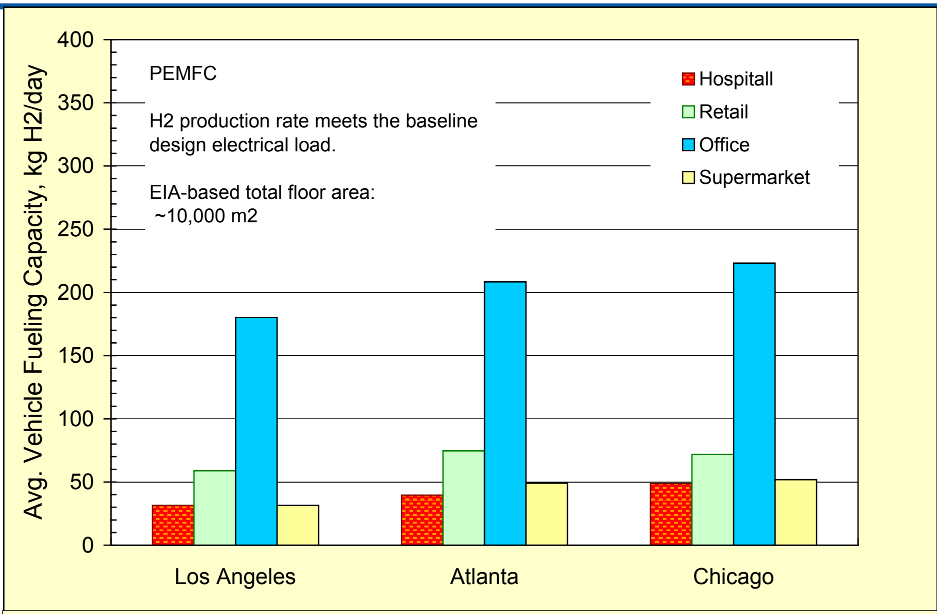
Vehicle Refueling Capacity / Model I—EIA Community

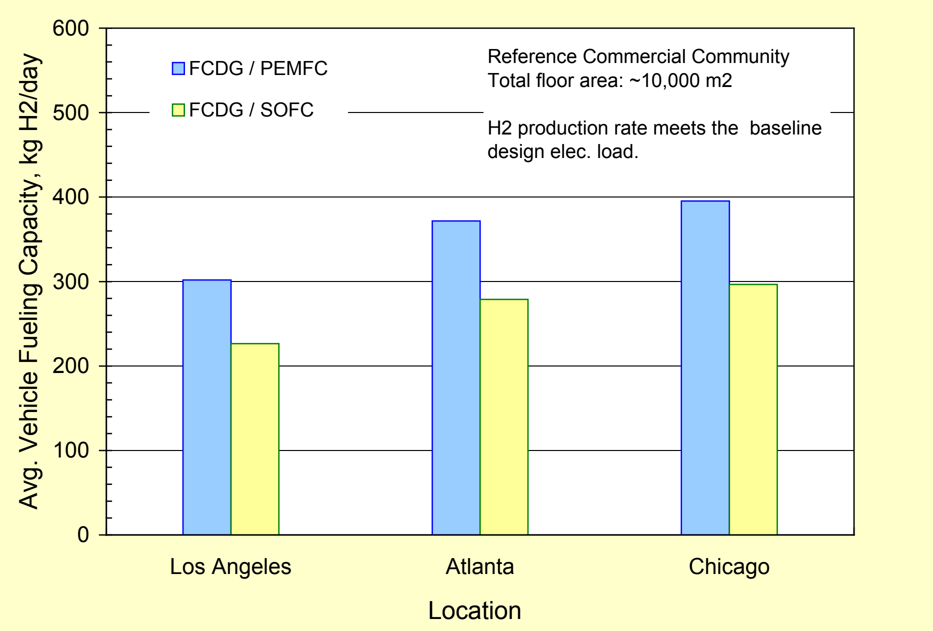
- Community of hospitals, retails, offices, and supermarkets

  EIA-aggregated floor area: 10,000 m^2

- Office buildings have the largest share of the total fueling capacity.

- Commercial buildings with a total floor area of 50,000 m^2 can support a 1,500 kg/day fueling station in LA and a larger station in Atlanta and Chicago when PEMFC is used in Model I.





Economic Impact of System Integration

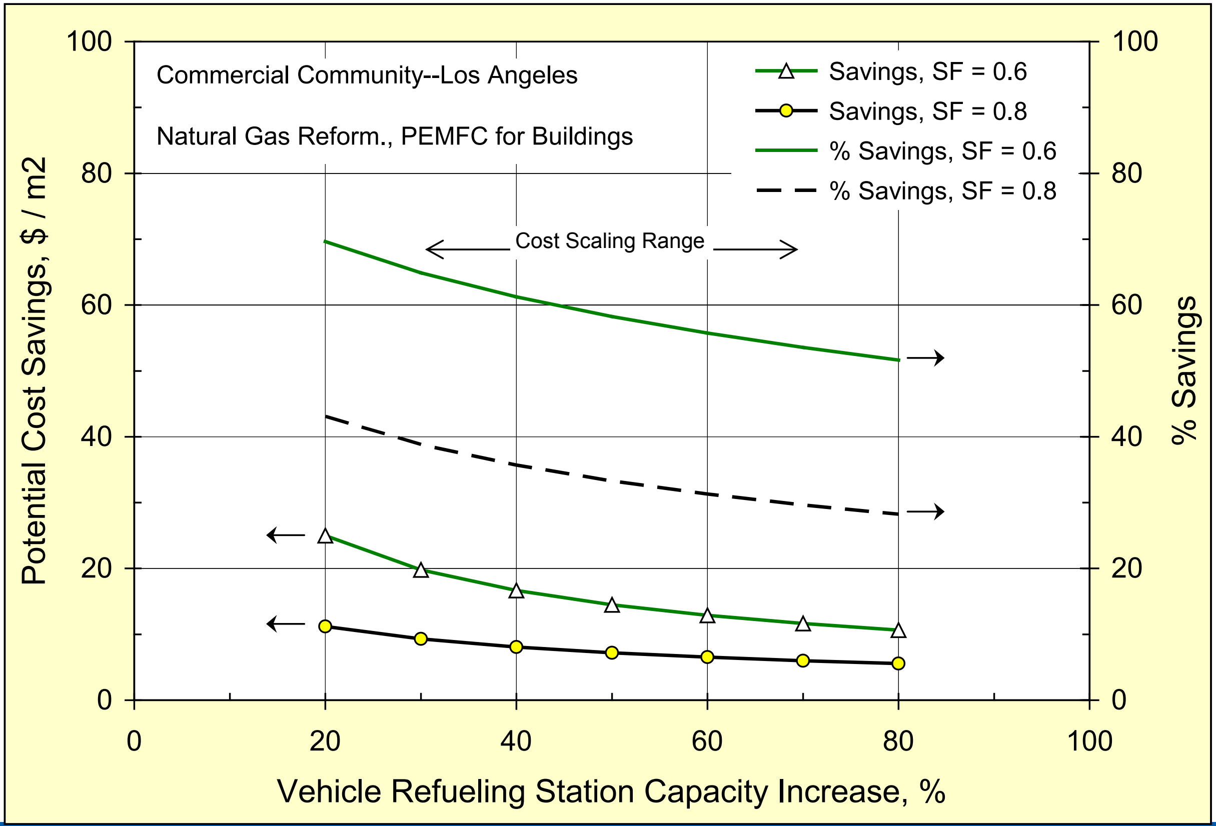
- Model I supporting a 50,000-m^2 commercial community can avoid installation of a 1,500-kg/day refueling station—saving about $1M.

- In Model II, the refueling station oversized by 60% (i.e., 1,500 x 1.60 kg/day) can support a 30,000-m^2 commercial community—saving only about $0.5M.

<u>Model II:</u>

Scaling Ratio:

1.30 – 1.70



Conclusions

- Advanced system, FCDG-ADV, incorporating SOFC and internal heat recovery yields significantly higher amounts of primary energy and GHG reductions than the other two alternatives, particularly FCDG.
- With water recovery management in place, the net increase in on-site water consumption is estimated to be less than 3%.
- Integration of stationary/transportation applications can lead to significant cost reduction by avoiding stranded investment in H2 production.
- The integration Model I (using buildings' excess H2 for FCV refueling) is economically more tenable than Model II (scaling up the FCV-refueling production facility to support the community's commercial buildings).

Questions / Comments ?

Thank you!

Ali.Jalalzadeh@nrel.gov