Life-Cycle Analysis of Criteria Pollutant Emissions from Stationary Fuel-Cell Systems

Michael Wang, Amgad Elgowainy, Jeongwoo Han
Argonne National Laboratory
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Project ID AN012

Overview

Timeline

- Start: Oct. 2002
- End: not applicable (OFCT program)
- % complete: not applicable

Budget

- Total project funding from DOE: $3.5 million through FY10
- Funding received in FY09: $800K
- Funding for FY10: $650K

Barriers to Address

- Energy and emission benefits of H2 FCVs
- Inconsistent data, assumptions, and guidelines
- Suite of models and tools
- Unplanned studies and analyses

Partners

- NREL and other labs
- Industry stakeholders

Objectives

- Expand and update the GREET model for hydrogen production pathways and for applications of FCVs and other early market FC systems
- Conduct well-to-wheels (WTW) analysis of hydrogen FCVs with various hydrogen production pathways
- Conduct fuel-cycle analysis of early market FC systems (to help development of hydrogen production and FC technologies)
- Provide fuel cycle results for DOE OFCT activities such as the Hydrogen Posture Plan and the MYPP
- Engage in discussions and dissemination of energy and environmental benefits of FC systems and applications

Approach

- Obtain data for hydrogen production pathways
  - Open literature
  - H2A simulation results
  - Process engineering simulations with models such as ASPEN
  - Interaction with hydrogen producers
- Obtain data for hydrogen FCVs and other FC systems
  - Open literature
  - PSAT and H2A simulations
  - Data of available FCV models and FC systems
  - Data from industry sources
- Expand and update GREET
- Conduct WTW or fuel-cycle simulations with GREET
- Analyze and present WTW or fuel-cycle results

Milestones of Fuel-Cycle Analysis of Hydrogen Pathways and Early Market FC Systems

- The most recent GREET version – GREET1.8c – was released in March 2009
- Fuel-cycle studies were completed:
  - Energy and GHG effects of FC forklifts and distributed power generation in 2008
  - Energy and GHG effects of PHEVs including FC PHEVs in 2008-2010
  - Energy and GHG emissions effects of fuel-cell systems for combined heat, hydrogen, and power (CHHP) generation in 2009
  - **Criteria pollutant emissions of CHP and CHHP in 2010 (this presentation)**

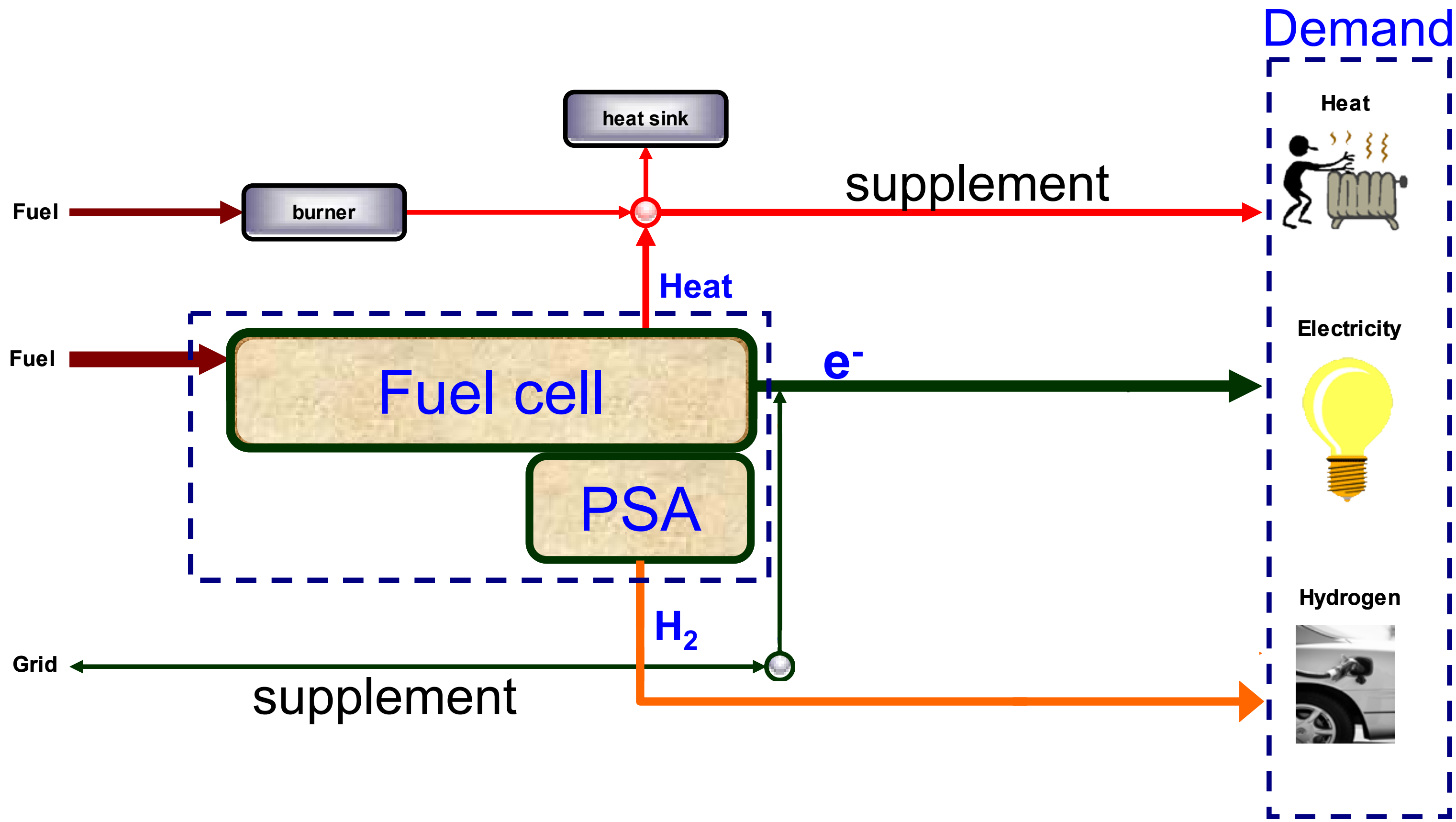
Coverage of Fuel-Cycle Analysis of FC Distributed Power Generation

- Examine energy use and GHG emissions for baseline and alternative technologies
- Track the energy use and emission occurrences throughout the upstream processes up to the primary source of energy for each technology
- Include the following fuel-cycle stages:
  - The recovery, processing, and transportation of the primary fuel (e.g., NG)
  - The conversion of the primary fuel (e.g., NG to H2 or electricity)
  - The conditioning of the fuels (e.g., compression of H2)
  - The use of the conditioned fuels for distributed power generation
- Expand Argonne's GREET model to estimate the fuel-cycle energy use, GHG emissions, and criteria pollutants emissions for distributed power generation technologies

Evaluation of Combined Heat, Hydrogen, and Power (CHHP) Generation Systems

- CHHP has been identified as an early FC market application and to co-produce hydrogen for FCVs
- Argonne examined energy and emissions implications for different CHHP system configurations
- CHHP energy and emissions benefits depend on:
  - FC system efficiency
  - Emission performance of FC technology
  - Shares of heat, hydrogen and power from CHHP systems

CHHP System Configuration for Production of Heat, Power and Hydrogen

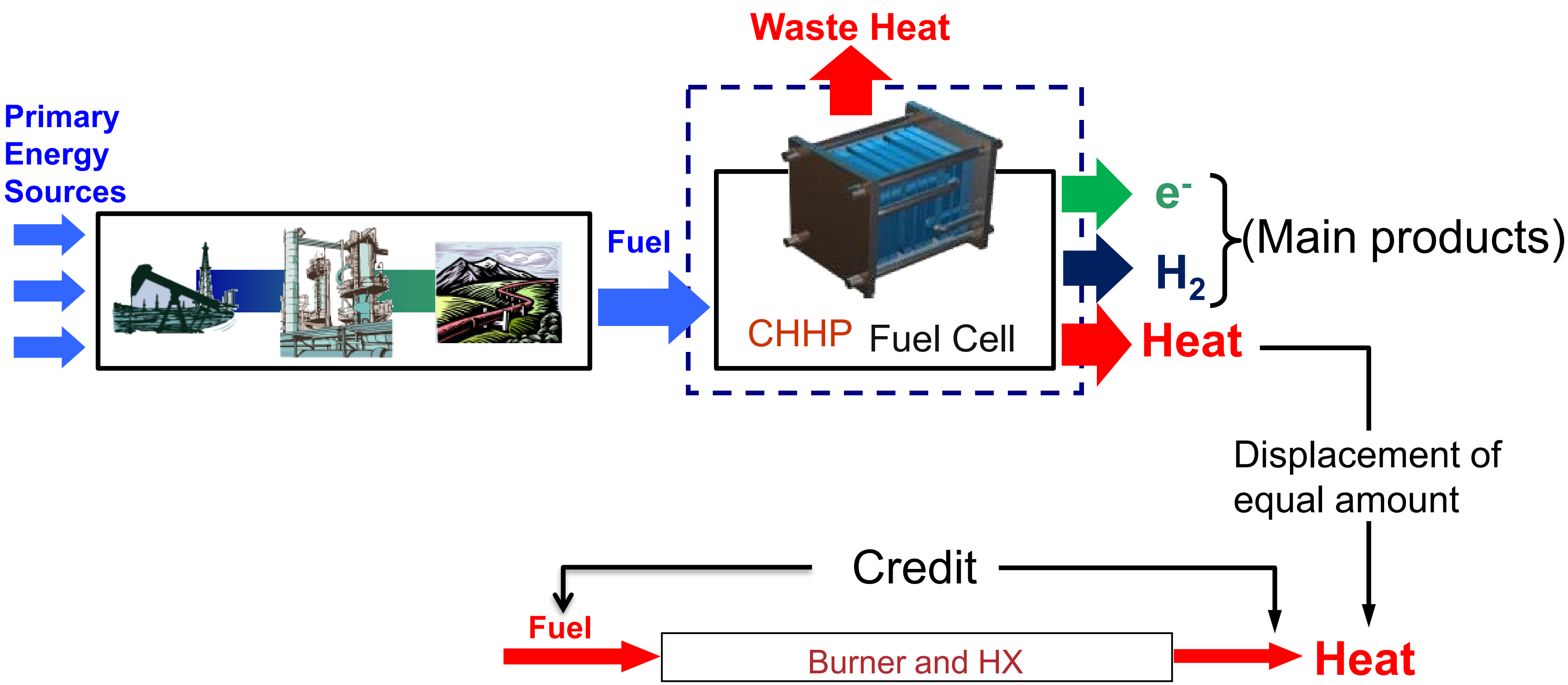


Source: Darlene Steward of NREL

Fuel-Cycle Analysis of CHHP Systems: Dealing with Multiple Products

- Two potential methods
  - Fuel cycle analysis from facility operator's point of view (that is, to meet a given mix of demand for heat, power, and hydrogen) – the total demand approach
    - ✓ Fuel cycle function unit: per mmBtu of electricity, heat, and hydrogen combined for a given mix of the three demands
    - ✓ Requires detailed simulation of the interaction between production and demand for each
  - The displacement approach
    - ✓ Fuel cycle function unit: per mmBtu of electricity and hydrogen combined (heat is treated to be a byproduct)
    - ✓ Can apply to other generation technologies without detailed simulations of interaction between production and demand
- Other methods such as allocation on the energy output basis may not be appropriate for CHHP system evaluation

The Displacement Approach



- The byproduct heat is assumed to displace an equal amount of heat produced by existing baseline technology (e.g., NG-fired burner)
- Usually, three separate efficiencies are defined with three separate outputs (electricity, hydrogen, and heat) vs. fuel input

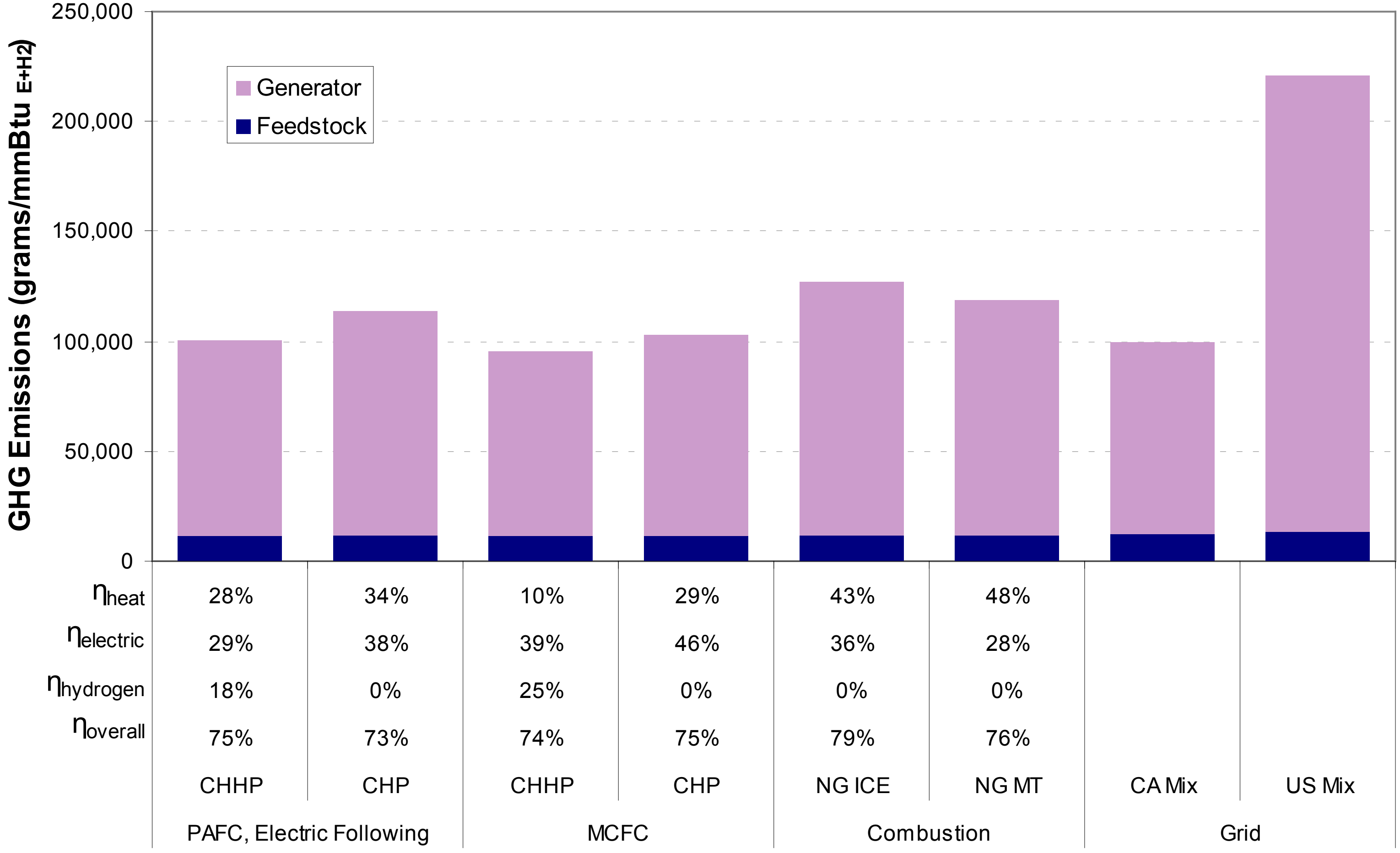
Results of Distributed Power Generation Are Affected by Several Key Assumptions

- FC technology types
- Application types
- FC system efficiency
- FC system emissions

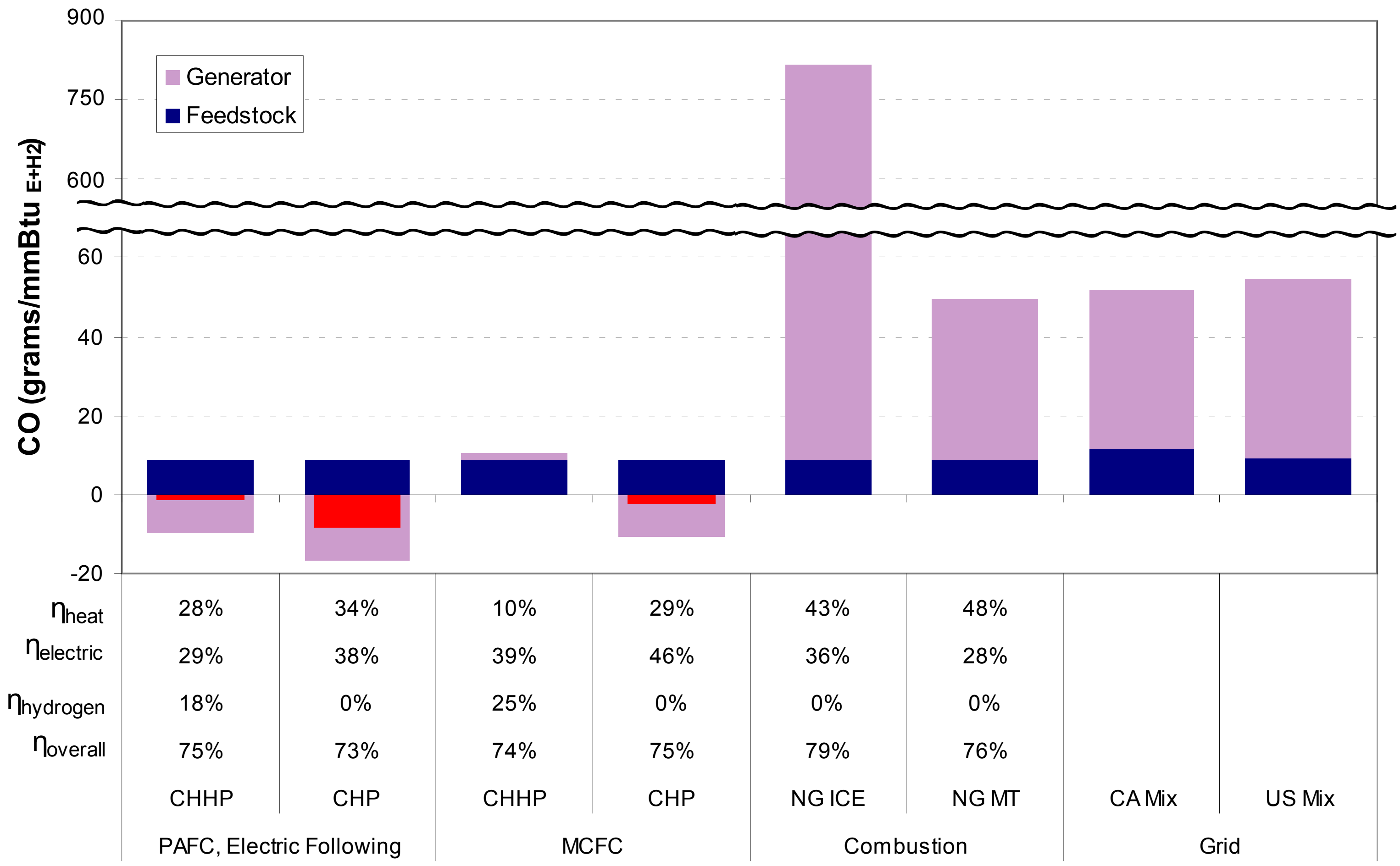
- Data sources for this analysis
  - NREL H2A Power model
  - EPA reports
  - Industry sources
  - CARB (personal communication)

Technology	**Type**	**Efficiency**			**Emission Factors** (grams/mmBTU of fuel input)				
		Electric	Hydrogen	Overall	VOC	CO	NOx	PM10	SOx
PAFC	CHHP	29%	18%	75%	1.204	2.558	4.108	1.354	0.269
	CHP	38%	0%	73%					
MCFC	CHHP	39%	25%	74%					
	CHP	46%	0%	75%					
NG ICE	CHP	36%	0%	79%	76.89	302.0	19.10	3.465	0.269
NG MT	CHP	28%	0%	76%	0.779	25.26	34.35	3.341	0.269

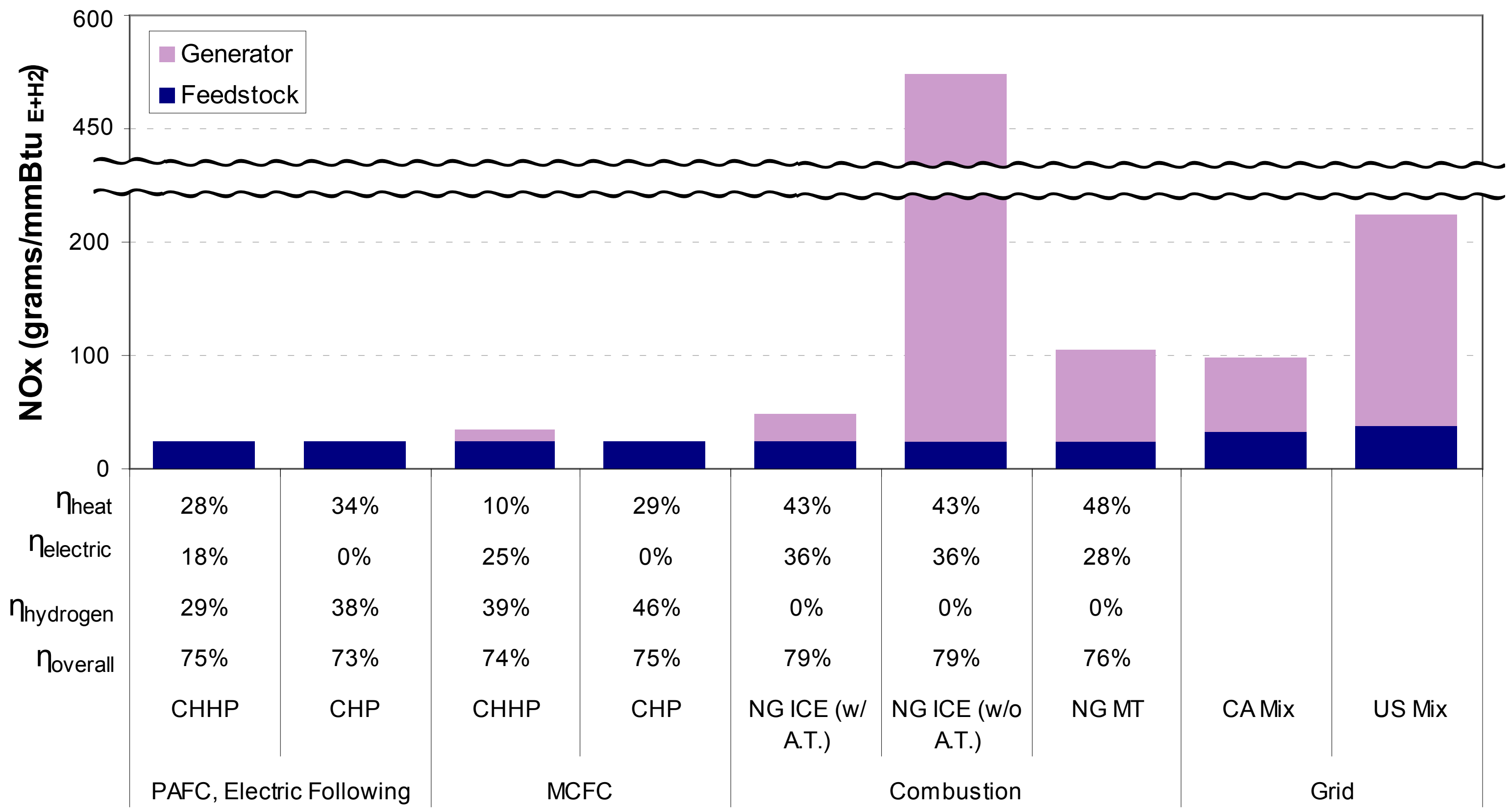
GHG Emissions of CHHP, CHP, and Competing Technologies



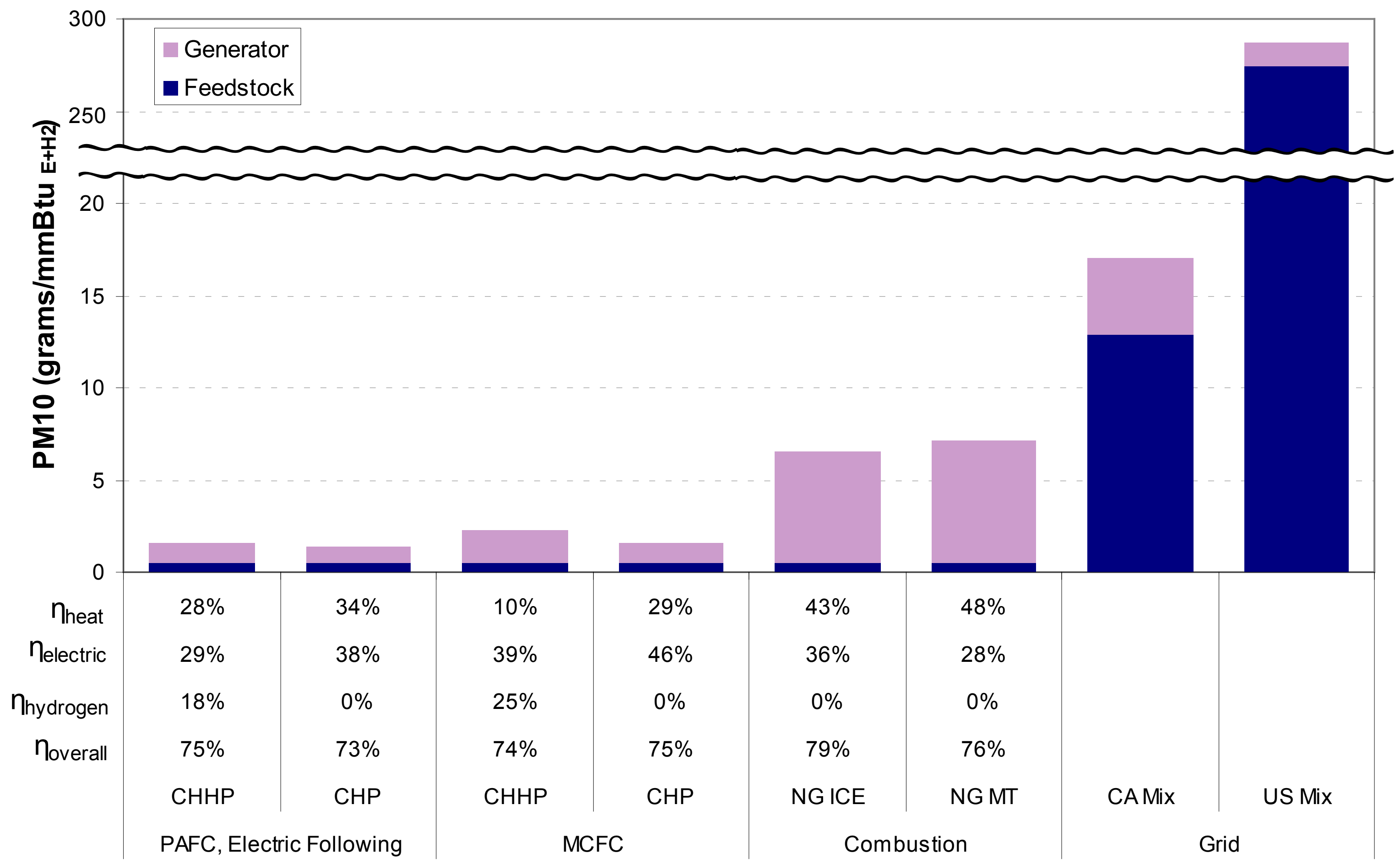
CO Emissions of CHHP, CHP, and Competing Technologies



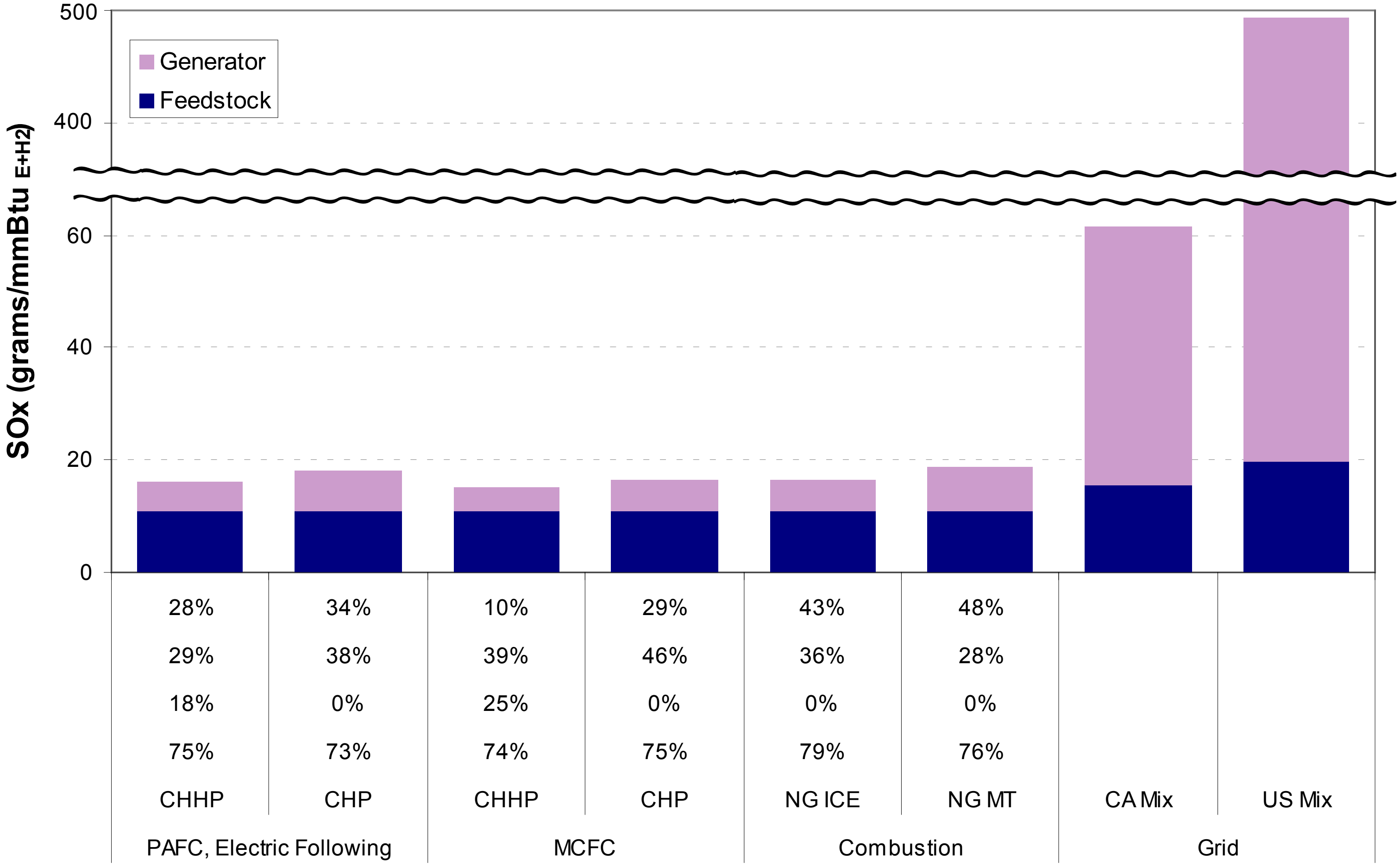
NOx Emissions of CHHP, CHP, and Competing Technologies



PM Emissions of CHHP, CHP, and Competing Technologies



SOx Emissions of CHHP, CHP, and Competing Technologies



Summary

- Fuel cycle analysis is an integral part of examining energy and environmental effects of H2 FCVs and other FC systems
- FC systems for distributed power generation in CHP or CHHP achieve significant reductions in criteria pollutant emissions
  - FC systems for CHP and CHHP provide significantly less CO, PM, and NOx emissions compared to conventional generation technologies
  - Utilization of byproduct heat is critical to the fuel-cycle emission performance of FC systems for distributed power generation
  - CHHP FC systems provide better utilization of byproduct heat compared to CHP FC systems (heat is utilized in reforming more H2)

Future Work

- Add new hydrogen production options
  - Biogas/landfill gas to hydrogen
- Complete fuel-cycle analysis of FC CHHP systems for criteria pollutants as well as energy use and GHGs
- Develop GREET with a new programming platform for easier expansion and use