DOE Hydrogen and Fuel Cells Program Record		
Record #: 5003	**Date:** January 4, 2006	
Title: Carbon Displacement Using Net-Zero Carbon Sources		
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Approved by: JoAnn Milliken	**Date:** April 4, 2006	

Item:

"… if **175 billion kWh of grid electricity** (10% of the growth of the electric generation market in 2025) is replaced by fuel cells operating on hydrogen at **50% LHV efficiency**, about **10.5 million tons of hydrogen** would be needed. If this hydrogen were made from a non-carbon (e.g. nuclear) or net-zero carbon (e.g. biomass, coal with carbon sequestration) source, then it could potentially displace about **27.5 million tons of carbon**."

Calculations/References:

Analysis by TIAX for DOE, August 24, 2005:

- "**10.5 million tons of hydrogen**"
  Required H_2 = 175 billion kWhe[a] / (50% kWhe/kWh H_2)[b] / (33.3 kWh H_2/kg H_2)[c] = 10.5 billion kg H_2 (=10.5 million tons of H_2)
- "**27.5 million tons of carbon**"
  Carbon displaced = [175 billion kWhe[a] / (34% kWhe/kWh fuel)][d] x 3,413 Btu/kWh[e] x 15.7 kg C/MMBtu fuel[f] = 27.5 million tons of carbon

Assumptions:

[a] Grid electricity replacement of 175 billion kWh:
1. This amount of electricity is based on ~10% of grid electricity growth from 2003 to 2025 minus power growth contribution from renewables.
2. The source is Table A8; U.S. Department of Energy, Energy Information Administration, Annual Energy Outlook 2005, p. 152, DOE/EIA-0383(2005), January 2005.

[b] Fuel Cell System Efficiency (H_2 to AC Power) = 50% (LHV)
1. 0.75 V operation
2. 95% anode utilization
3. 90% power electronics efficiency
4. Parasitic loads (e.g. fans, blowers) = 0.016 kWh/kW H_2

[c] Heating Value of Hydrogen = 33.3 kWh/kg (LHV)

[d] "Grid Efficiency" (fuel to AC Power) = 34% (LHV)
1. Based on discussions with industry.
2. This is really the average utility delivery efficiency (accounting for fuel conversion losses, plant use of electricity, and T&D losses).

3. Consistent with HHV efficiencies of 31.1% for 2002 and 31.3% projected for 2005 from: Table 6.2.4; 2004 Buildings Energy Databook; prepared for the US Department of Energy, Office of Energy Efficiency and Renewable Energy; prepared by Jordan Kelso, D&R International, Ltd., Silver Spring, MD; January 2005 version. Available at: http://buildingsdatabook.eere.energy.gov/ .

[e] Units Conversion = 3,413 Btu/kWh (60^{o}F)

[f] Carbon Emission Factor = 15.7 kg C/MMBtu fuel input

1. OBT: Table E; Guide for the Evaluation of Energy Savings Potential; Office of Building Technology, State and Community Programs (BTS); February 3, 2000. This was an attachment to the solicitation: Energy Efficient Building Technologies; Announcement No. DE-PS26-04NT42114.000; May 5, 2004 https://e-center.doe.gov/IIPS2005Archive.nsf/UNID/85256F27004A420B85256E8A0073D9B1/$file/Building_Technologies_Solicitation.doc
2. This source does not state whether the factor assumes LHV or HHV. The LHV which yields a grid efficiency of 34% was used in the calculations.