WinDS-H2 Model and Analysis

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May 27, 2005

This presentation does not contain any proprietary or confidential information

Project AN4

Project Overview

- Schedule
  - Start Sept 2003
  - End Oct 2004
  - 100% complete
- Total funding $225k
  - DOE $225k
  - FY04 $225k
  - FY05 $200k new focus started April 2005

- Technology Validation Barriers addressed
  - C. Lack of a Macro-System Model
  - D. Stove-piped/siloed analytical capabilities
  - E. Transition to a H_2 economy

- Partners/collaborators
  - H2A
  - Utility Wind Interest Group
  - UC Davis H_2 System Modeling Workshop
  - NREL: Wind, GIS

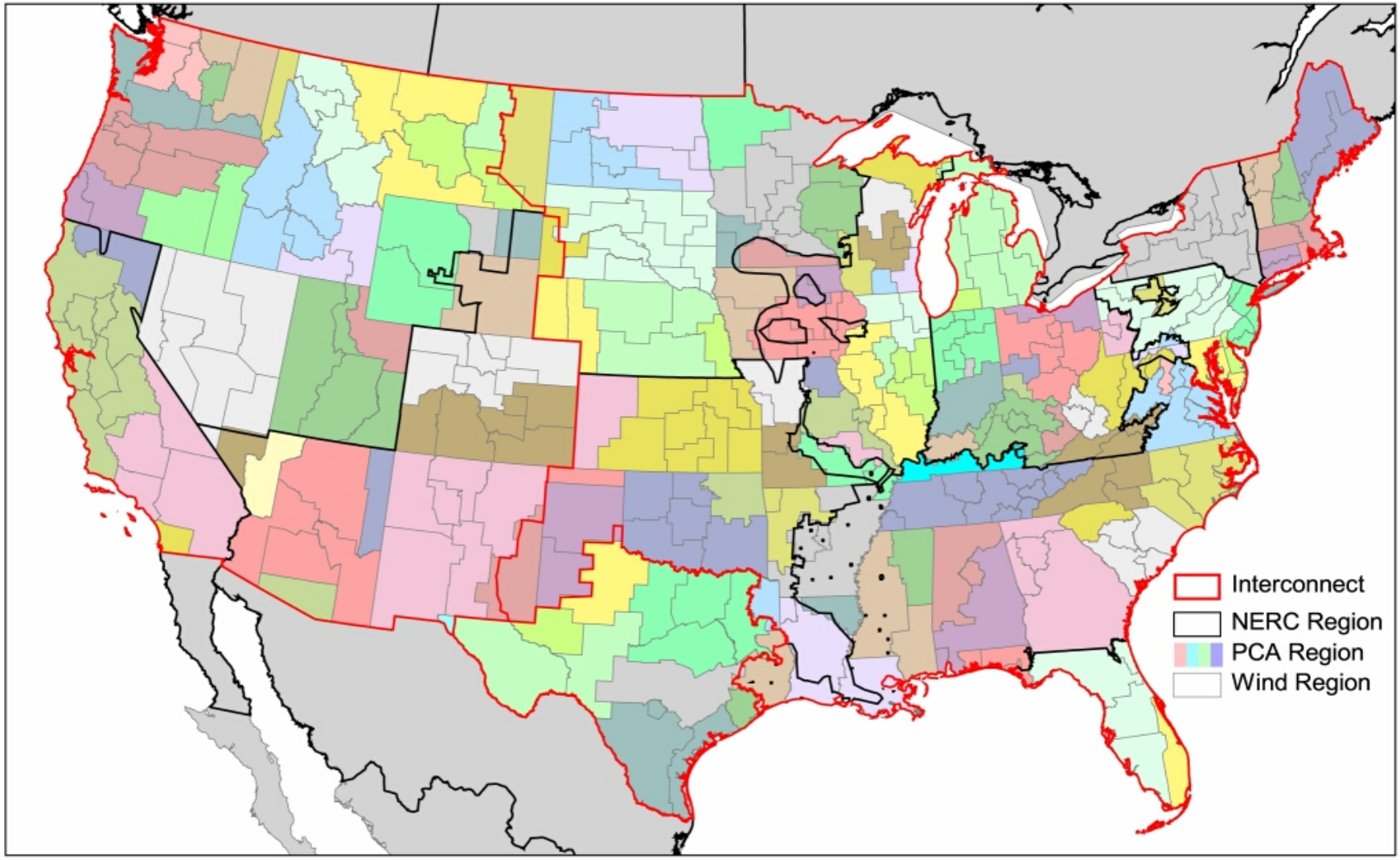
Objective

- Identify the regions in the United States that have the greatest potential for employing wind turbines to produce both electricity and hydrogen, and the conditions and time frame under which they are likely to become economical?
- Identify the opportunities for reducing system cost, by designing hybrid wind-based systems specifically for production of electricity and hydrogen?

Approach

- Developed a regional model that can simulate the market potential of both hydrogen and electricity from wind. Requires evaluation of both hydrogen and electricity as joint products
  - HyDS (**Hy**drogen **D**eployment **S**ystems model -formerly WinDS-H2) is a multi-regional, multi-time-period model that:
    - Enables accurate tracking of H2 transport and electricity transmission from remote wind sites
    - Accounts for the intermittency of wind
    - Considers competition with other distributed sources of H2 production – distributed electrolysis and SMR

HyDS Regions



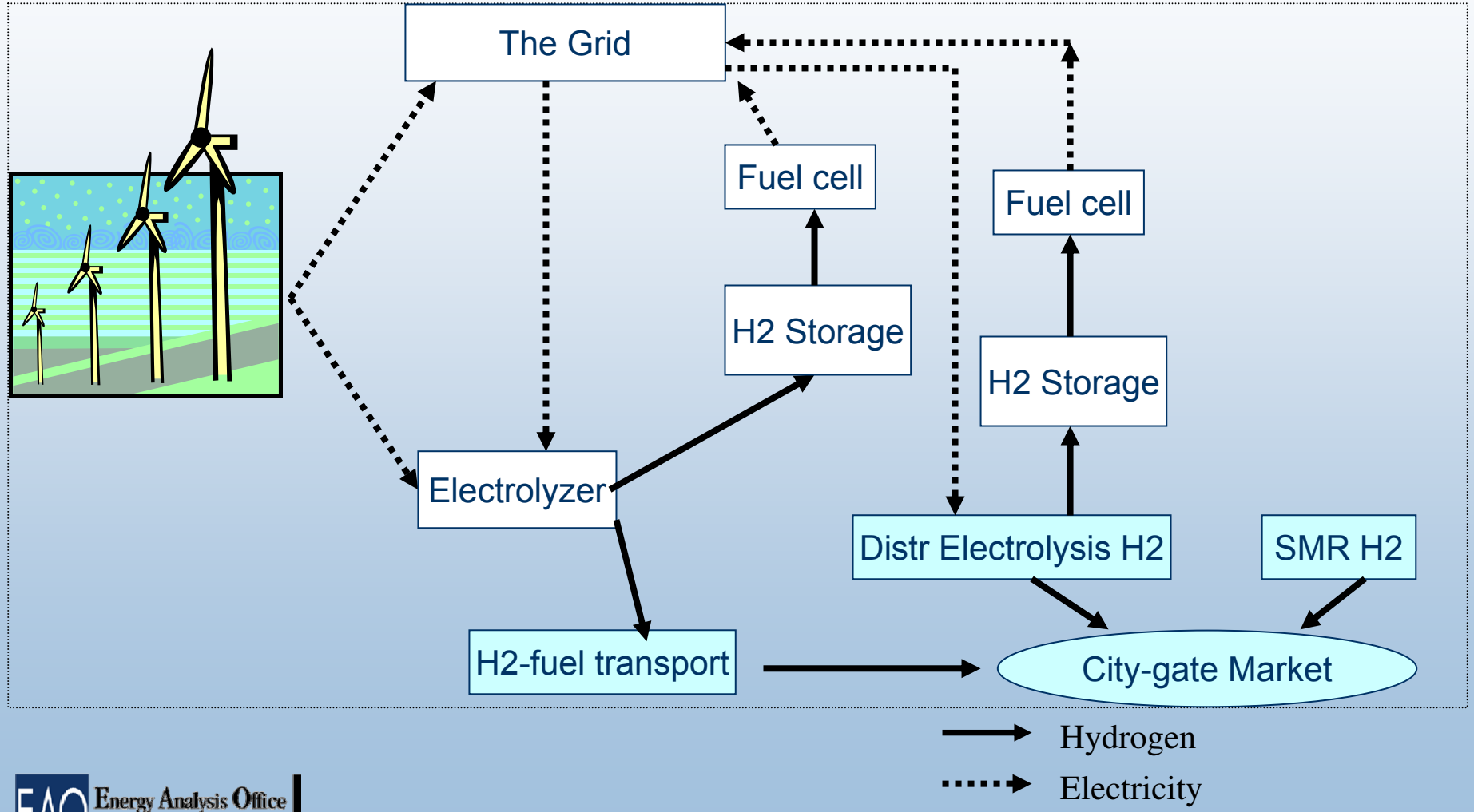
Technical Accomplishments

- Completed the HyDS model to assess H_2-from-wind potential
- Developed a base case and sensitivity cases
- Showed that:
  - If program goals are met, H_2 production at wind sites competitive in many areas of the country when
    - Wind close to load center
    - High-quality, fully developed wind site, very remote from load
  - Distributed electrolysis generally preferred over wind-sited electrolysis,
  - Distributed SMR, the preferred initial distributed production technology, wanes in later years with high gas prices

Development of HyDS
General Characteristics of HyDS

- Linear program cost minimization for each of 26 two-year periods from 2000 to 2050
- Includes hydrogen production from wind electrolysis, distributed electrolysis, and steam methane reforming
- Hydrogen used for transportation demands and/or on-peak electricity production
- Hydrogen transport within and between regions
- Sixteen time slices in each year: 4 daily and 4 seasons
- 5 wind classes (3-7), onshore and offshore shallow and deep
- Other generation technologies – hydroelectricity, gas CT, gas CC, 4 coal technologies, nuclear, gas/oil steam
- Existing and new transmission lines

HyDS Representation of H_2



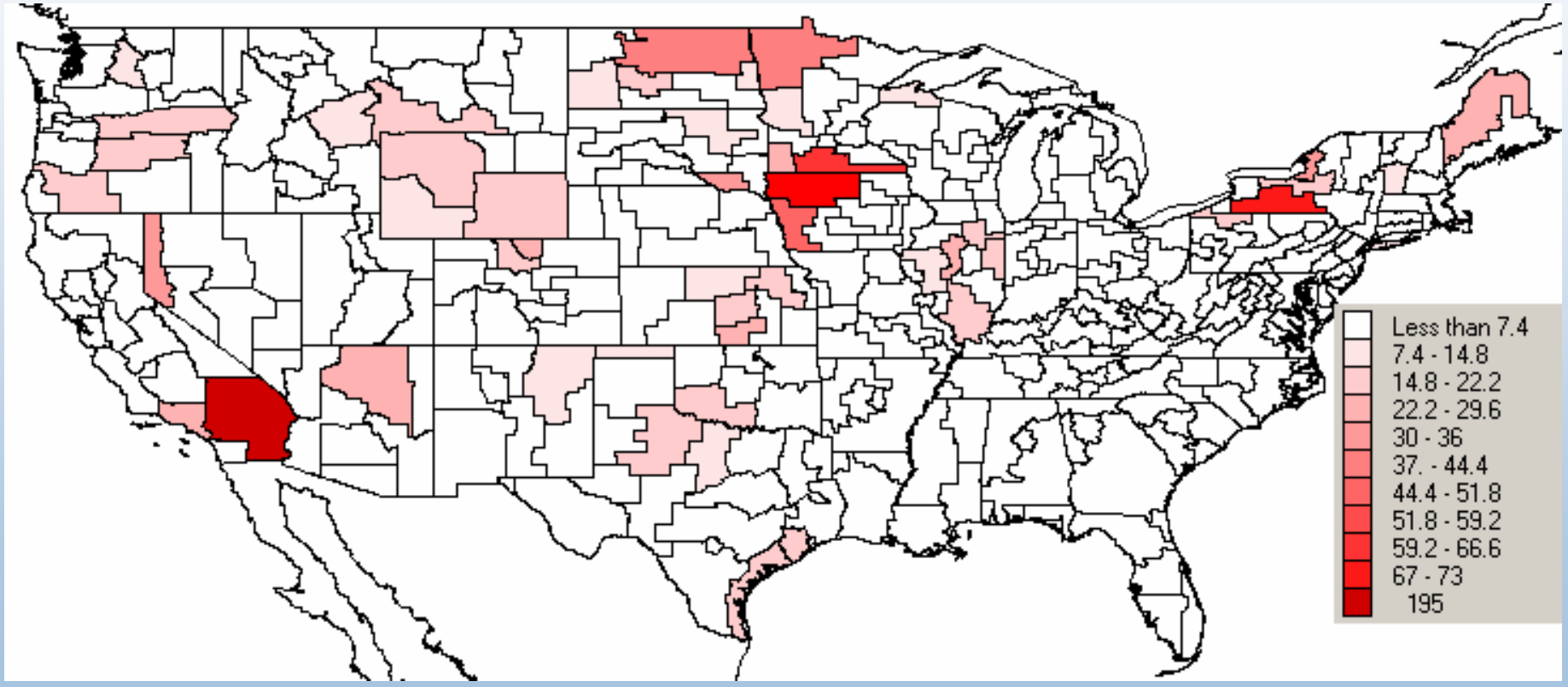
Modeling Assumptions for H_2

- **Hydrogen production and storage**
  - H_2 produced only during off-peak electric load times
  - Daily storage in wind turbine towers
- **Hydrogen for transportation fuel**
  - Competed on the basis of fuel cost
    - Produce up to regional demand level as long as you can make a profit at $2/kg at city gate (base case).
- **Hydrogen as a means of storing electricity**
  - H_2 used in fuel cells only during on-peak times when the wind generators are not fully active, i.e. when there is transmission capacity available.

Model Improvements Since 2004 HFCIT Program Review

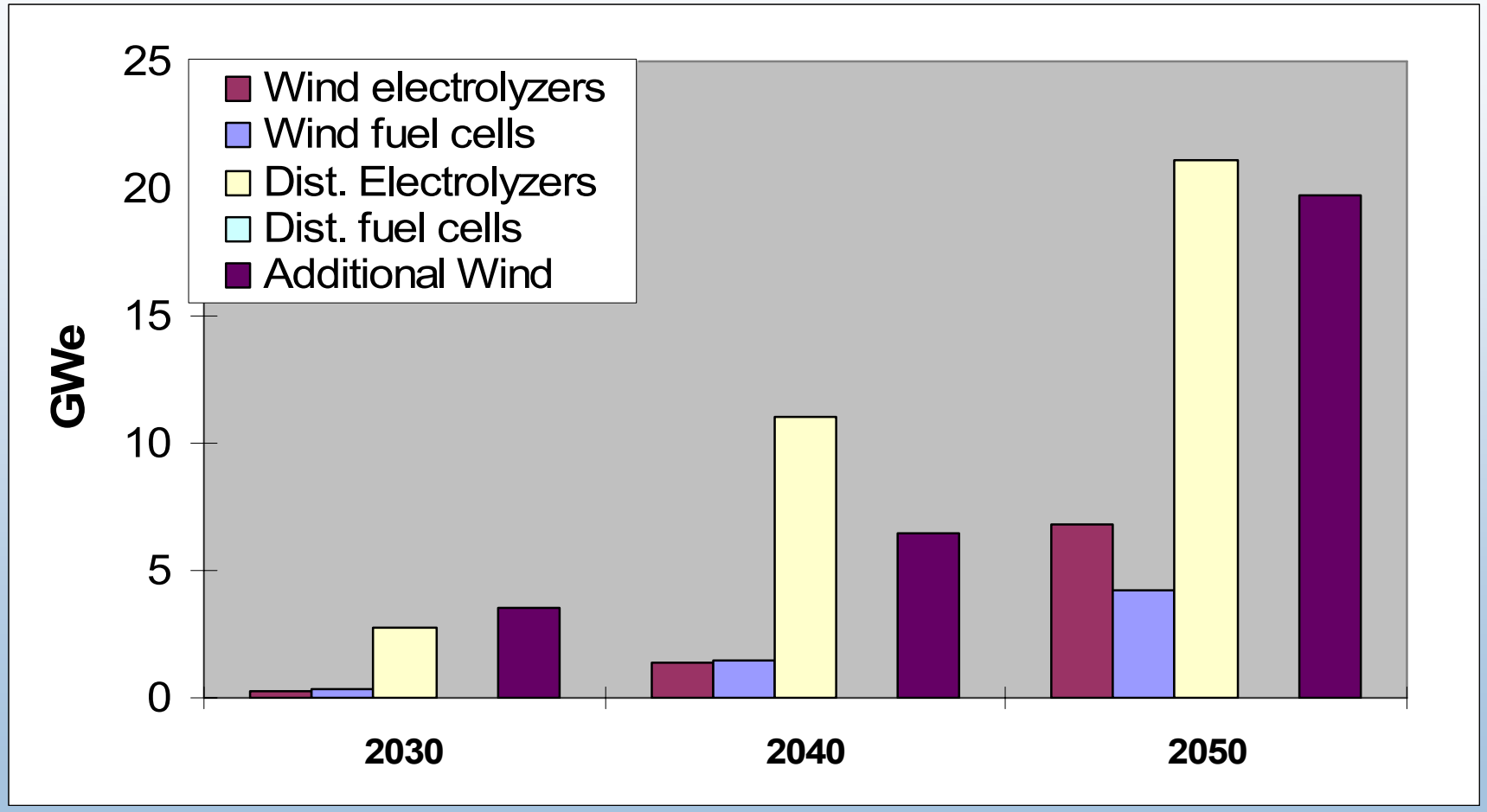
- Refined representation of distributed SMR
- Changed inter-region H_2 transport from trucks to pipelines
- Incorporated cost synergisms with wind, i.e. in-tower storage, reduced cost of joint control system for wind and electrolyzer – roughly 12% savings on electrolyzer and fuel cell costs at windsite.
- Added possibility of grid electricity to power electrolyzer at a wind site
- Added electrolysis/storage/fuel cells to HyDS in the general grid as a storage option
- Changed county-gate markets to city-gate markets

Base Case H_2 Production* from Wind

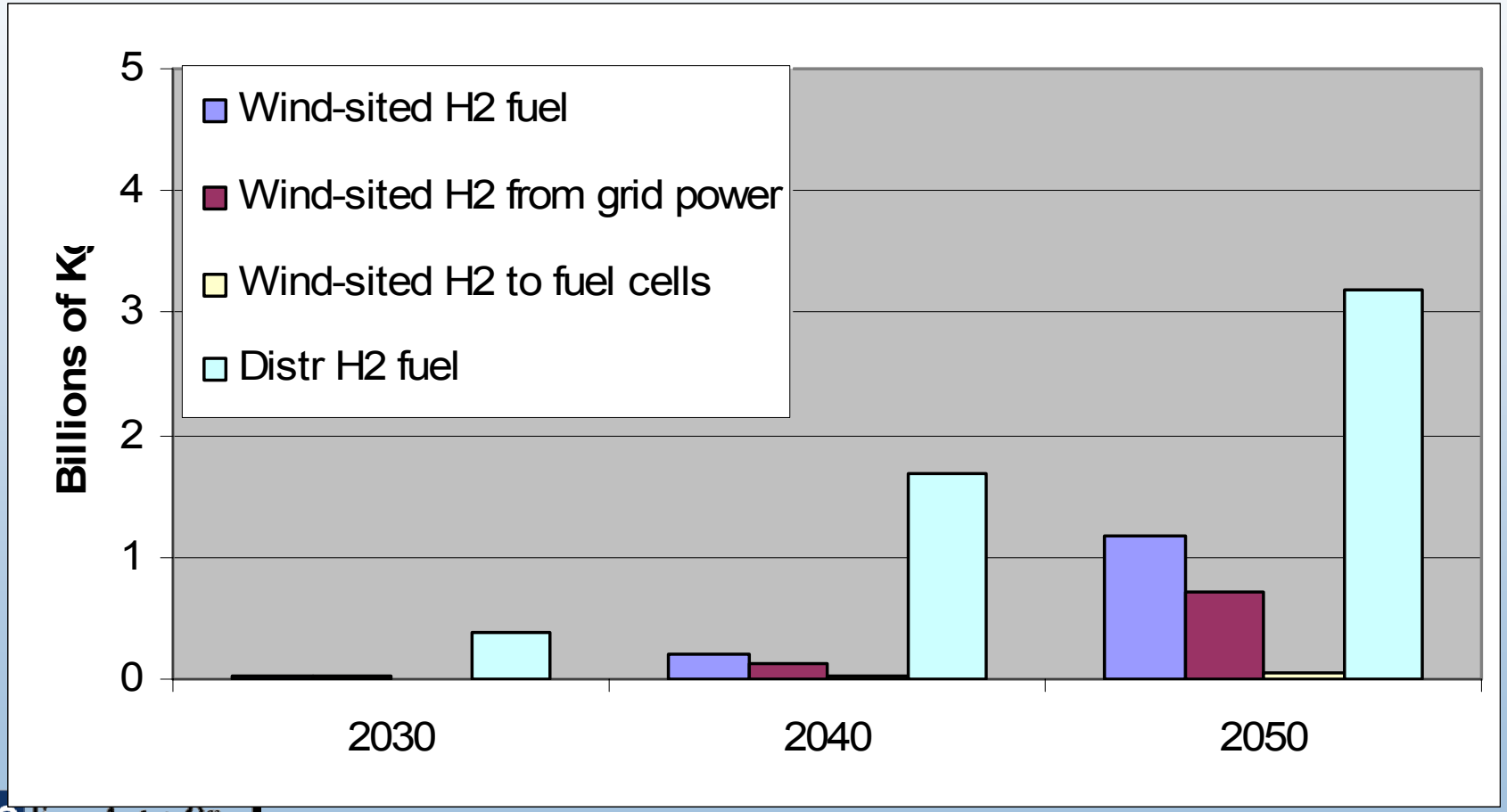


* Kilotons/yr

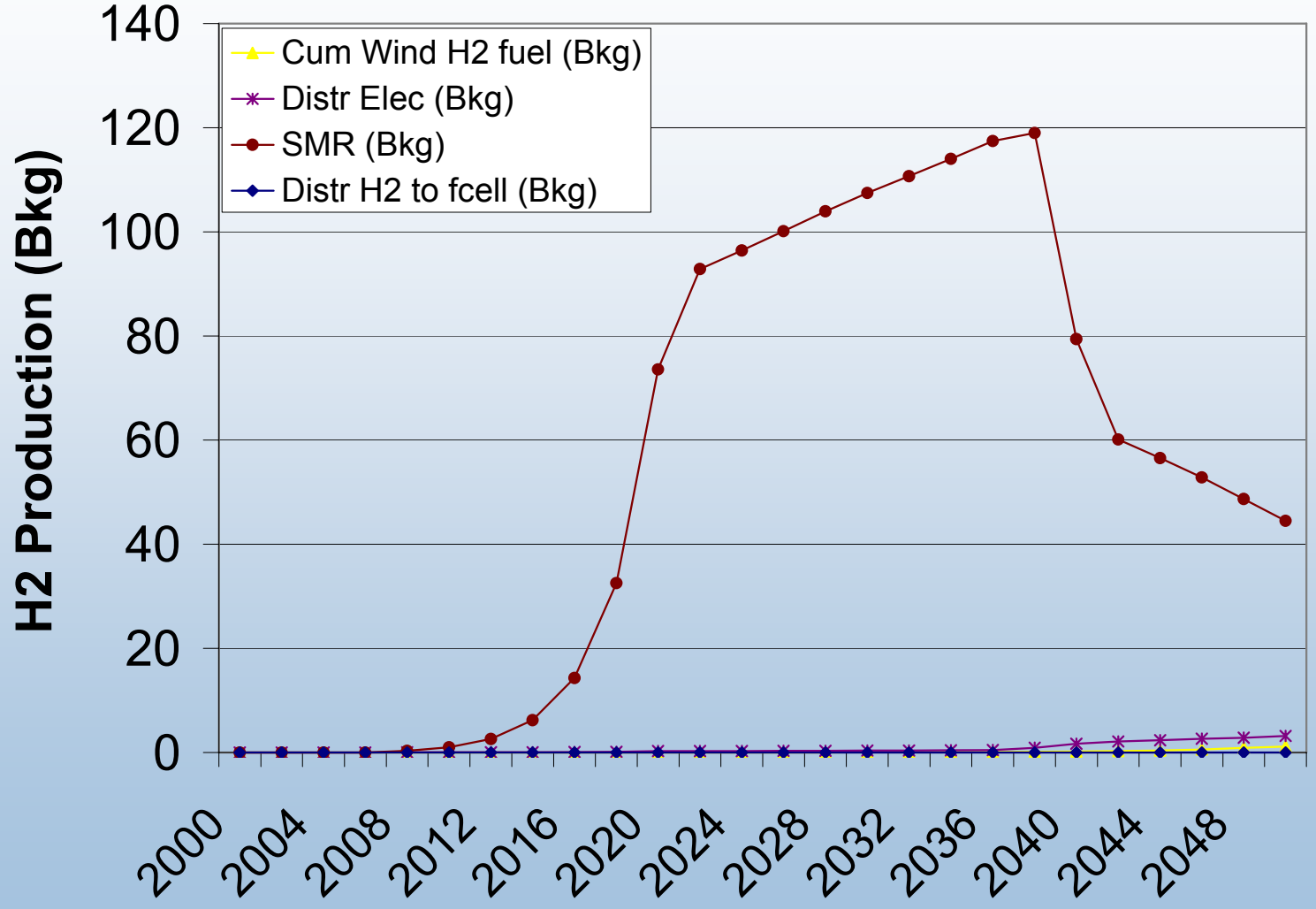
Capacities in the Base Case



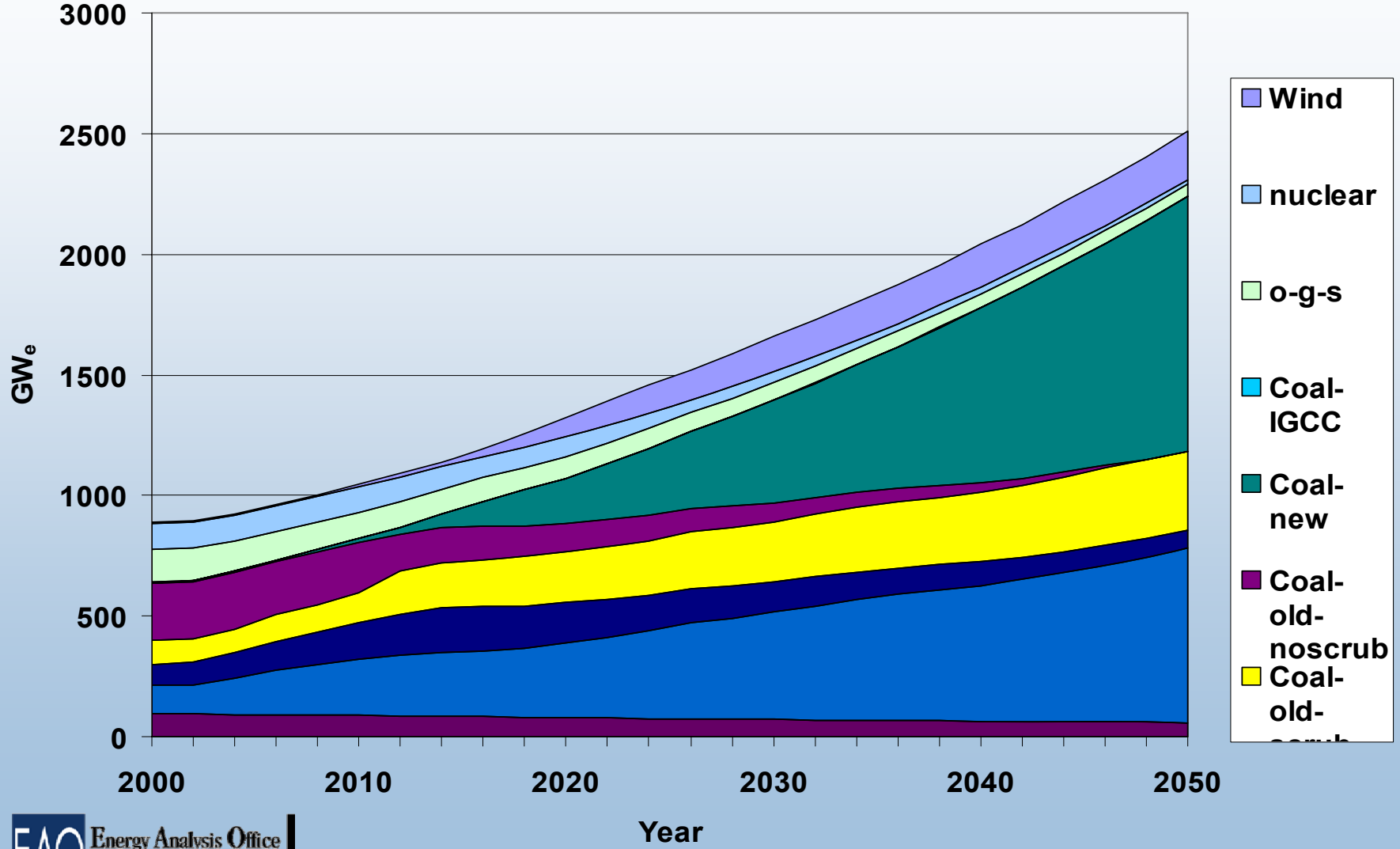
Hydrogen Produced in the Base Case



H_2 from SMR

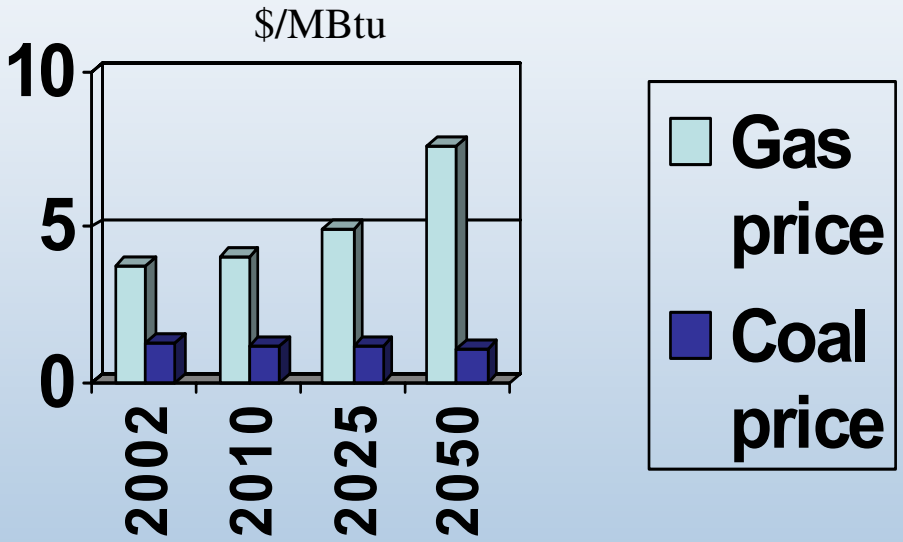

H2 Production (Bkg)
140
120
100
80
60
40
20
0
Cum Wind H2 fuel (Bkg)
Distr Elec (Bkg)
SMR (Bkg)
Distr H2 to fcell (Bkg)
2000
2004
2008
2012
2016
2020
2024
2028
2032
2036
2040
2044
2048

Base Case Electricity Capacity



General Base Case Data Inputs

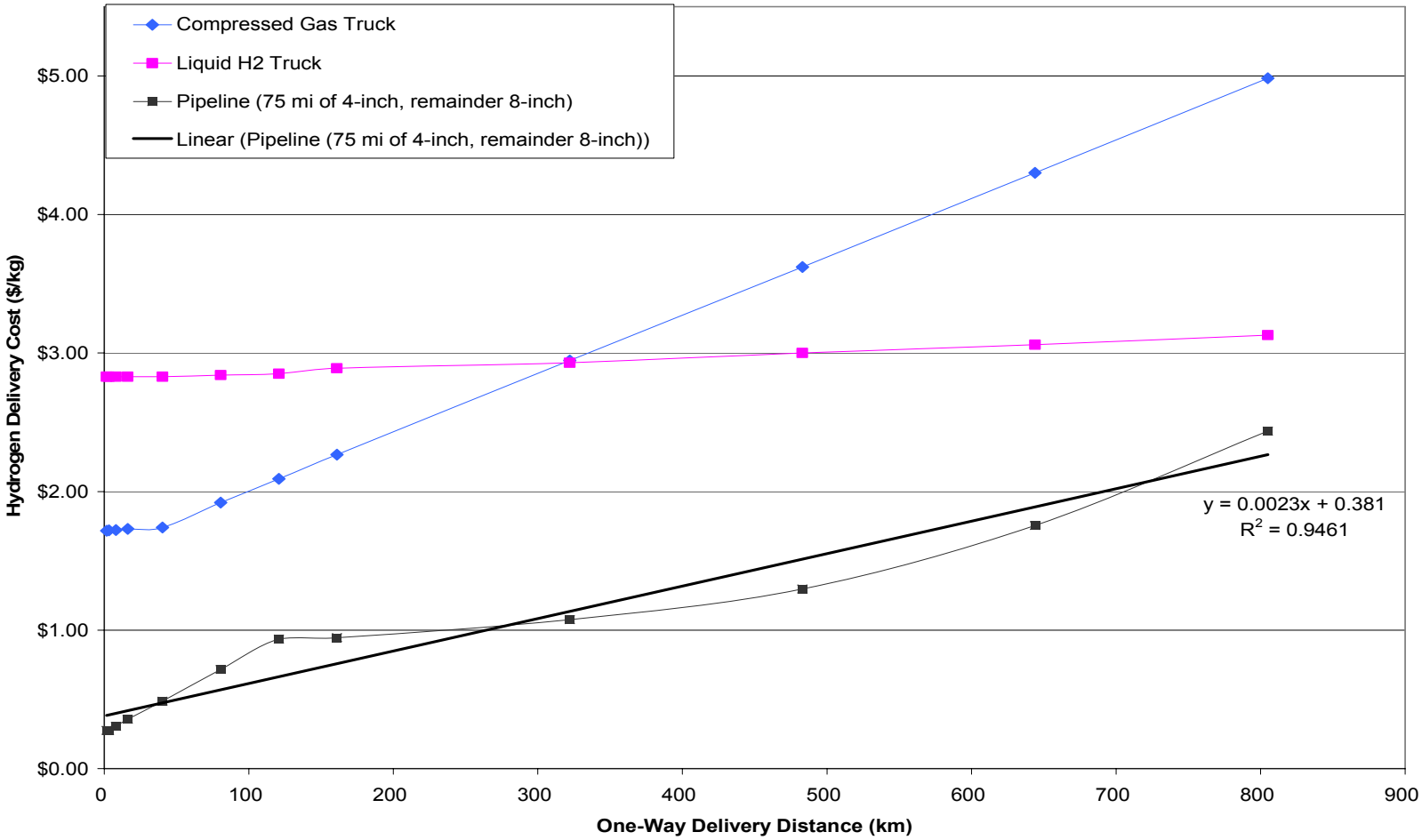
- Fossil Fuel Prices – Source: AEO2004
- Transportation fuel demand based on state gasoline demand and population; grows at 1.9%/year
- Electric demands by NERC region – 1.8%/year - Source AEO2004



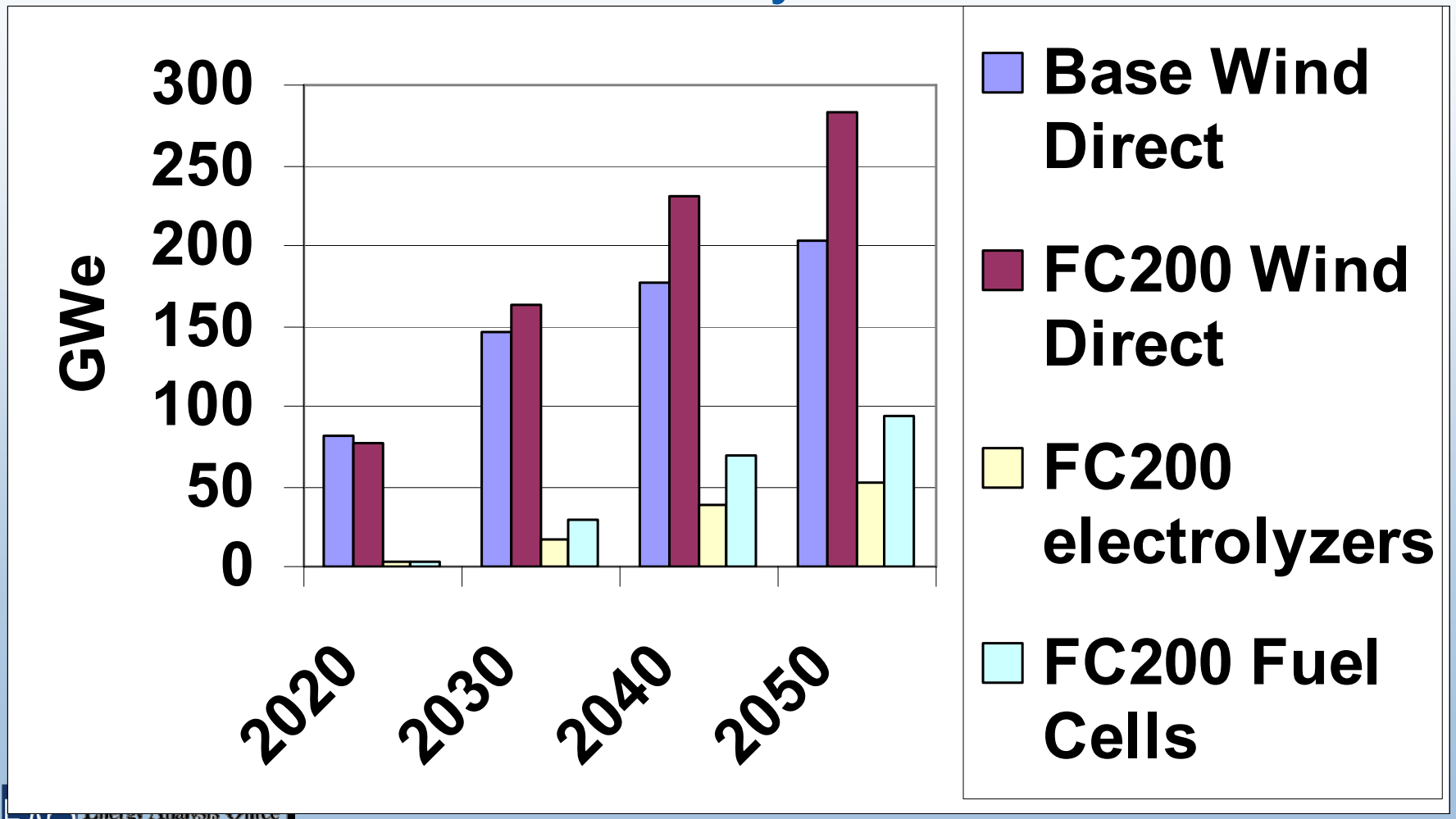
Base Case 2010
H_2 Technologies Cost/Performance

Technology	Capital Cost	Efficiency %
Electrolyzer	$150/kWe	80
Fuel Cell	$400/kWe	50
Steam Methane Reformer	$4/kg-yr	70

Modeling the Inter-regional Transport of H_2 from Wind



Wind and Fuel Cell Capacities with Reduced Stationary Fuel Cell Costs



Conclusions

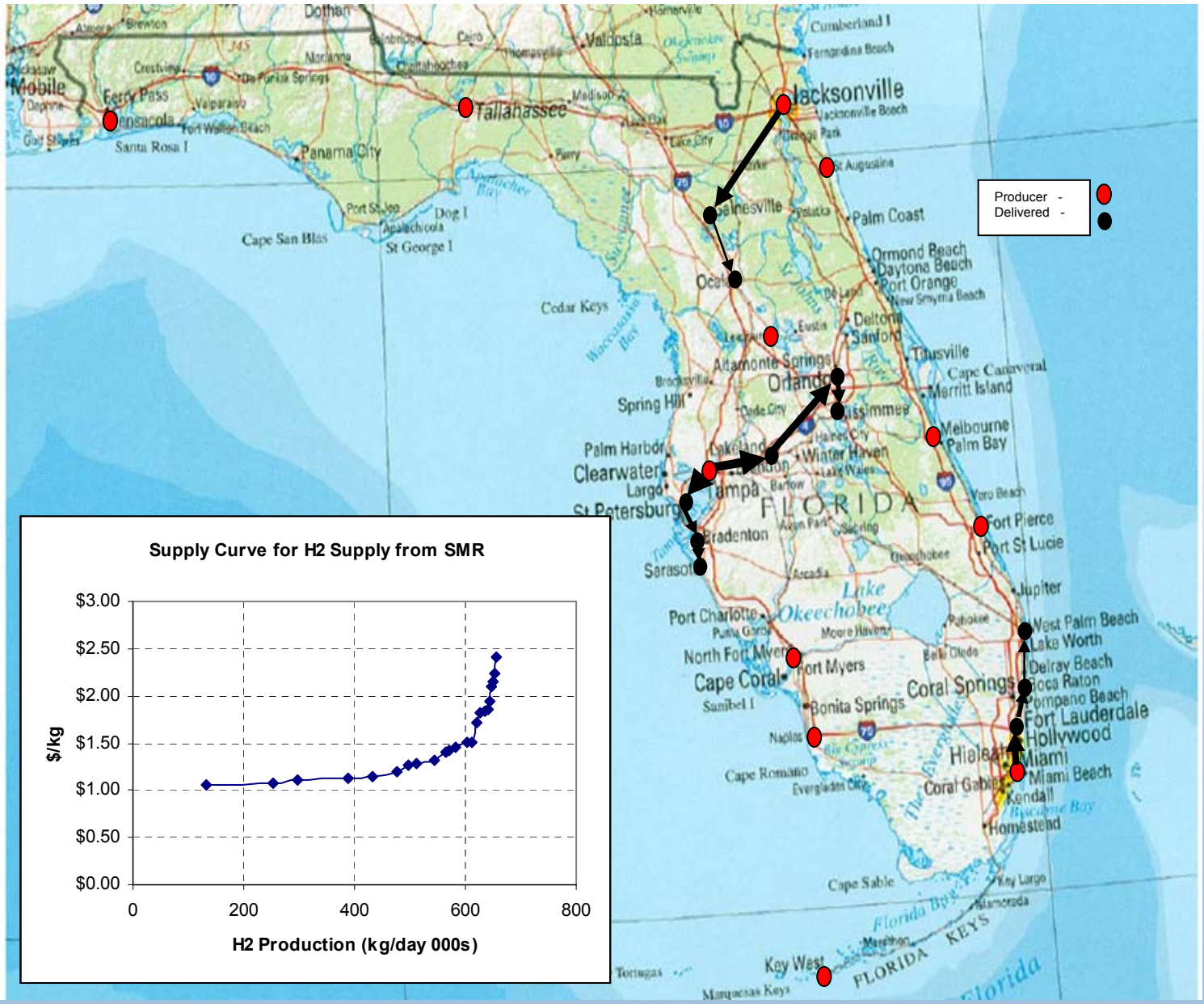
- Where wind resources are close to transportation fuel demand centers, electrolyzers at wind farms may be preferred to electrolyzers distributed close to the demand center.
- Wind's most substantial contribution may be as power to the grid to meet the additional demand for power required by distributed electrolyzers.
- The use of electrolyzers and fuel cells at wind sites to store/shift wind generation from off-peak to on-peak periods occurs almost exclusively at remote, well-developed wind sites with good wind resource.

Future Research and Model Improvements

- **Focus on other central hydrogen production and transportation technologies**
  - Add other central hydrogen sources, e.g. central SMR, coal gasification, biomass
  - Incorporate economies of scale in production for these new central sources
  - Optimize pipeline routes from these central production plants incorporating
    - pipeline economies of scale
    - increasing capacity utilization after installation
- **Examine/identify scenarios with increased hydrogen production**
  - Collaborate with other scenario developers

Example H2 Regional Supply Curve

Supply Curve by City	
Tampa	$1.06
Jacksonville	$1.08
St. Petersburg	$1.11
Miami	$1.13
Lakeland	$1.14
Fort Lauderdale	$1.19
Boca Raton	$1.27
Bradenton	$1.28
Orlando	$1.32
Gainesville	$1.41
Sarasota	$1.43
West Palm Beach	$1.46
Tallahassee	$1.50
Kissimmee	$1.52
Melbourne	$1.71
Pensacola	$1.81
Fort Myers	$1.84
Ocala	$1.85
Fort Pierce	$1.94
Key West	$2.10
Naples	$2.16
Leesburg	$2.24
St. Augustine	$2.40



Presentations

- American Wind Energy Association WindPower 2005, Denver CO, May 18 2005, poster
- ITS-Davis Hydrogen Systems Modeling Workshop, September 20, 2004, Davis CA
- 15th Annual U.S. Hydrogen Conference, April 27, 2004, Anaheim CA
- HFCIT Program Review, May 25, 2004

Hydrogen Safety

- There are no hydrogen hazards associated with this project