ARGONNE NATIONAL LABORATORY

TRANSPORTATION TECHNOLOGY R&D CENTER

Hydrogen Demand, Production and Costs by Region to 2050

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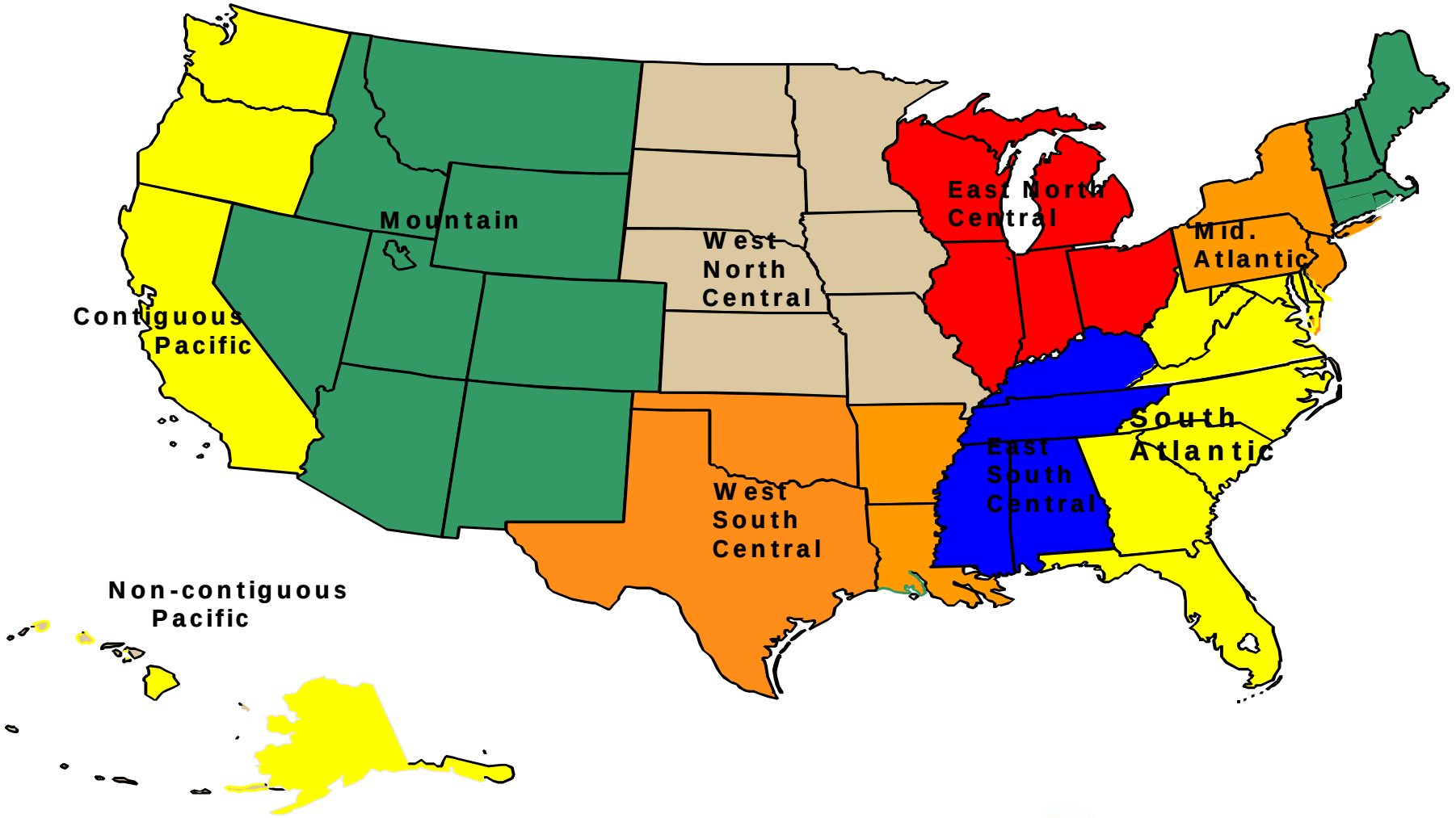
What We Mean by "Region"



Why Conduct Regional H2 Analysis?

- Extensive efforts underway to estimate future H2 costs
  - Typical focus: national average costs
  - No comprehensive assessment of H2 costs by Census region
- But future H2 costs may vary by region:
  - Rural H2 costs likely to be higher than non-rural
    - Some regions are proportionally more rural
  - Costs to produce H2 vary by feedstock
    - Regional variation exists in feedstocks available for H2 production
  - For same H2 feedstock, regional variation in capital and energy costs
  - H2 delivery costs will vary by region
    - Variation in shipment distances, capital and energy costs

Why Conduct Regional H2 Analysis (continued)?

- So, this preliminary analysis of regional H2 demand, production and costs was intended to help identify key regional issues
- Further, EIA indicated that if regional H2 price estimates could be developed, it would use them in NEMS
  - In the past, used a single H2 price for all regions
  - In AEO 2005, used our regional H2 cost estimates

This presentation then describes how we developed regional H2 demand, production and cost estimates and highlights some key regional issues that need to be further addressed.

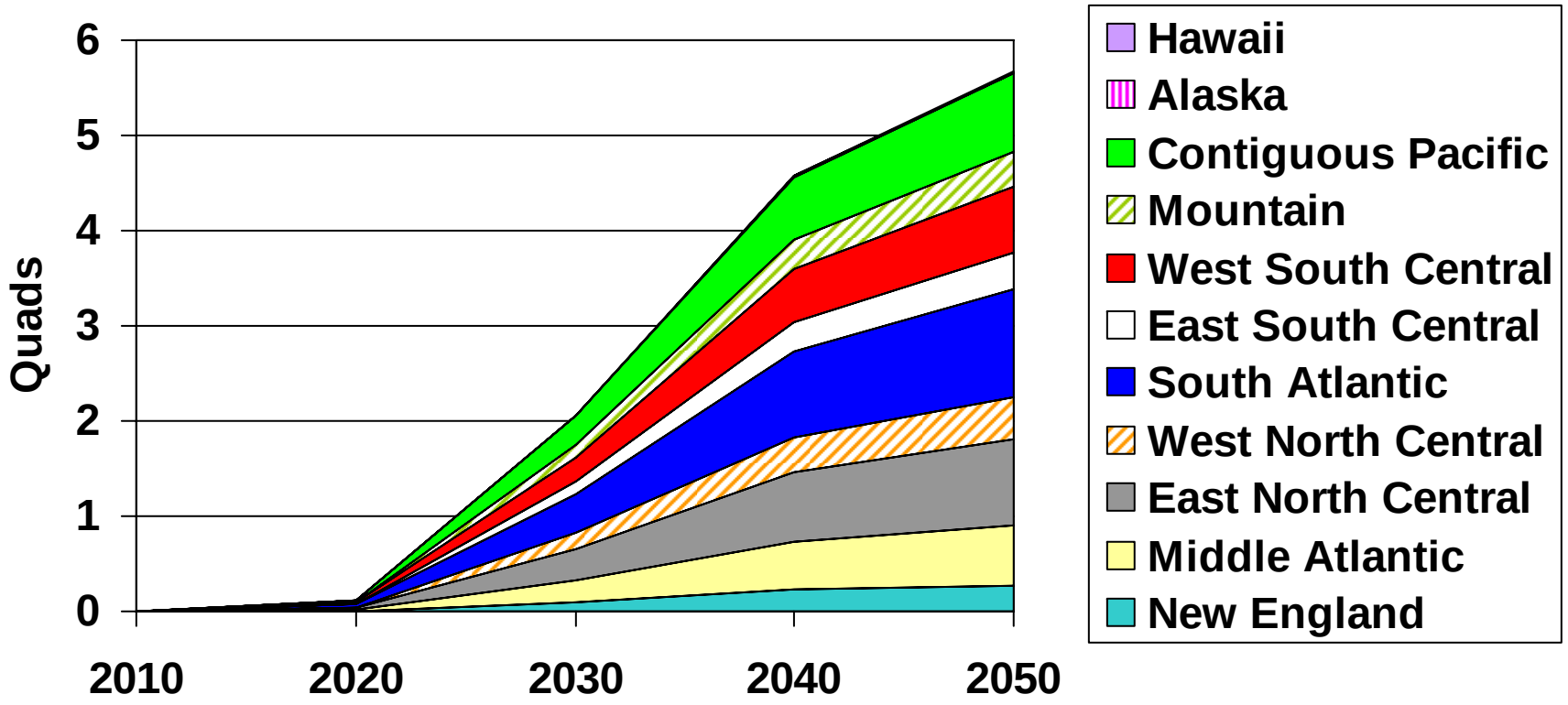
Methodology

- Develop a scenario of significant H2 demand by FCVs by region
  - U.S. Census Divisions = “Regions”
  - Disaggregate the Pacific region (Alaska and Hawaii are separate)
- Estimate H2 production by region, feedstock, production method, and delivery method over time
  - Amount produced from different feedstocks is dependent on feedstock availability, not costs
    - Did not have costs estimates by region to use
- Estimate H2 cost for each production/delivery method by region

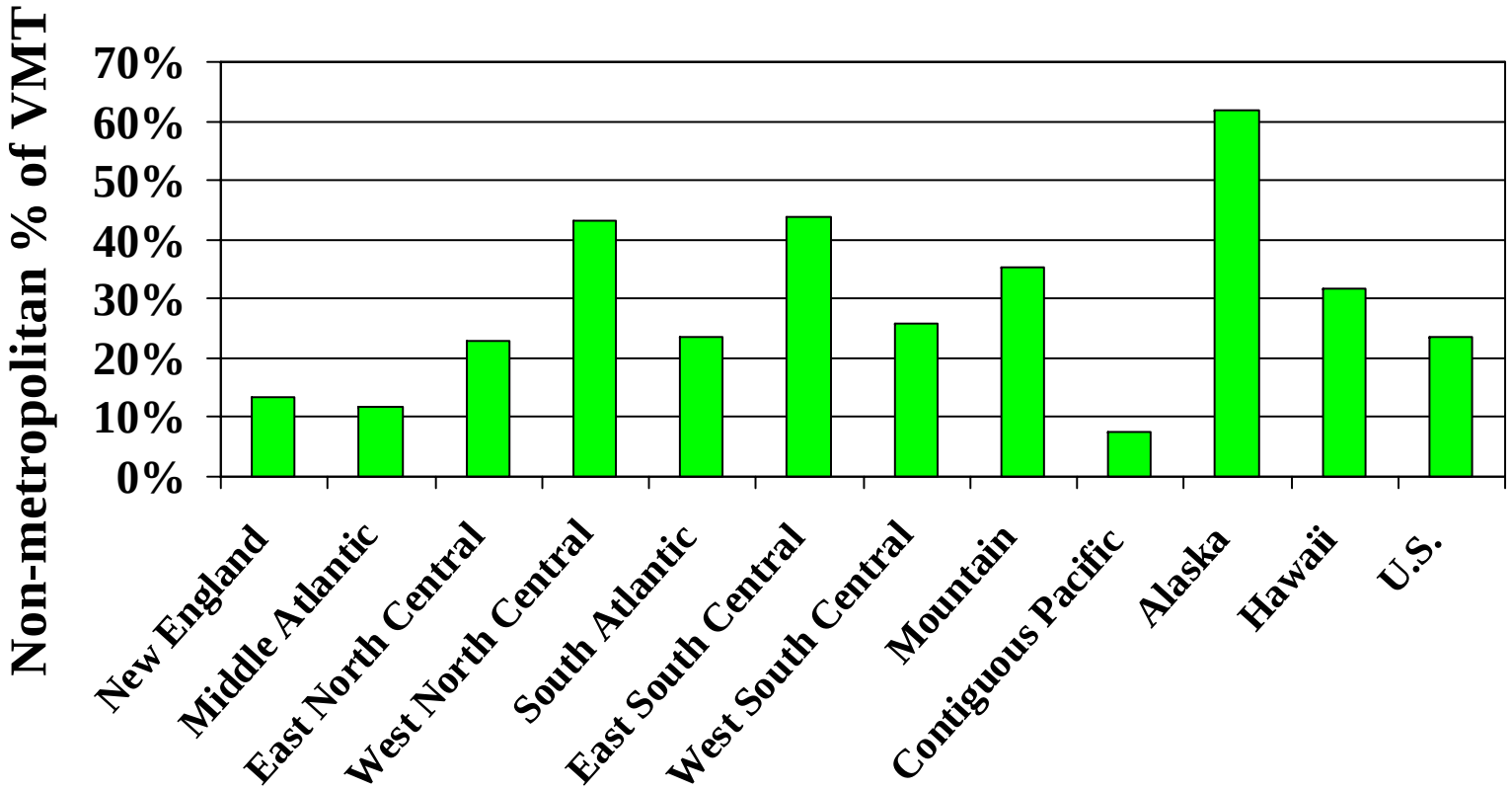
Regional H2 Demand Estimates

- Assumed H2 penetration of GYOW scenario from the joint DOE/NRCan 2050 study (2003)
  - FCVs 2015 commercialization (demos earlier)
  - FCVs 50% of LV sales by 2035 and stabilize at 50%
  - See http://www.eere.energy.gov/office_eere/ba/future.html
- By 2050, FCVs are 50% of stock and use ~6 quads (~45 billion gallons (GGE)) annually
- Allocated to regions according to current gasoline demand
- Allocated within regions according to metro/non-metro area travel
  - Used U.S. EPA county VMT estimates
- Assumed FCVs travel initially only in and between metro areas, but eventually would expand throughout the U.S. like today's vehicles

Regional H2 Demand in GYOW



Non-metropolitan H2 Demand Varies Among Regions in GYOW

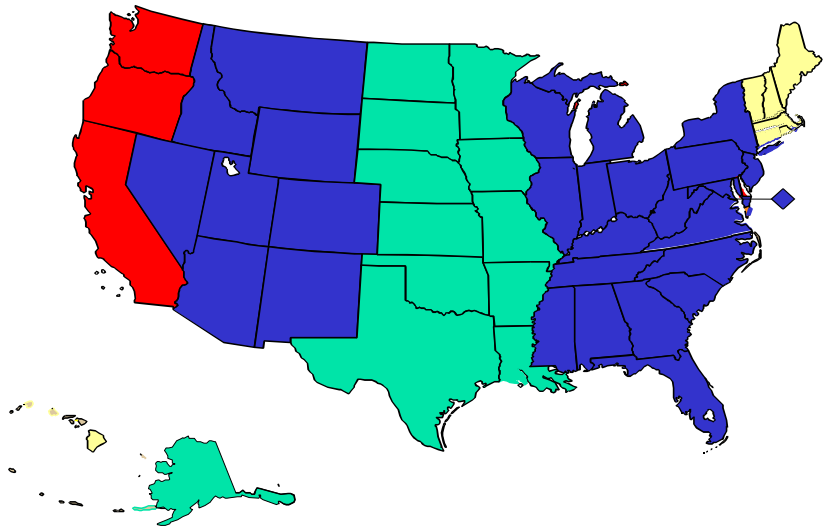


Regional H2 Production Estimates: Key Assumptions

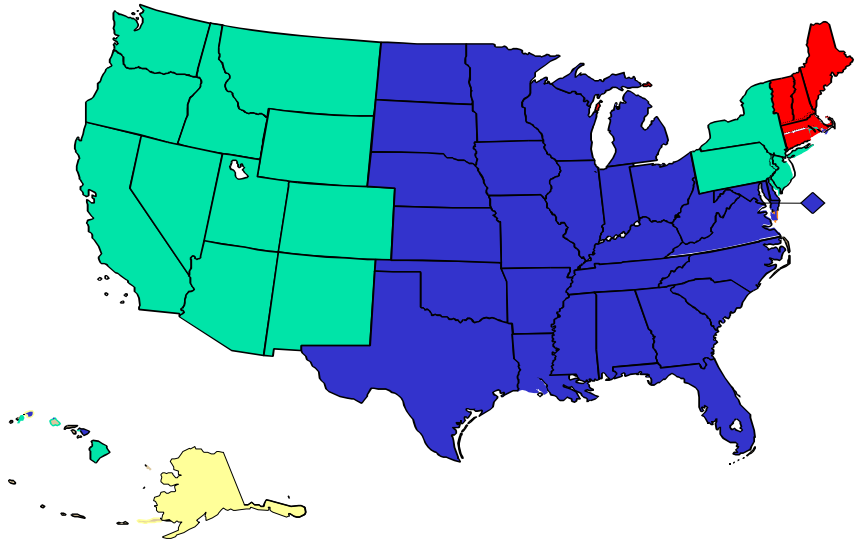
- Each region produces sufficient H2 to meet its demand
- H2 in metro areas: centralized production from diverse sources
- H2 in non-metro areas: predominantly produced at fueling stations (distributed production) from natural gas and/or electrolysis
- Feedstocks used to produce H2 depend solely on region-specific resource availability
  - Resource characterization derived from EIA, NREL, ORNL
  - In general, the greater the resource in a region, the more likely it will be used
- Natural gas as a feedstock phased out by 2050
  - DOE program “desire”

Examples of Regional Resource Characterization

Coal

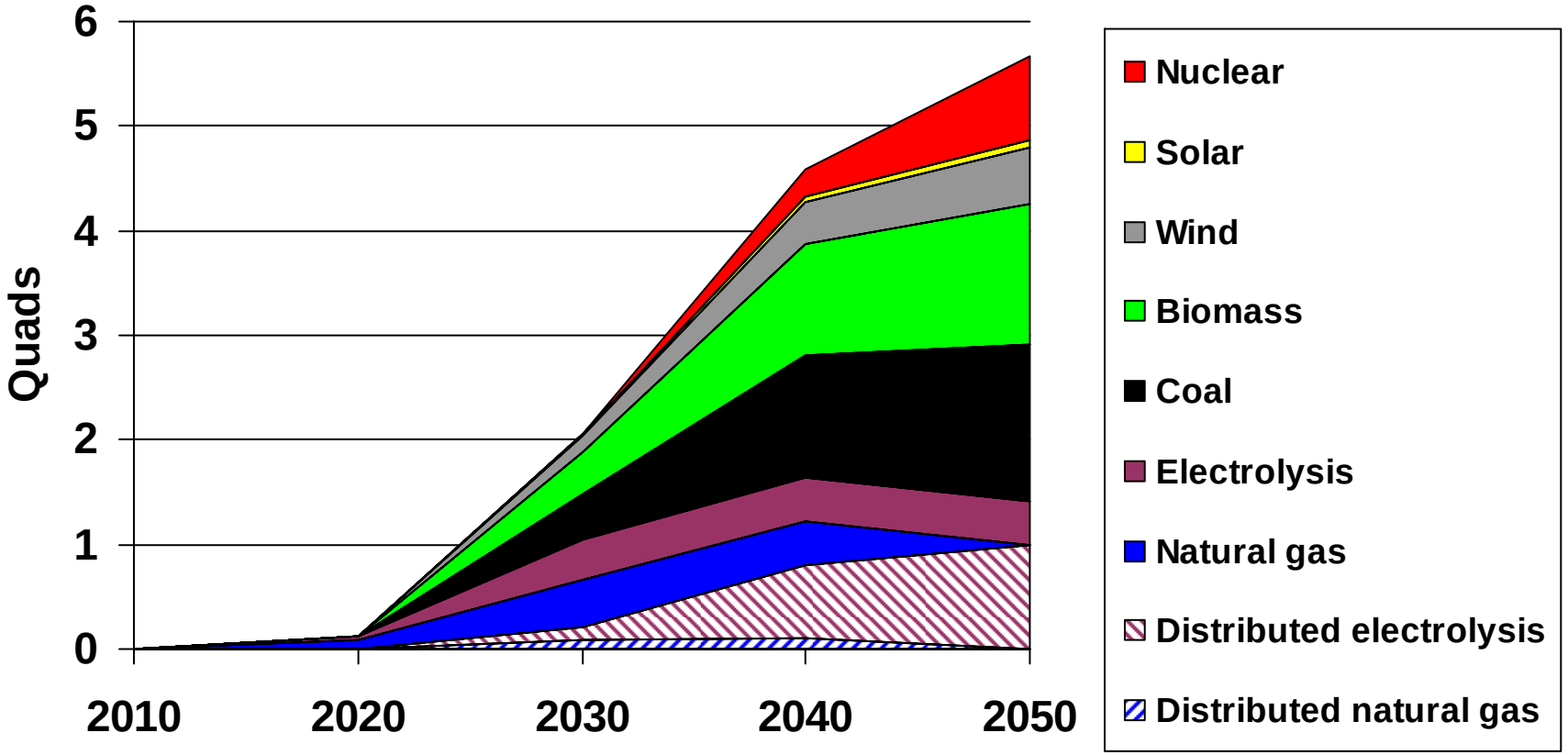


Biomass

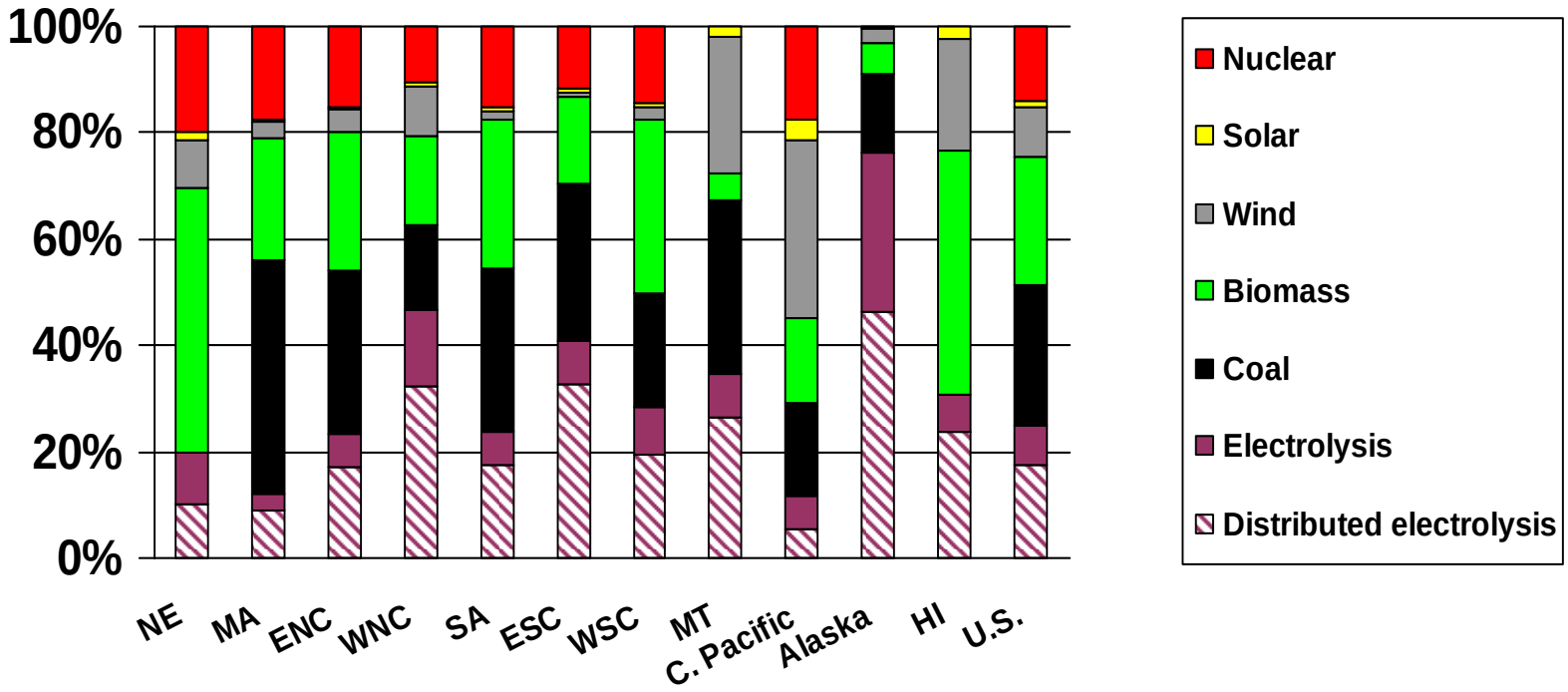


Resource availability relative to other regions
Blue: High Green: Good Red: OK Yellow : Low

U.S. H2 Production by Feedstock Varies Over Time



H2 Production by Feedstock Varies Significantly by Region

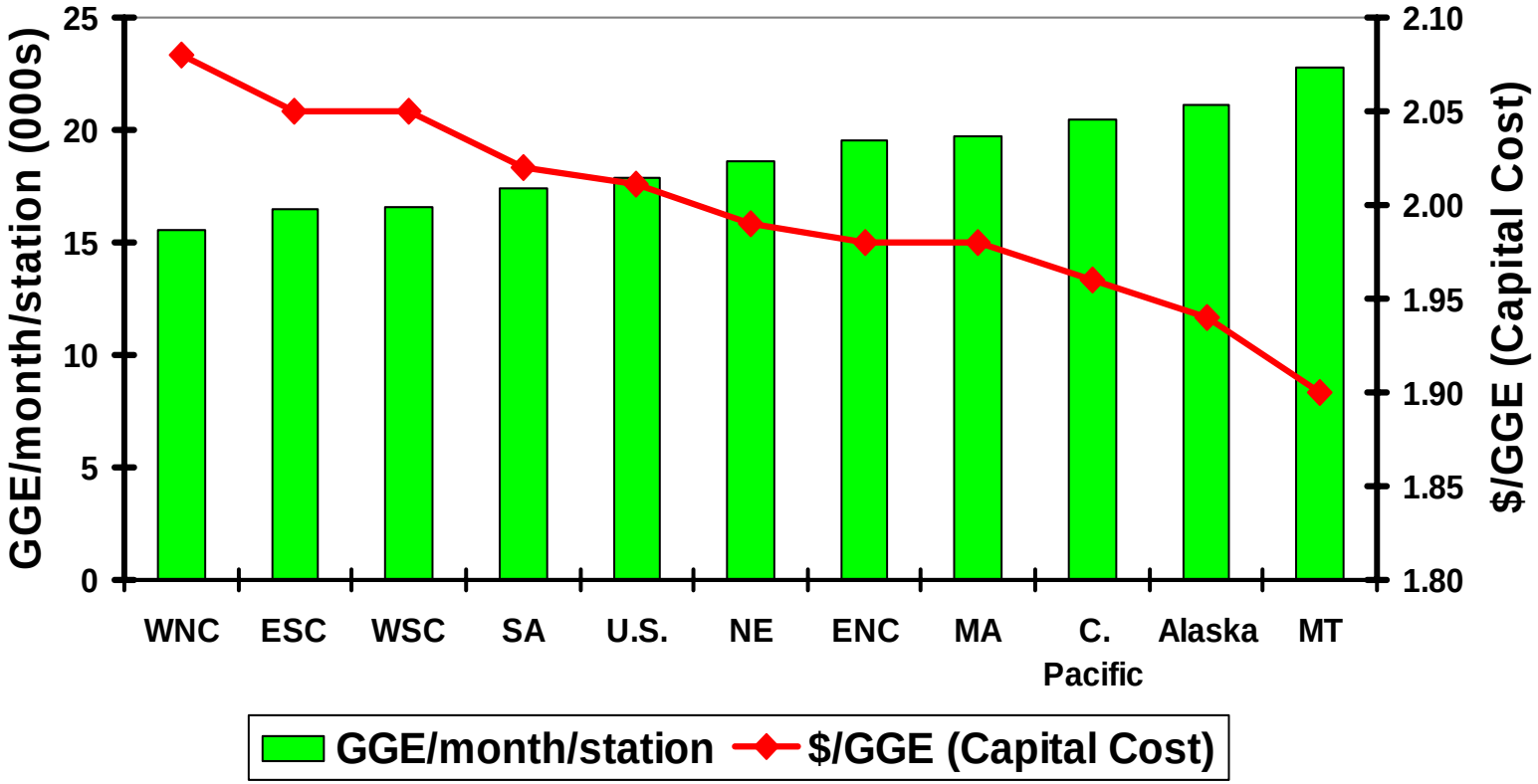


2050

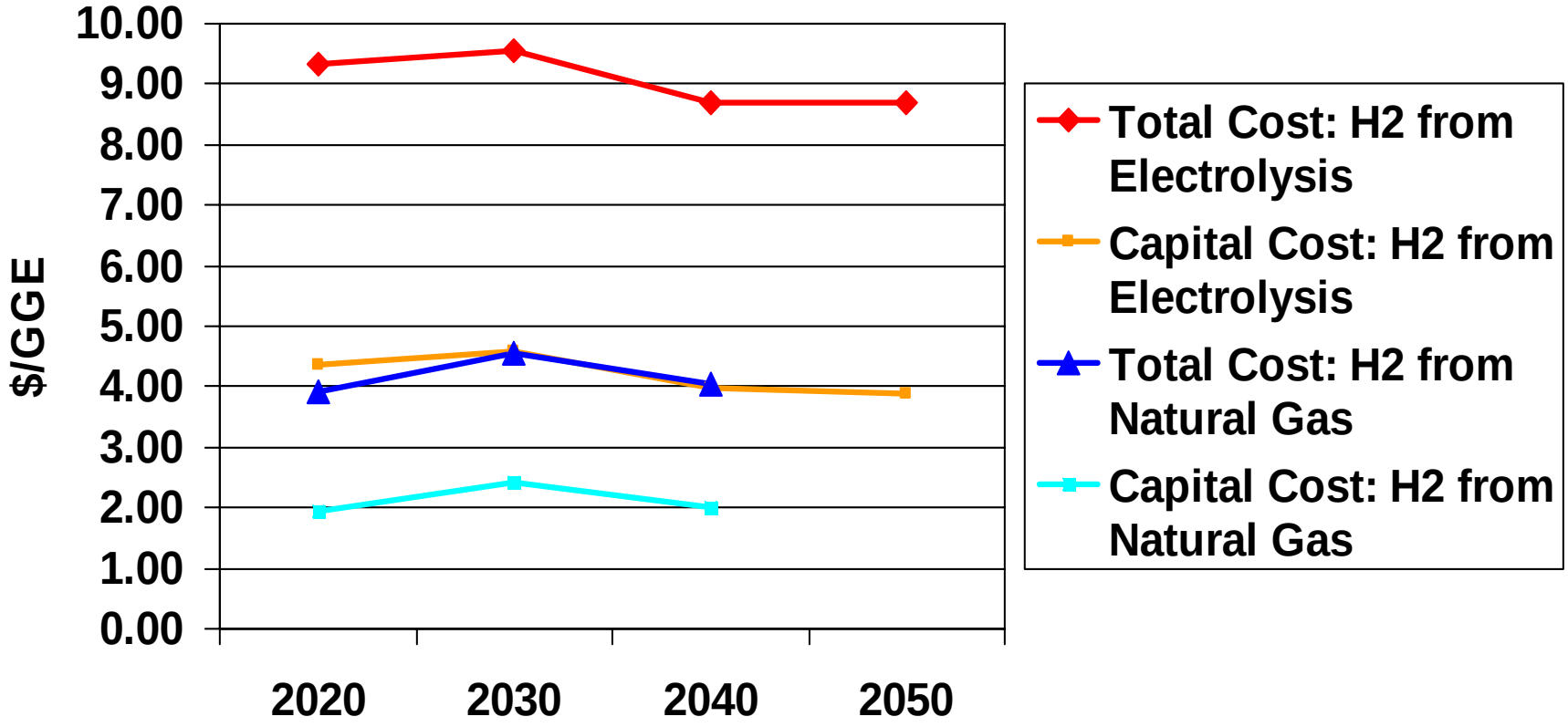
Regional Cost Estimates: Key Assumptions

- Starting point: Comprehensive analysis by SFA Pacific, Inc. (prepared for NREL)
- Modified to assume:
  - Technological improvements over time
  - Energy and capital costs variation by region and/or time
- Centralized production and delivery
  - Initial distribution by truck, then by pipeline
- Distributed production
  - For adequate geographic coverage in non-metro areas, H2 ultimately is available in same number of stations as provide gasoline now (~30,000 per U.S. Economic Census)
  - In the earlier years, less coverage (just non-metro interstates in 2020)

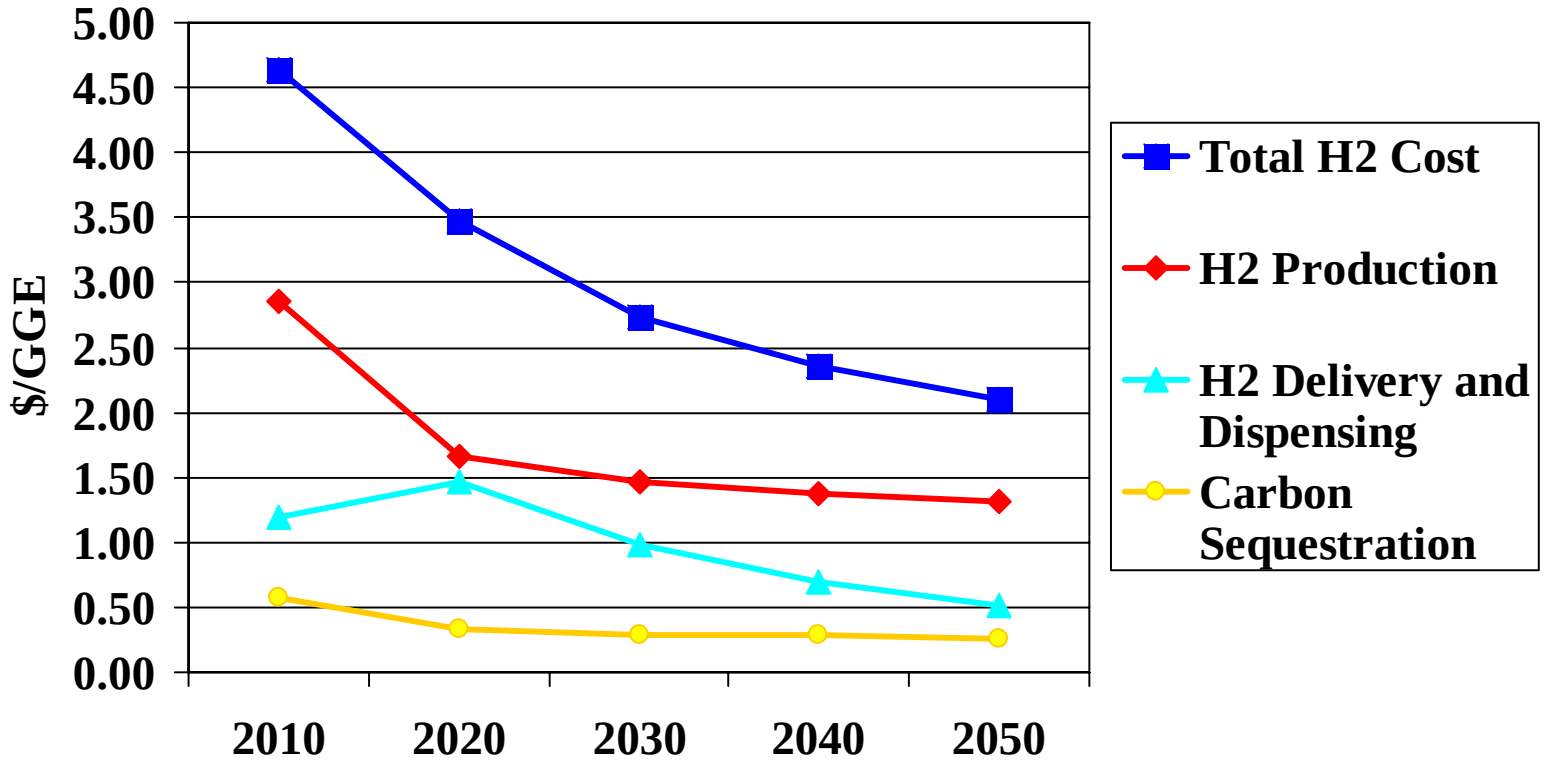
Non-Metro Area Station Totals and H2 Demand Lead to Variation in Station Size by Region Affecting Per Gallon Capital Costs (2040, Natural Gas)



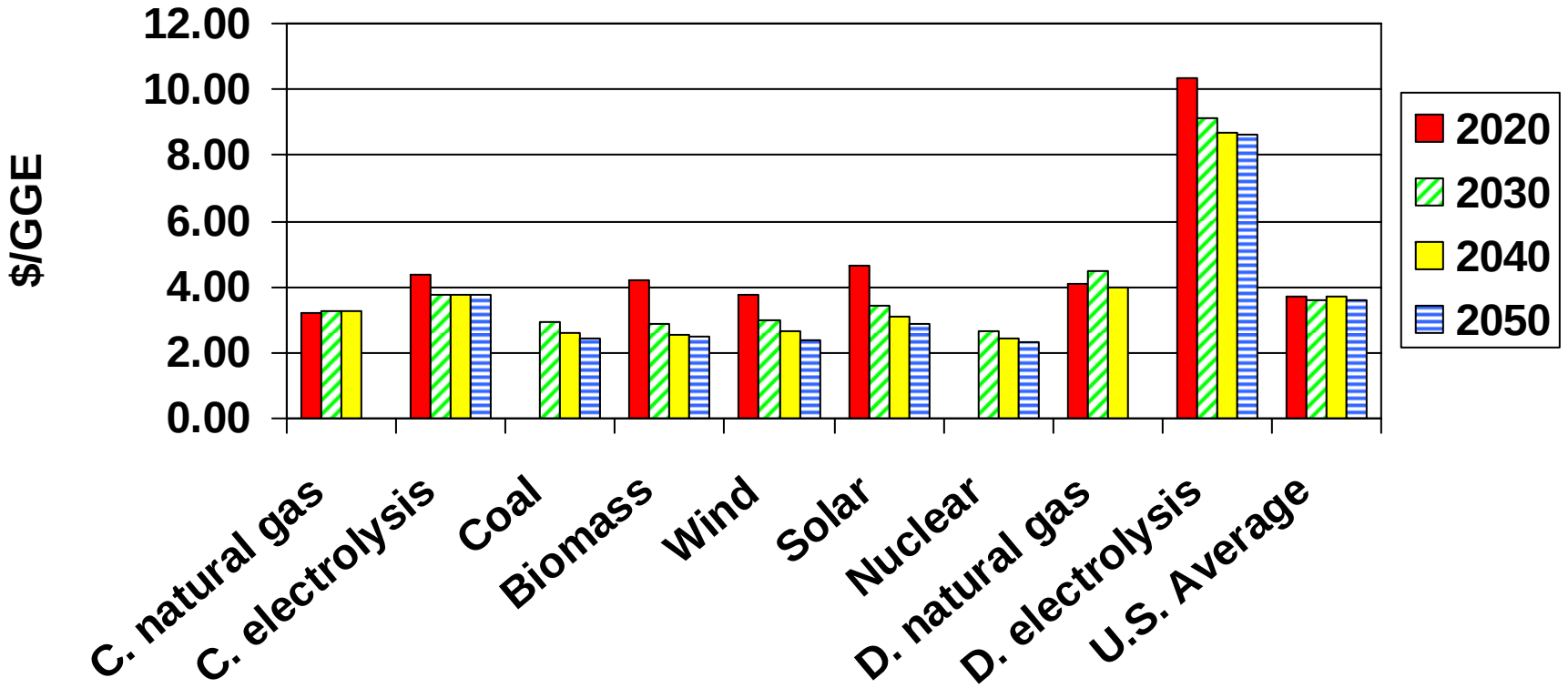
Example: Cost of Distributed Production in South Atlantic Region



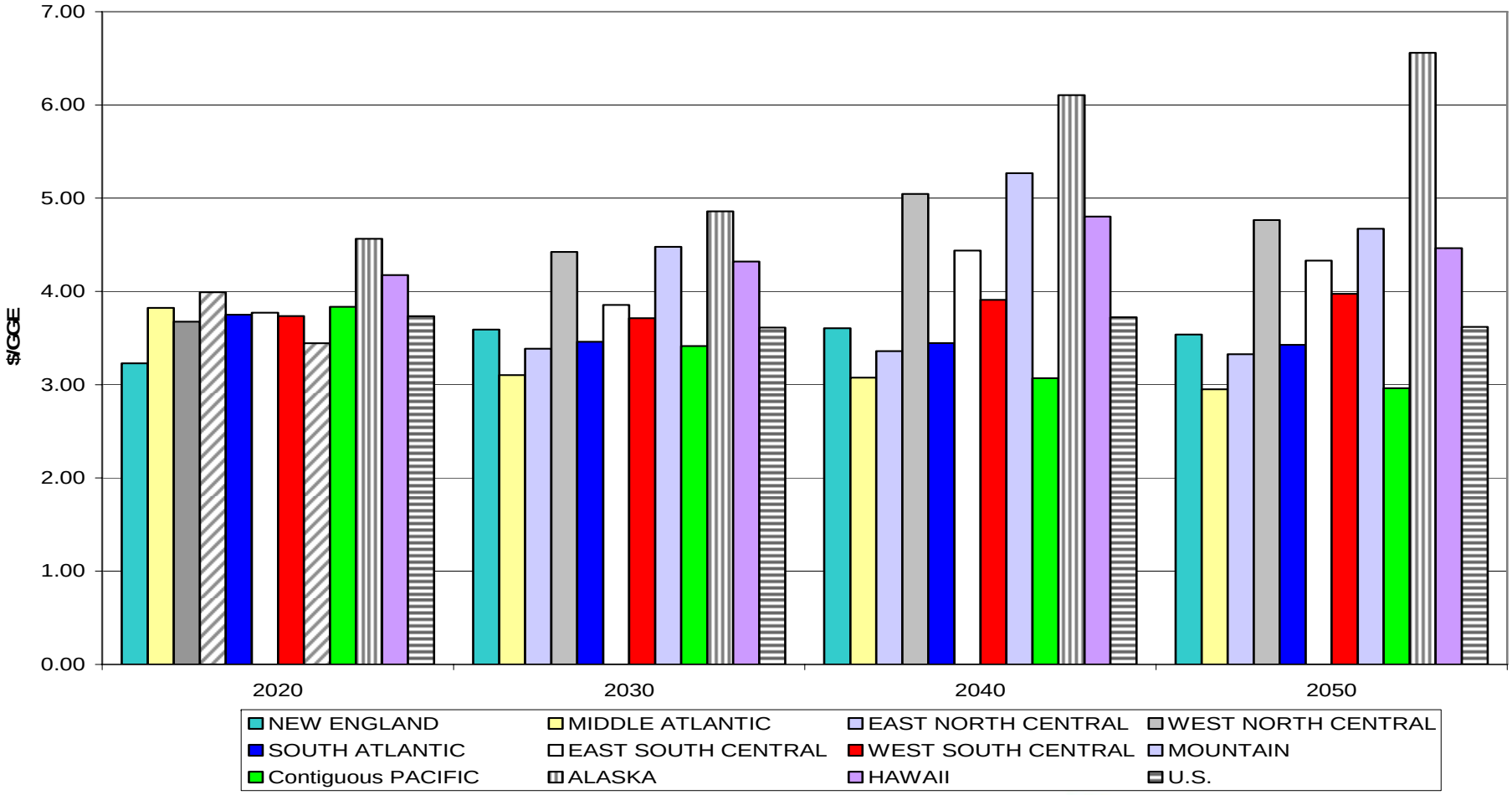
Example: Cost of Centralized Production of H2 from Coal and Delivery to South Atlantic Region



Results: In General, Delivered H2 Costs for All Technologies Decline Over Time, But U.S. Average Does Not



Results: Average H2 Costs Vary Among Regions and Over Time



Summary of Key Analysis Issues Identified in This Study

- What is the refueling infrastructure in rural (non-metro) areas now?
  - How many stations are there really and what volumes do they dispense?
    - 2 sets of estimates provide significantly different station numbers (U.S. Economic Census and National Petroleum News)
  - How much fuel is sold by other retail establishments?
  - What proportion of the stations are clustered together?
  - How many rural interstate stations exist?
  - How far do rural residents travel for fuel?
    - Recent survey says 1.4 miles or 70% further than in urban areas

Summary of Key Analysis Issues (continued)

- Assuming significant market penetration of FCVs, can we expect the refueling infrastructure in rural areas to be the same as what we have now for gasoline?
- Assuming distributed production using electrolysis is relatively expensive:
  - How much H2 will have to be generated by this method in rural areas?
  - Should the DOE program “desire” of “no natural gas use” by 2050 be reevaluated?
    - One sensitivity run with continued use of natural gas reduced cost $0.55/GGE by 2050
  - What other options are there for distributing H2 to rural areas that might reduce costs?

Summary of Key Analysis Issues (continued)

- This analysis assumed no difference among regions in the early years of FCV penetration. Is it more likely that FCVs will penetrate some regions earlier than others? Does that help with refueling infrastructure issues? One option for staged penetration:
  - Contiguous Pacific and Hawaii
  - New England and Middle Atlantic
  - East North Central
  - South Atlantic
  - West South Central
  - East South Central
  - Mountain, West North Central and Alaska

Summary of Key Analysis Issues (final)

- We need regional supply curves for all the resources that might be used to produce H2, so we can conduct a cost-based analysis.
- This analysis assumes each region is self sufficient. What interregional trading of H2 or H2 feedstocks might take place?
- What will be the effects of a regionally diverse expansion of extraction and harnessing of natural resources to produce H2?
  - Air, water, land use

Conclusions

- Regional differences in H2 demand and production will affect H2 costs
- A number of issues related to the provision of H2 in rural (non-metro) areas need to be addressed