



Geothermal Energy in Energy Planning



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**Geothermal Energy Generation in
Oil and Gas Settings Conference**

SMU, Dallas, TX

Tuesday, March 14, 2006

UCRL-PRES-219638 Draft

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

Since 1975, Lawrence Livermore National Laboratory (LLNL) has been publishing the U.S. Energy Flow Chart



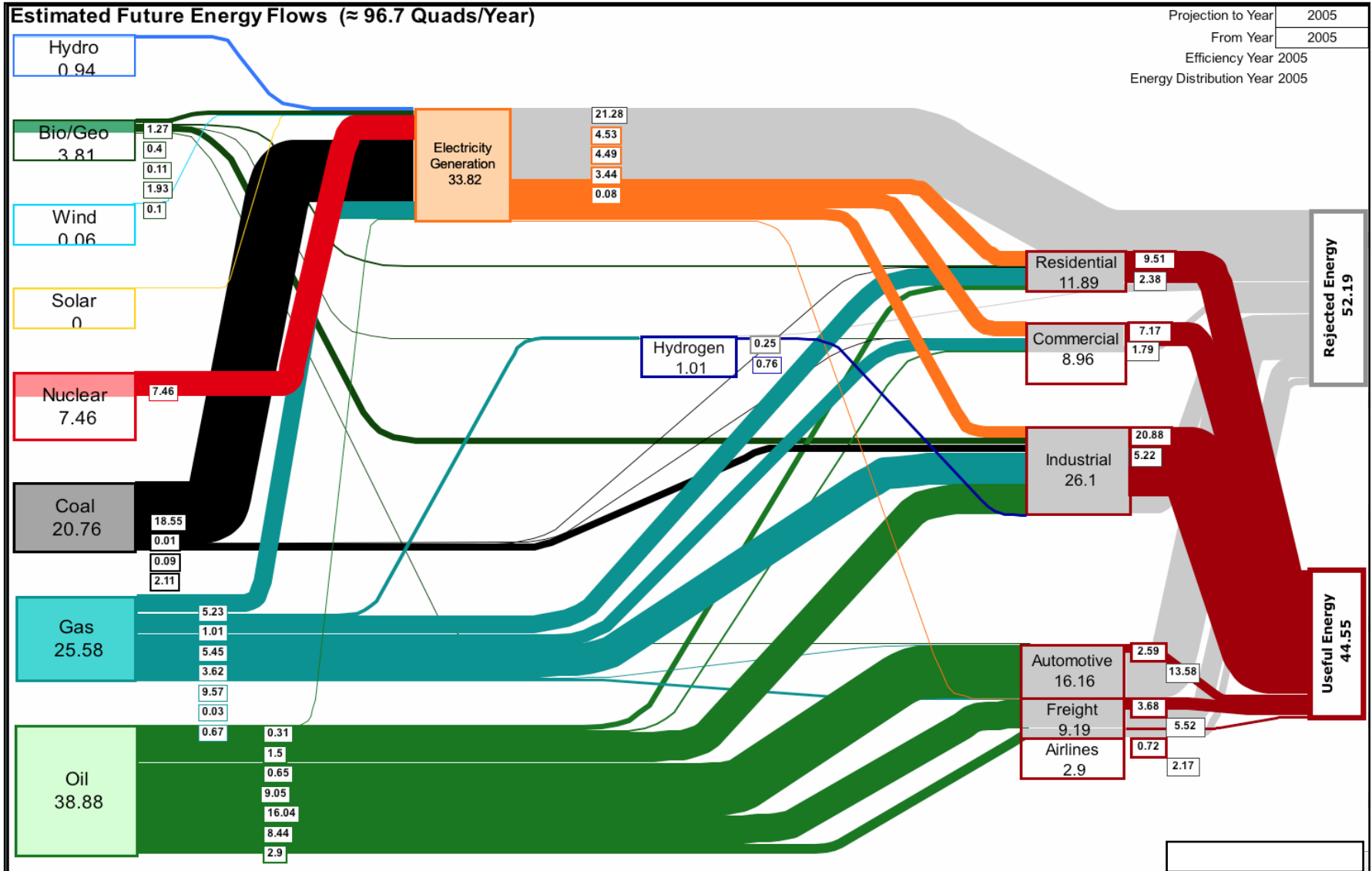
Energy Flow Chart:

- Based on published Energy Information Agency (EIA) and other data sources
- Balances energy supplies (natural gas, coal, oil, renewables, hydro and nuclear) and demands (electrical generation, residential/commercial, industrial and transportation) with energy efficiency estimates
- Over the years associated carbon flows charts, California and hydrogen automobiles have been added
- Starting in 2003, the Energy Flow Chart was automated:
 - » Energy and carbon flow charts are drawn automatically from a database
 - » Allows for trend analysis and future projections
 - » Allows for real-time what-ifs regarding assumptions, e.g., gas mileage, electricity plant efficiency
 - » Automatically calculates carbon flows for each chart

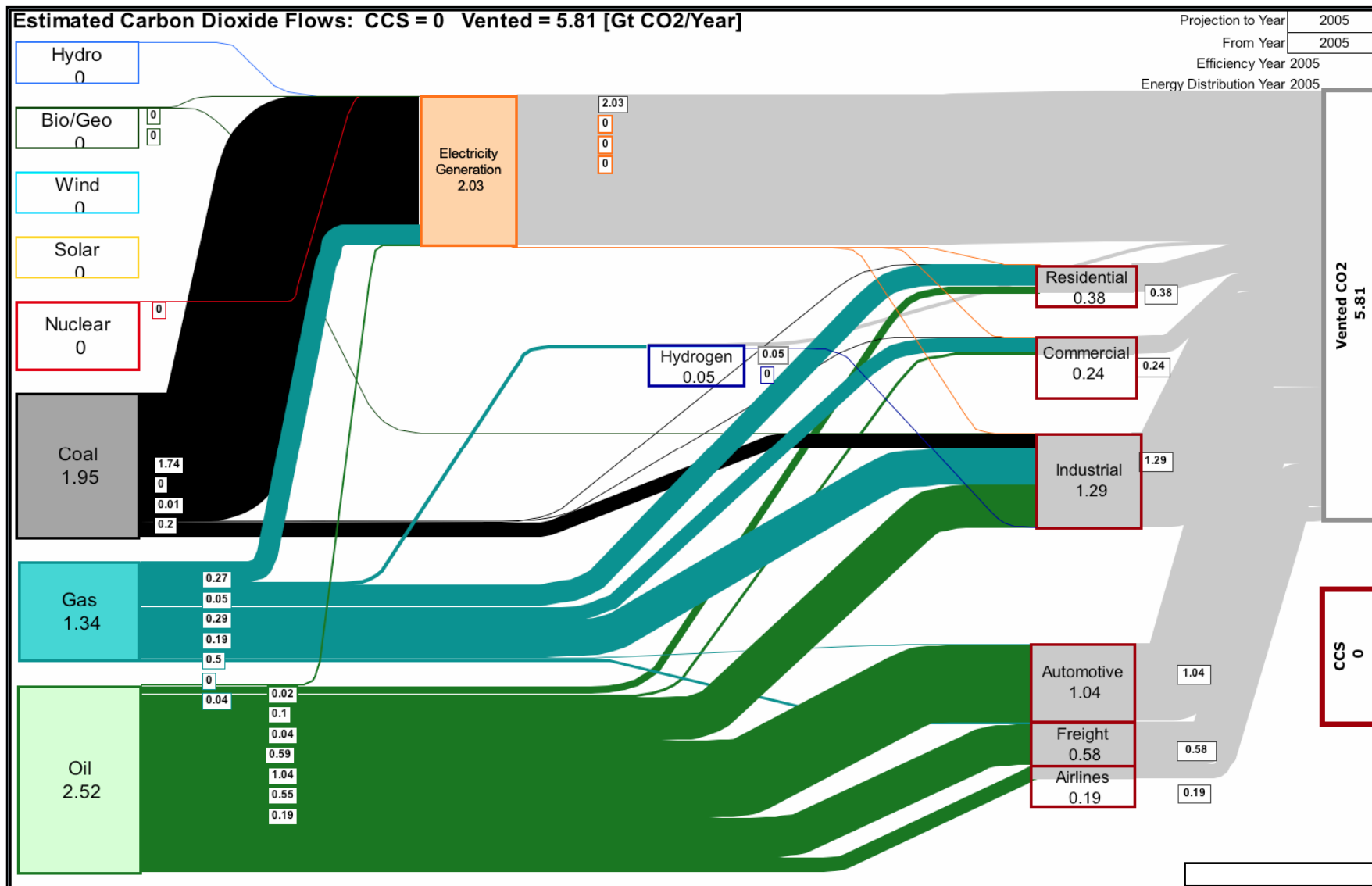
The value of the Energy Flow Chart is to integrate and understand system response to scenario drivers and focus attention on synergies, chokepoints while identifying critical technical challenges.

Energy Flow Chart is demand driven:

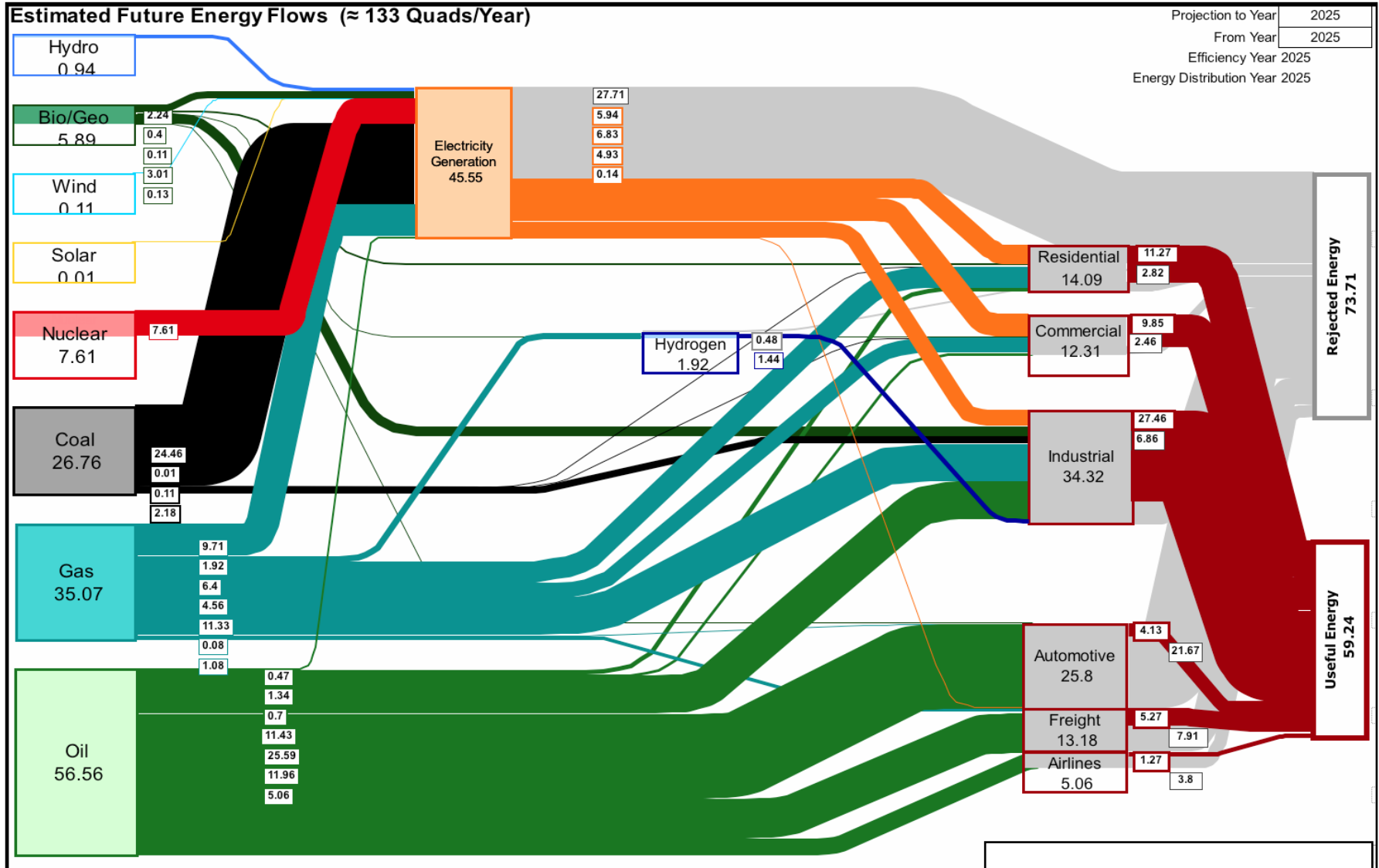
- includes major sources, electricity & H₂ generation, estimated efficiencies
- EIA 2005 forecast is shown



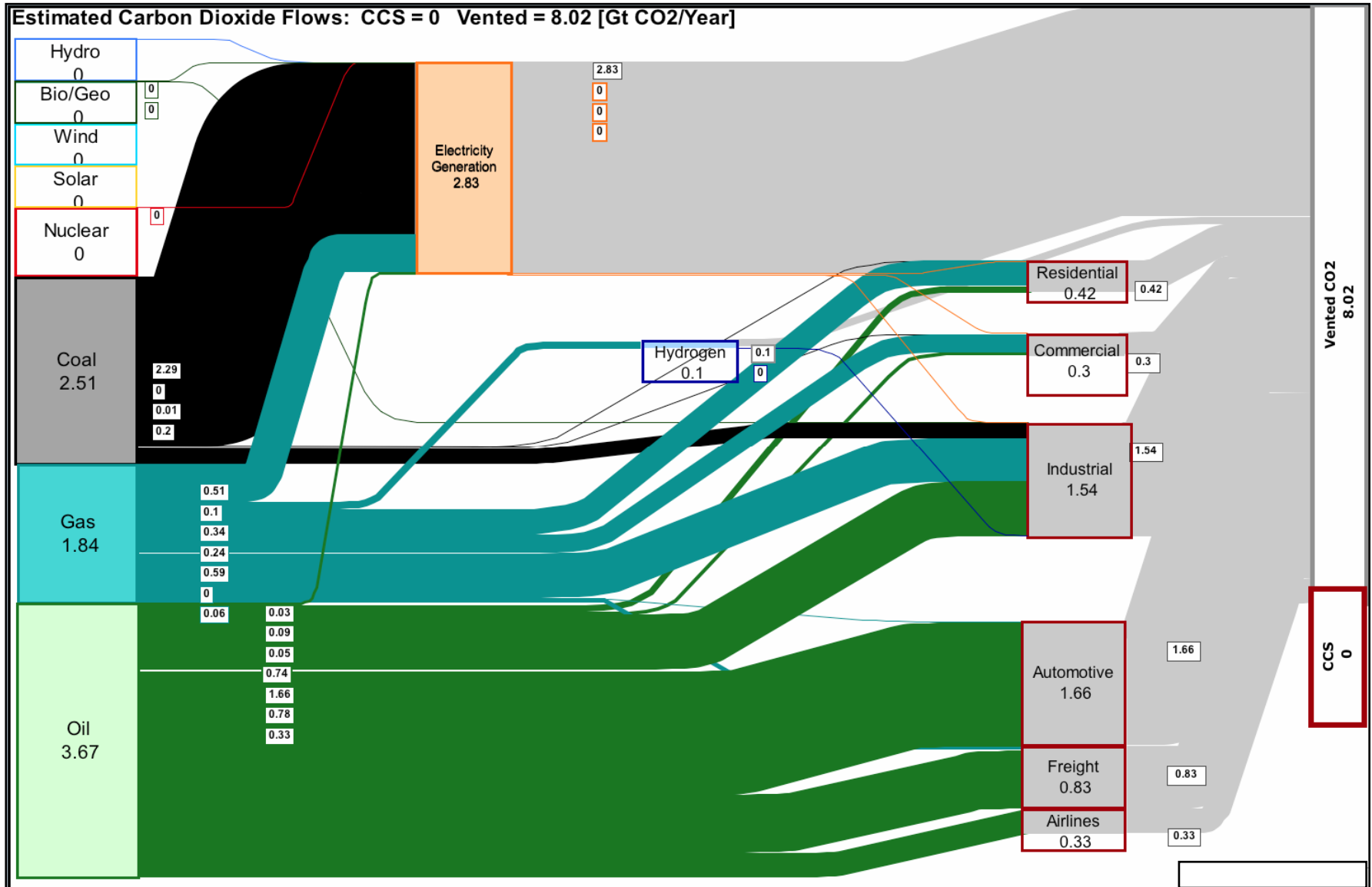
New 2005 Carbon Flow Chart is derived from energy flow, estimates energy, related CO₂ sources (5.8 GtCO₂/yr) and allows for an integrated CCS scenario construction



Energy flow for 2025: EIA projects rising demand for coal and oil reflecting rapid growth in electricity and transportation (assumes limited efficiency gains, 20 mpg average autos)

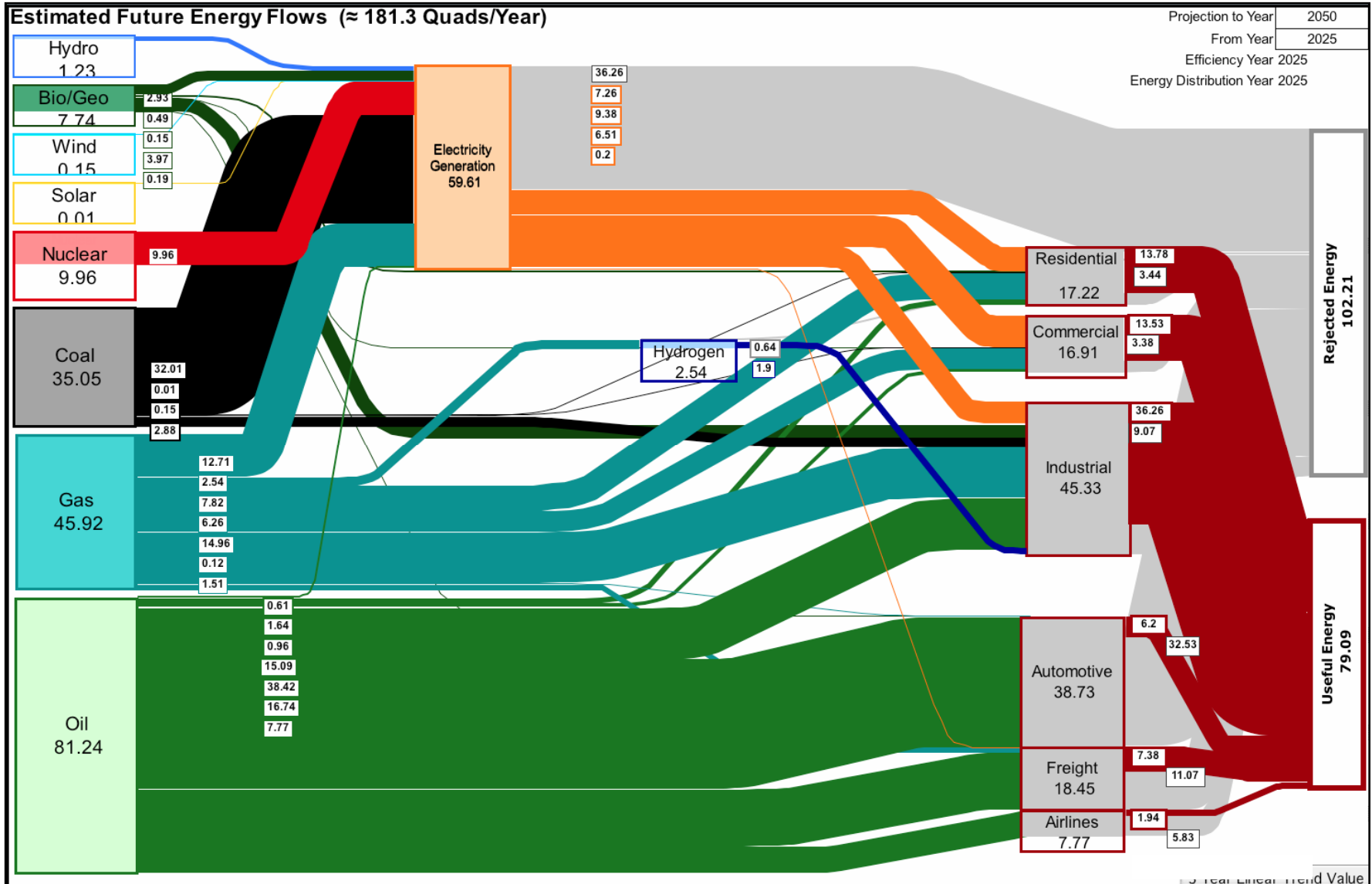


Companion carbon flow for 2025 reflects growth in vented CO₂ (8 GtCO₂/yr) driven by electricity generation (coal) and transportation (automobiles—oil)



Linear extrapolation from 2020-2025 EIA reference case to 2050

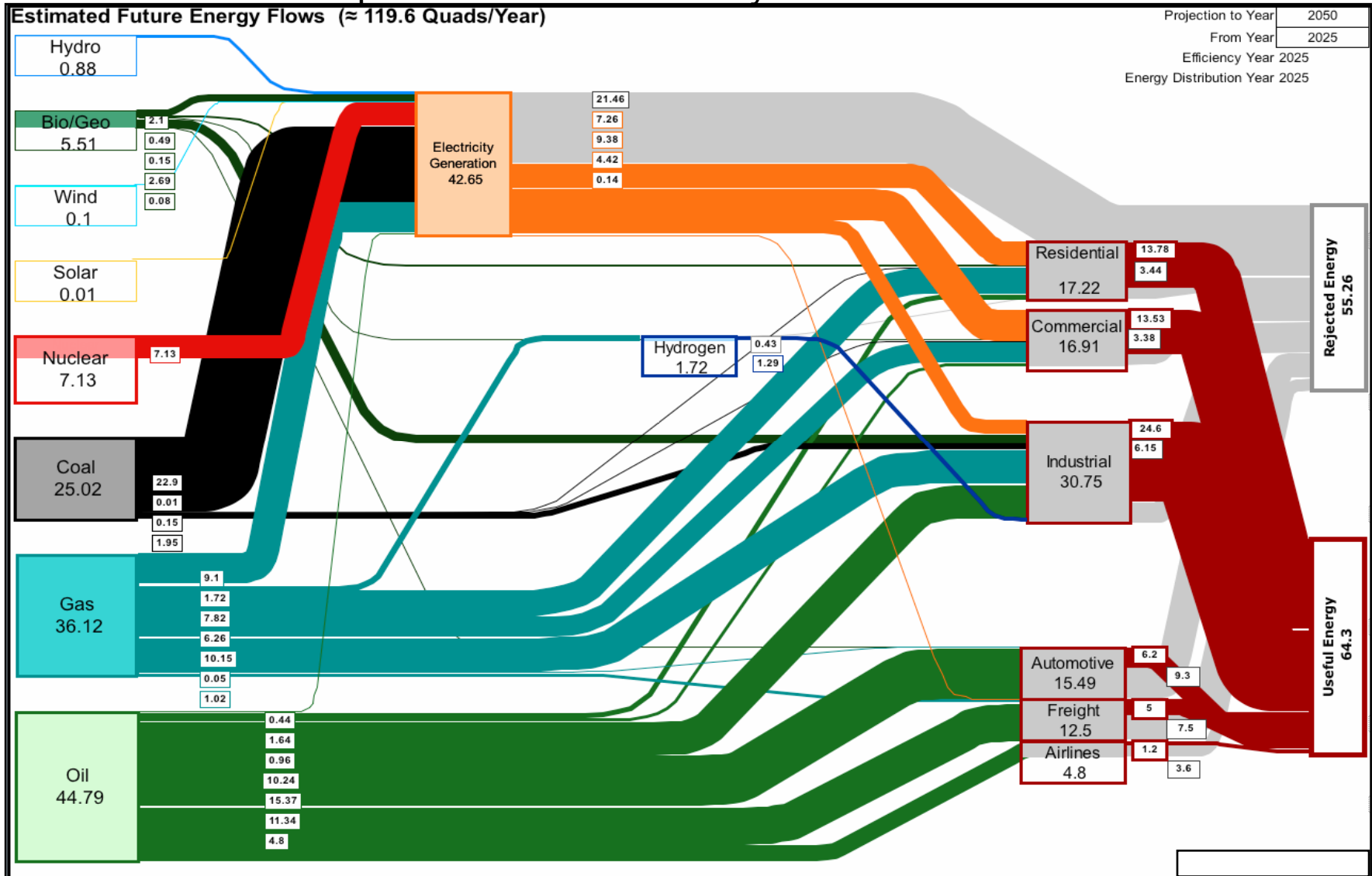
- U.S. petroleum consumption ~ 40 million bbl/day?
- Natural gas grows to ~ 45 TCF?



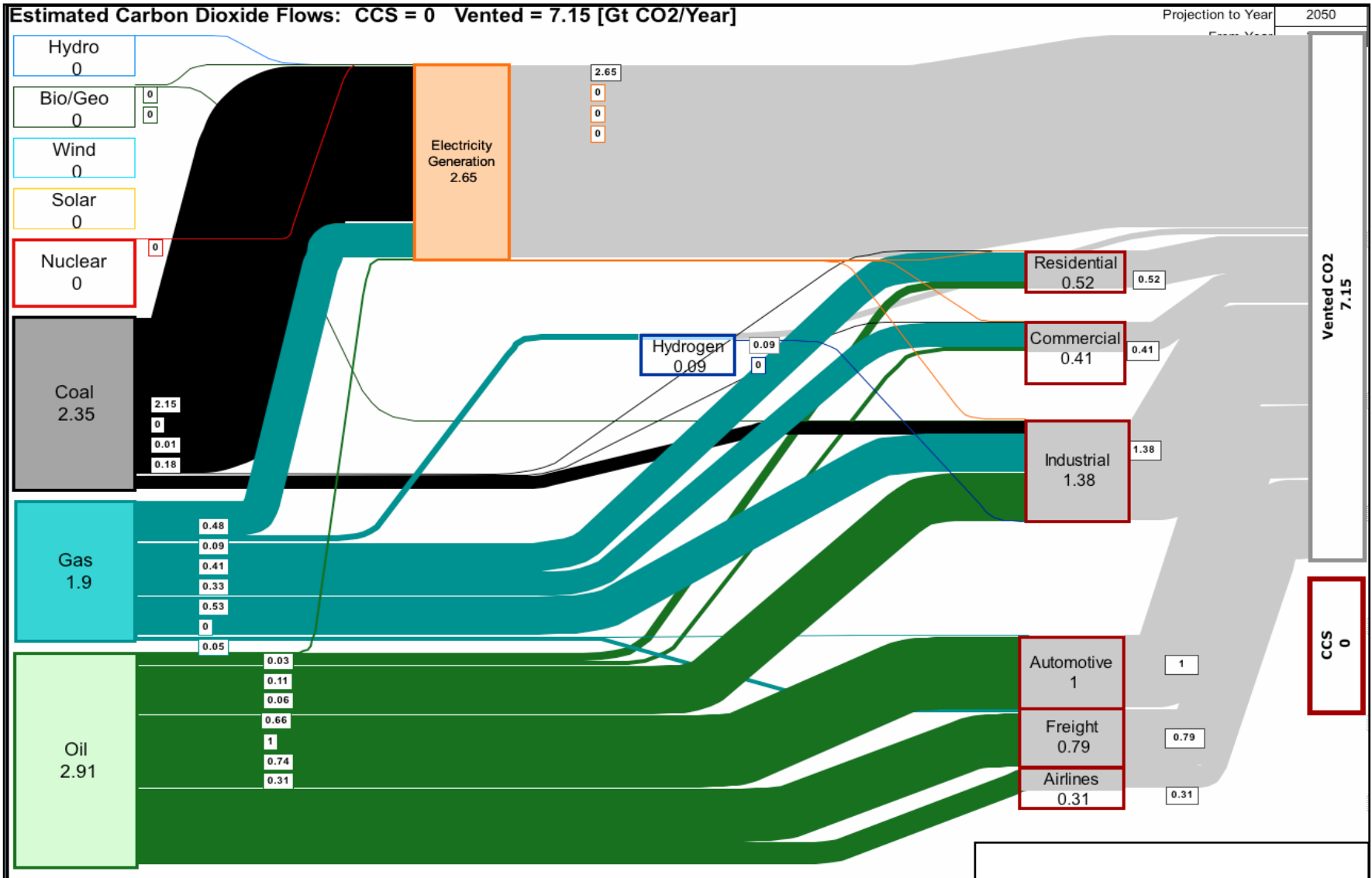
10 Year Linear Trend Value

Energy flow for 2050 high-efficiency case, aggressive but more realistic:

- 50% improvement in electric generation, industrial, freight and aircraft
- 50 mpg (average) US light-duty fleet
- Petroleum consumption ~ 22 million bbl/day

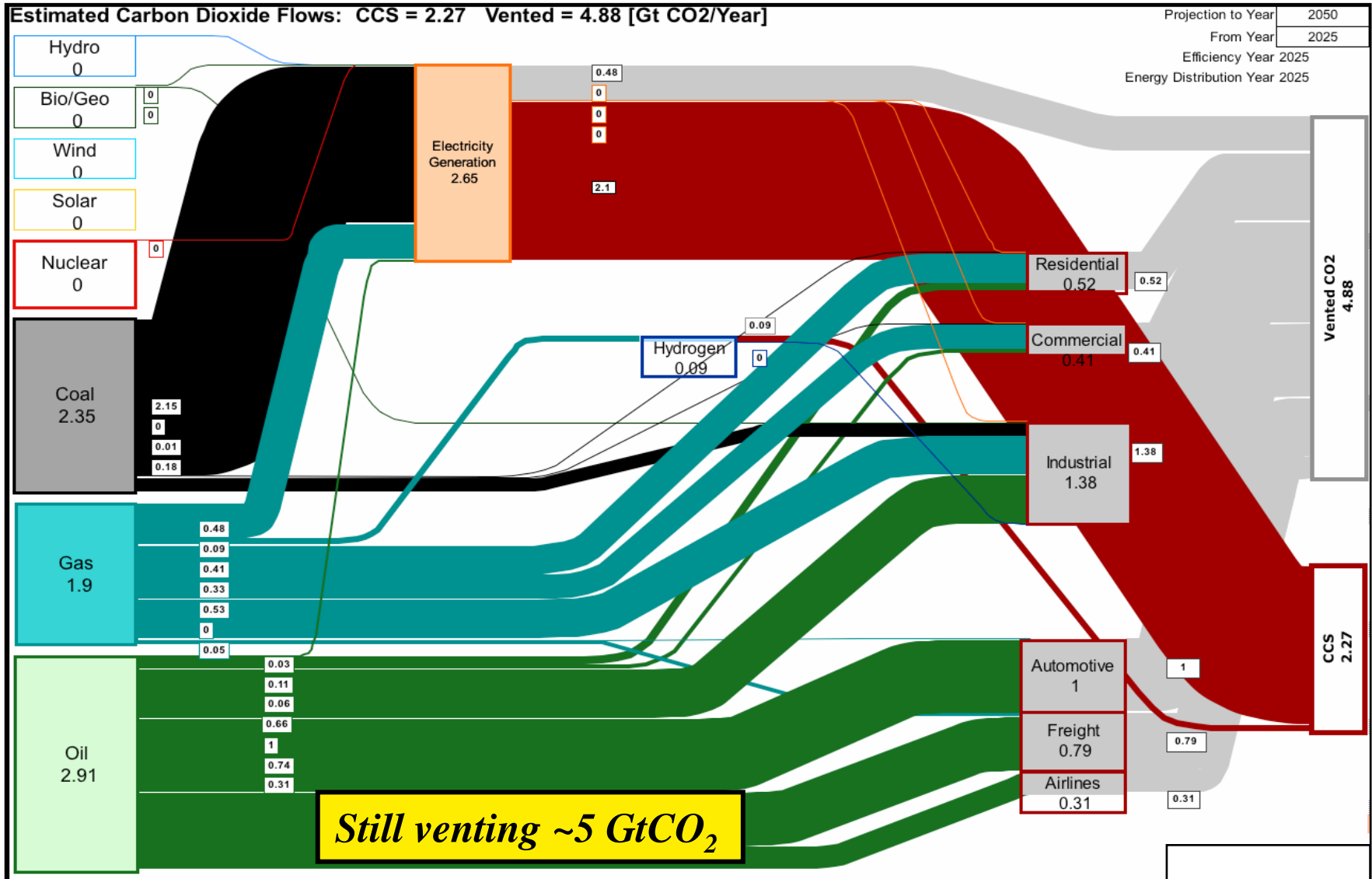


Carbon flow for 2050 energy efficiency case restrains emissions to 2025 levels: ~7 GtCO₂/yr vented without CCS implementation



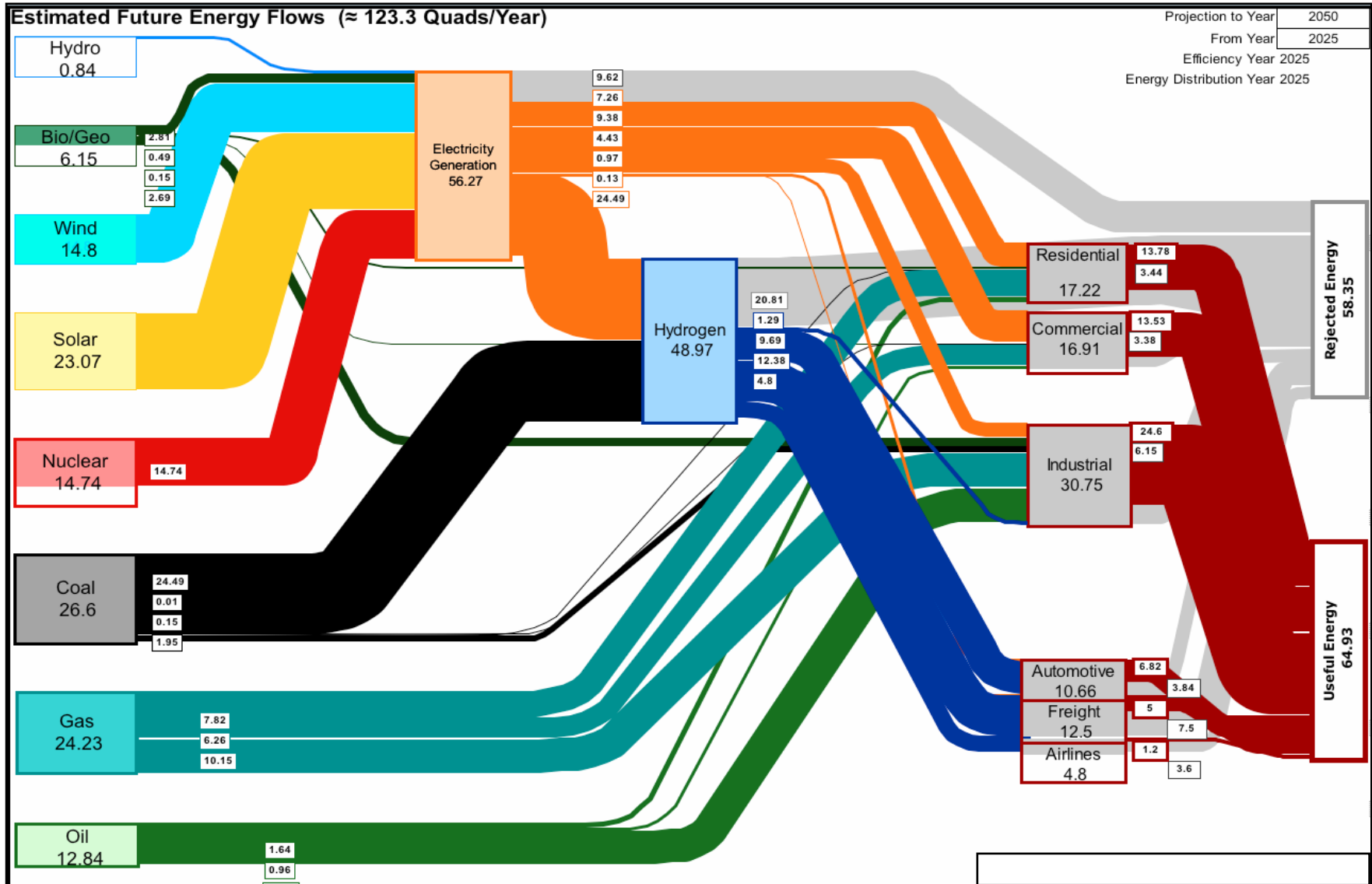
2050 efficiency carbon flow case *with* CCS (no capture energy penalty):

- coal-fired electric generation and industrial H₂
- captures ~ 2 but still vents ~ 5 GtCO₂



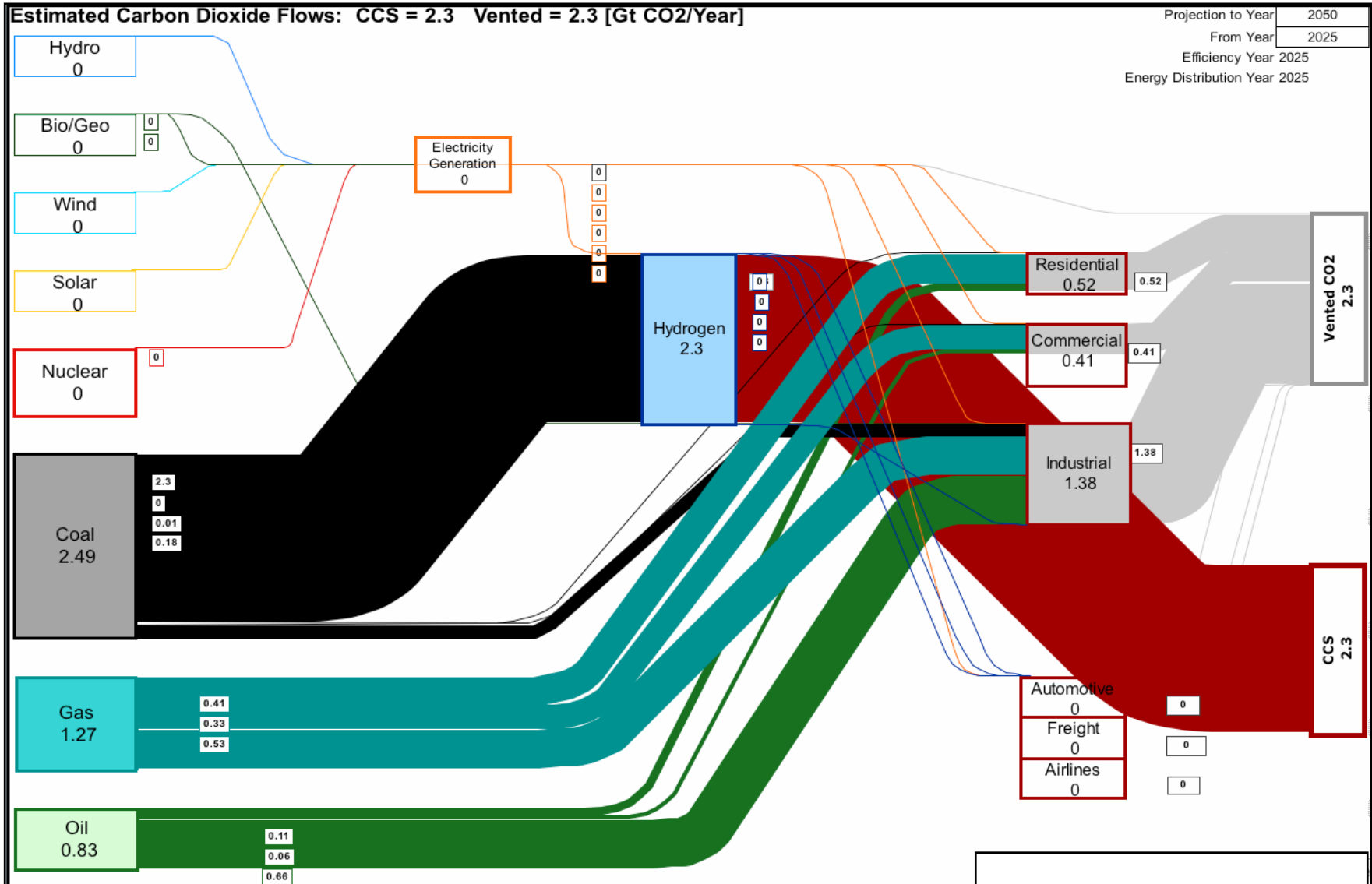
Massive carbonless electricity and transportation 2050 energy flow case:

- shifts sequestration burden from electricity generation to H₂ production
- use H₂ to replace oil and off-peak electricity to generate H₂



Carbon flow for “carbonless” utilities and transportation 2050 case:

- CCS and venting equal at 2.3 GtCO₂/yr (~60 million bbl CO₂/d)
- optimistic nuclear and renewables avoid 2.5 GtCO₂/yr



Massive, carbonless utilities and transportation 2050 case far exceeds EE&RE's FY05 projections for carbon emissions—

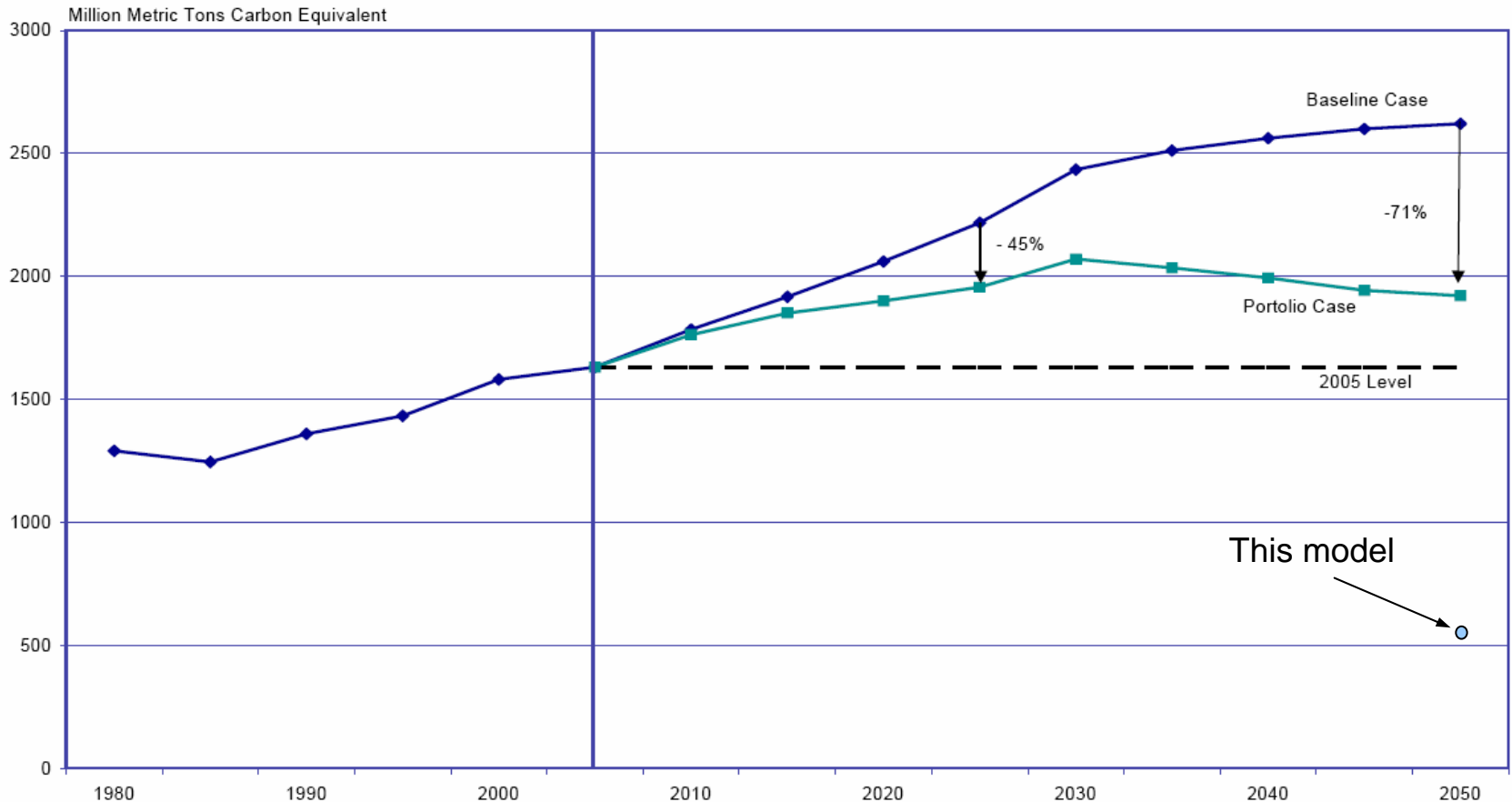
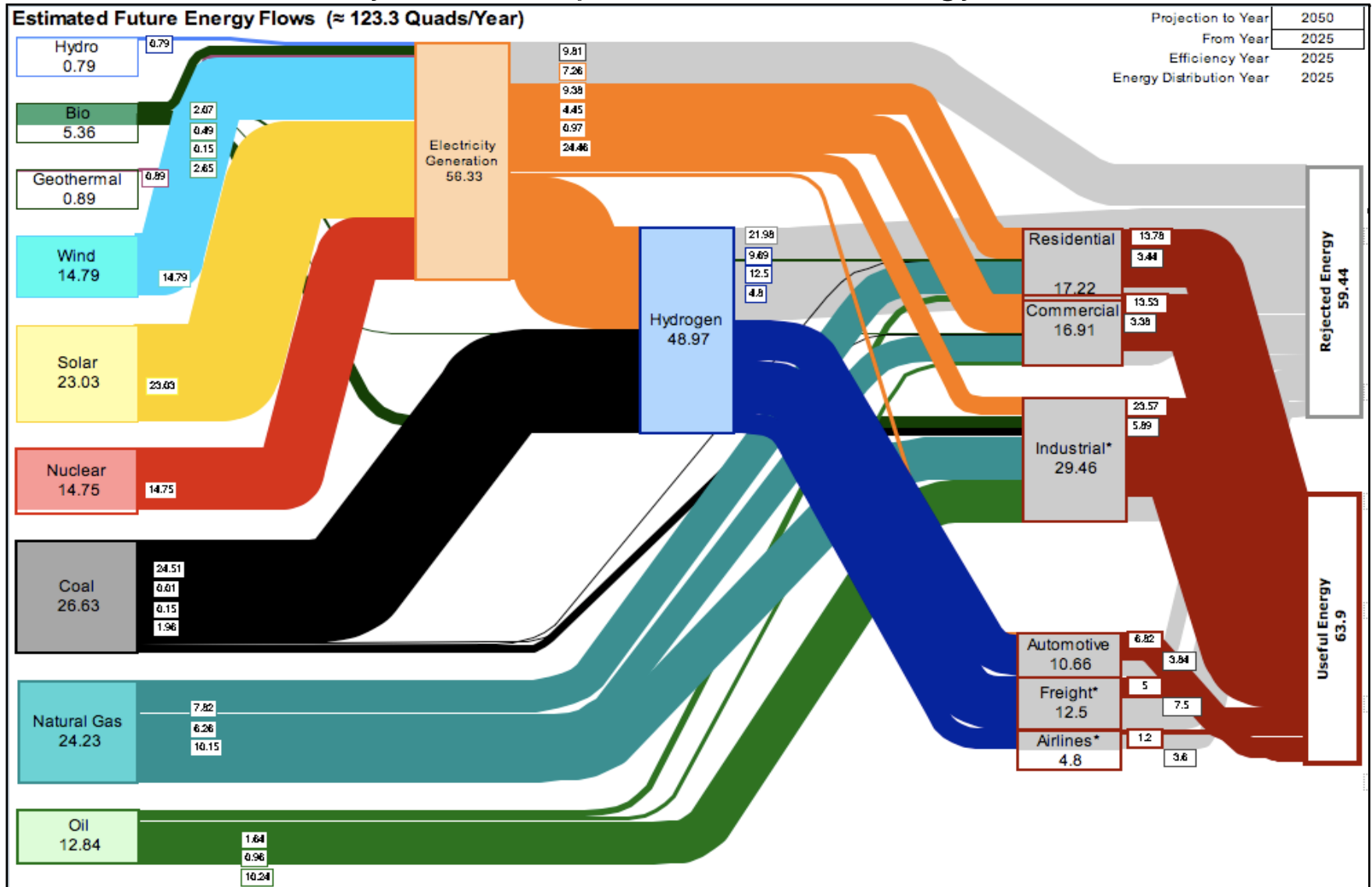


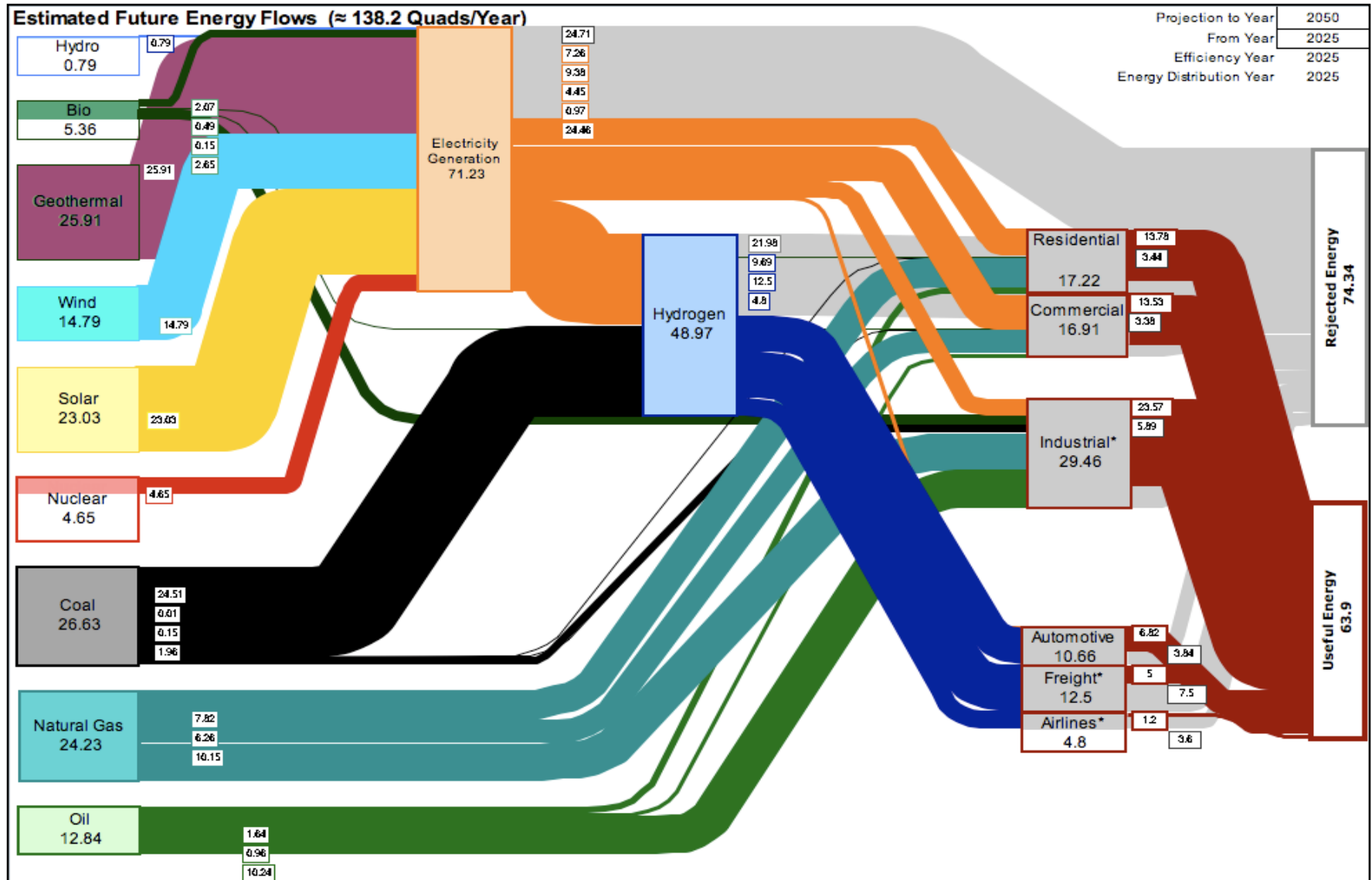
Figure ES.4. U.S. Carbon Emissions, 1980-2000, and Projections to 2050: Baseline and Portfolio Cases

From: Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs FY 2006 Budget Request, NREL/TP-620-37931, 3/2005

How do we take best advantage of geothermal energy's unique attributes: dispatchable and "built-in" storage in the massive carbonless electricity and transportation 2050 energy flow case?



Geothermal energy is dispatchable so 25 Quads/year should not replace intermittent renewables such as wind or solar but rather complement nuclear energy as base load.



Our model is more aggressive than EE&RE's FY05 portfolio case of nonrenewable energy in 2050—106 Quads versus 78 and 64 Quads

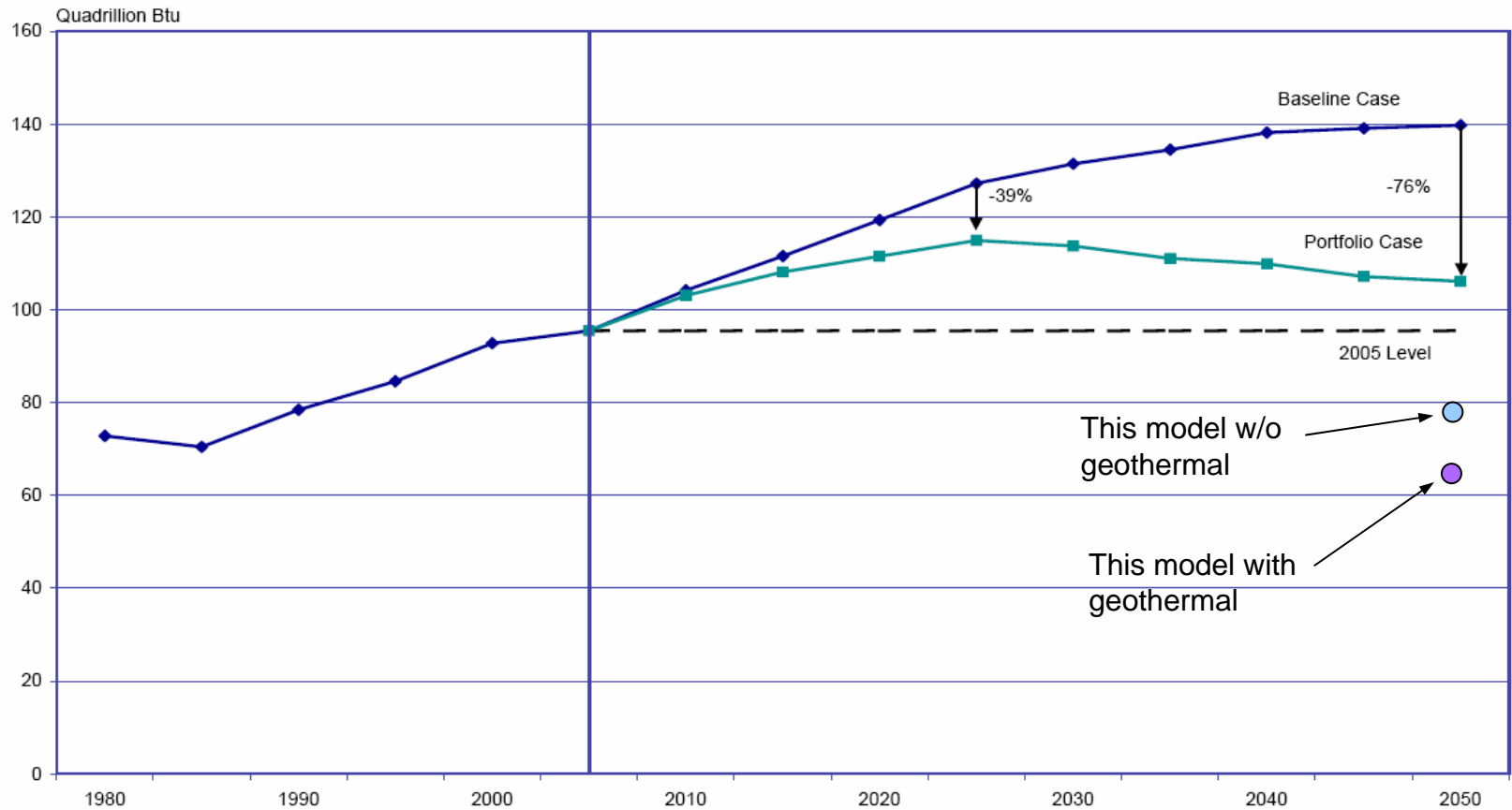


Figure ES.1. U.S. Nonrenewable Energy Consumption, 1980-2000, and Projections to 2050: Baseline and Portfolio Cases

From: Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs FY 2006 Budget Request, NREL/TP-620-37931, 3/2005

Conclusions



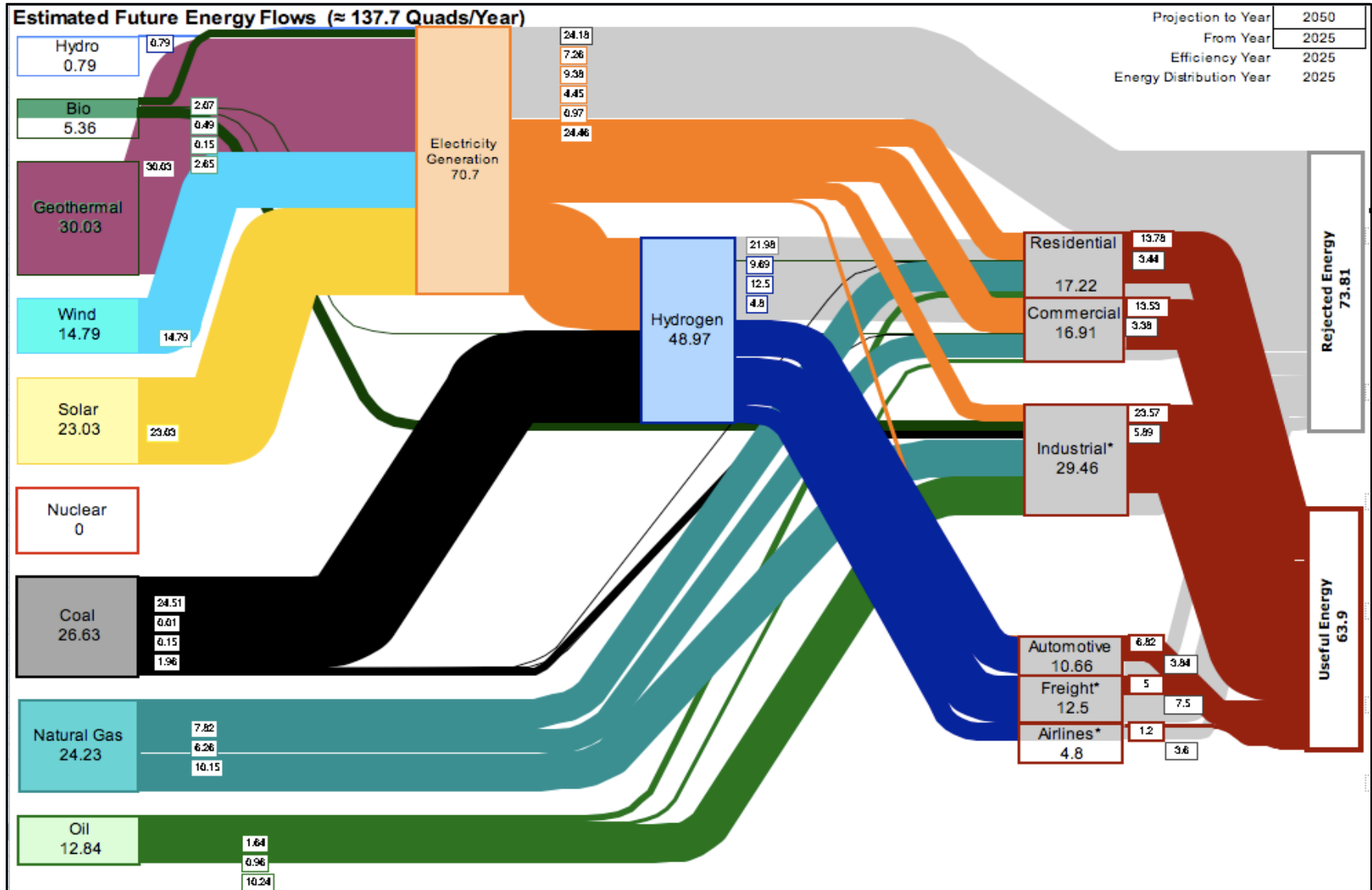
- Energy and carbon flow charts were employed to investigate possible end-member 2050 U.S. carbonless energy system configurations naturally integrating particular future demand-driven, source, efficiency and technology scenarios. (<http://eed.llnl.gov/flow/>)
- Major energy efficiency improvements, carbon capture and storage, hydrogen-fueled vehicles/trains/trucks/planes, and implementing V2G with an aggressive renewables/hydrogen program are all needed to affect steep reductions in emissions by 2050—but it is not enough.
- Geothermal energy's role may make significant contributions in electrical generation displacing, say, nuclear energy or other renewables but can only directly reduce carbon emissions when employed to heat/cool residential, industrial and commercial buildings.

Bottom line: besides competing with other renewables to de-carbonize the electrical system—massive application of passive geothermal by 2050 could provide a significant contribution to a carbonless energy system.

Backup Slides



At 30 Quads/year geothermal energy could entirely replace nuclear energy as a dispatchable base-load energy source



What is a very optimistic US geothermal energy resource estimate to use in the 2050 case?



- Today, the US is operating at about 2.7 GWe (~1.3 Quads/year)
- USGS Circ. 790 (1978) estimated 2,400 Quads from identified and undiscovered resources.
- Top 17 US geothermal fields (from Williams and Reed update, data from Circ. 790) total is about 800 Quads.
- Western Governors' Association (WGA) estimates that 13 GW of identified resources are expected to be developable within the next 10-20 years in the Western US.
- Geothermal Energy Association 1999 report: up to 18.9 GW of geothermal power could be produced in the US.
- So, we assumed 25 Quads/year as a very optimistic 2050 geothermal input (just 20X today).