Fourth Annual Conference on
Carbon Capture & Sequestration

Developing Potential Paths Forward Based on the Knowledge, Science and Experience to Date

Sequestration and Energy Policy2

Carbon, Hydrogen and Energy Flow Chart: Insights and Implications for the U.S. in 2050

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

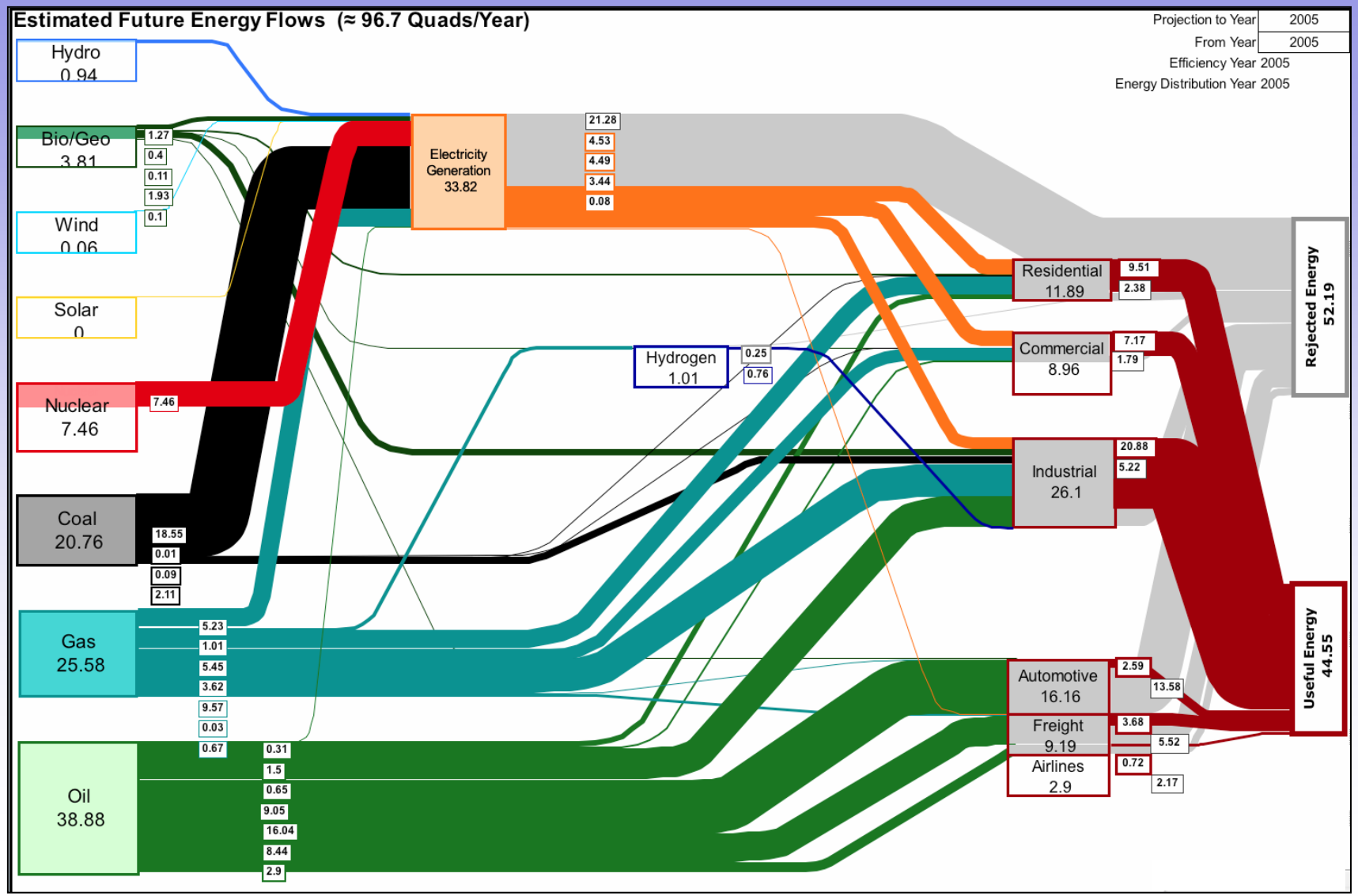
Energy Flow Chart:

- 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

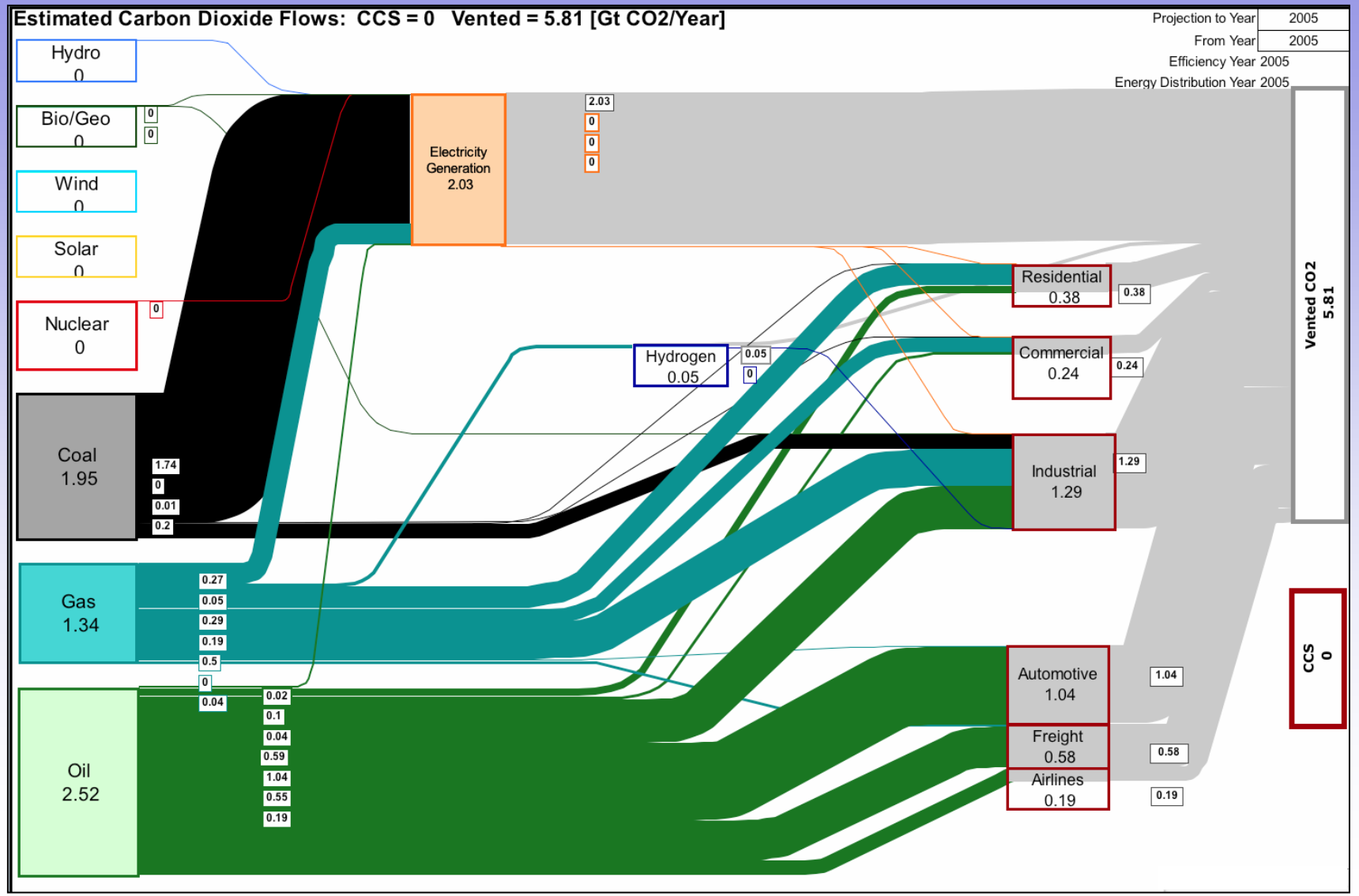
The value of the Energy Flow Chart is to integrate and understand system response to scenario drivers and focus attention on challenges and chokepoints

LLNL Energy Flow Chart is demand driven:

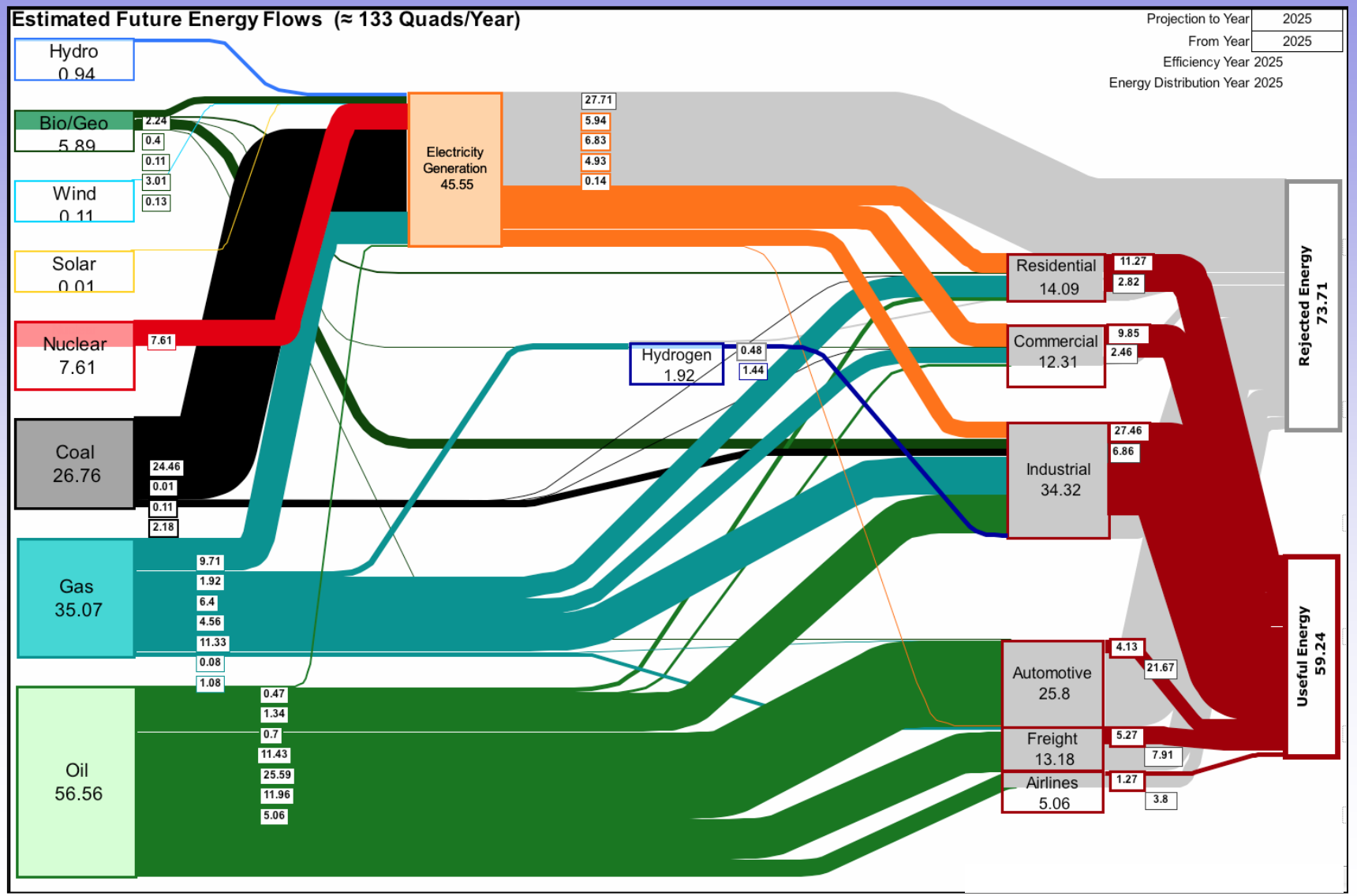
- includes major sources, electricity & H_2 generation, estimated efficiencies
- EIA 2005 forecast is shown



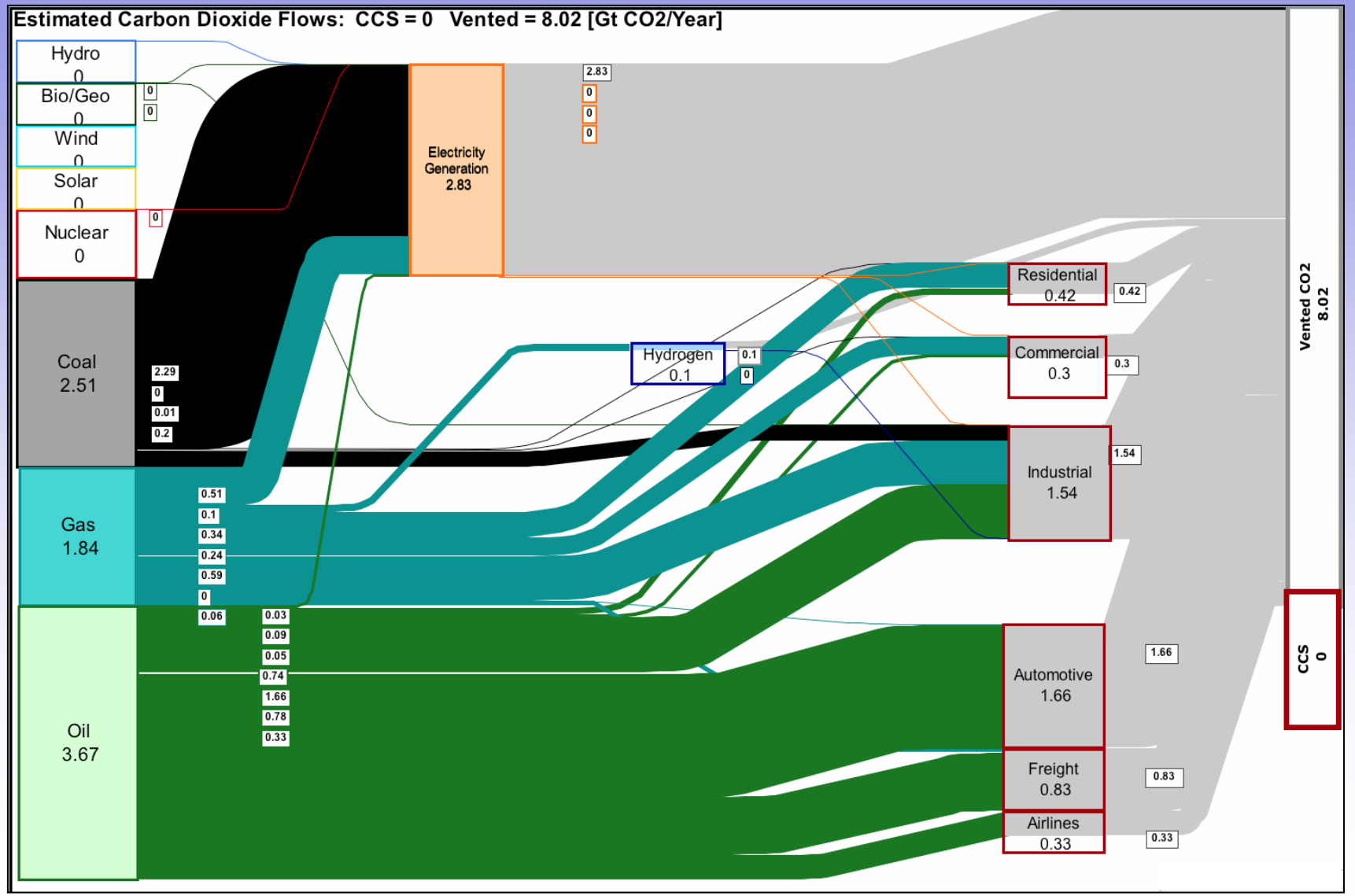
New LLNL 2005 Carbon Flow Chart is derived from energy flow, estimates energy related CO_2 sources (5.8 $GtCO_2$/yr) and allows for an integrated CCS scenario construction



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

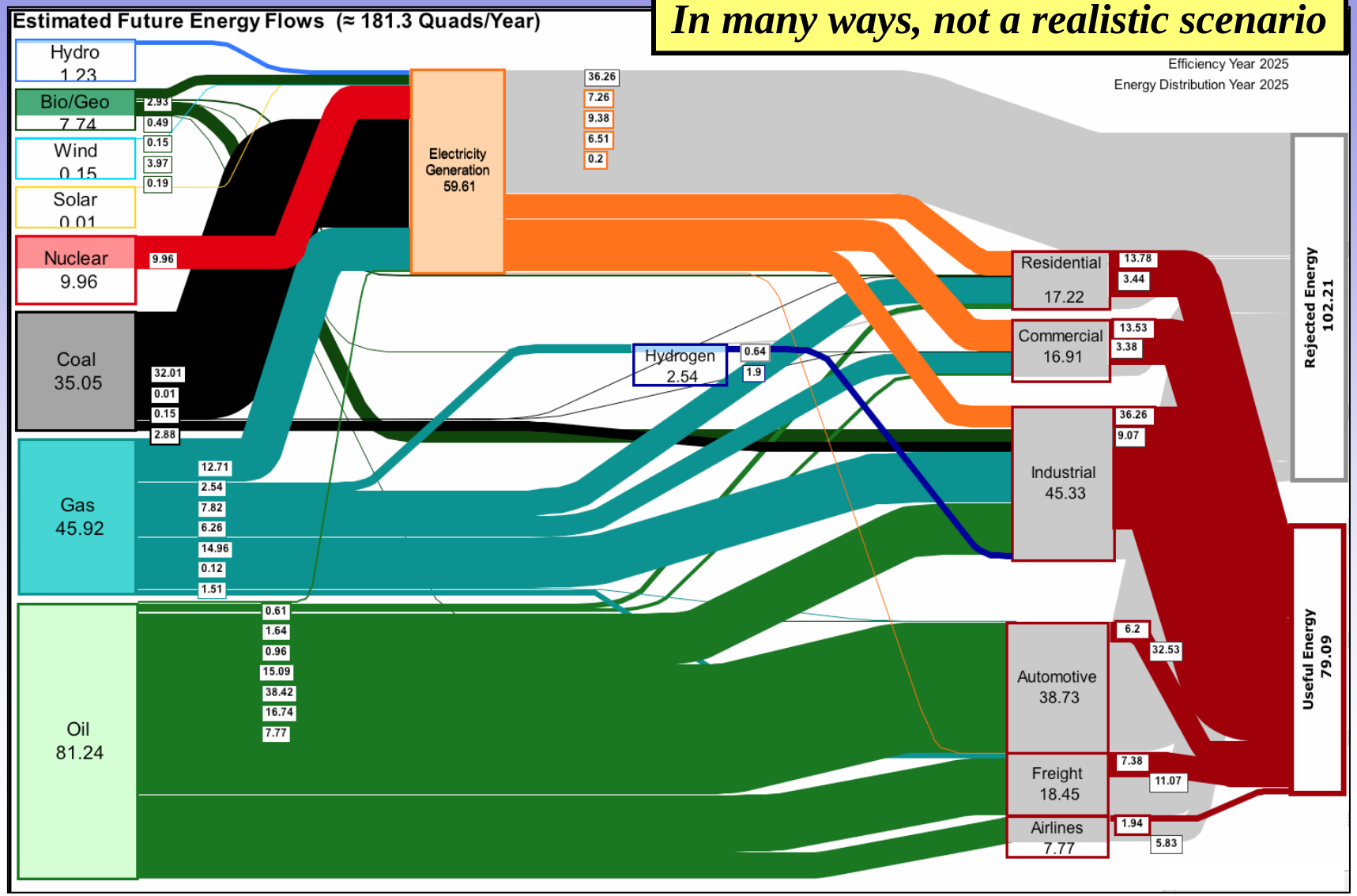


Companion carbon flow for 2025 reflects growth in vented CO_2 (8 $GtCO_2$/yr) driven by electricity generation (coal) and automobiles (oil)



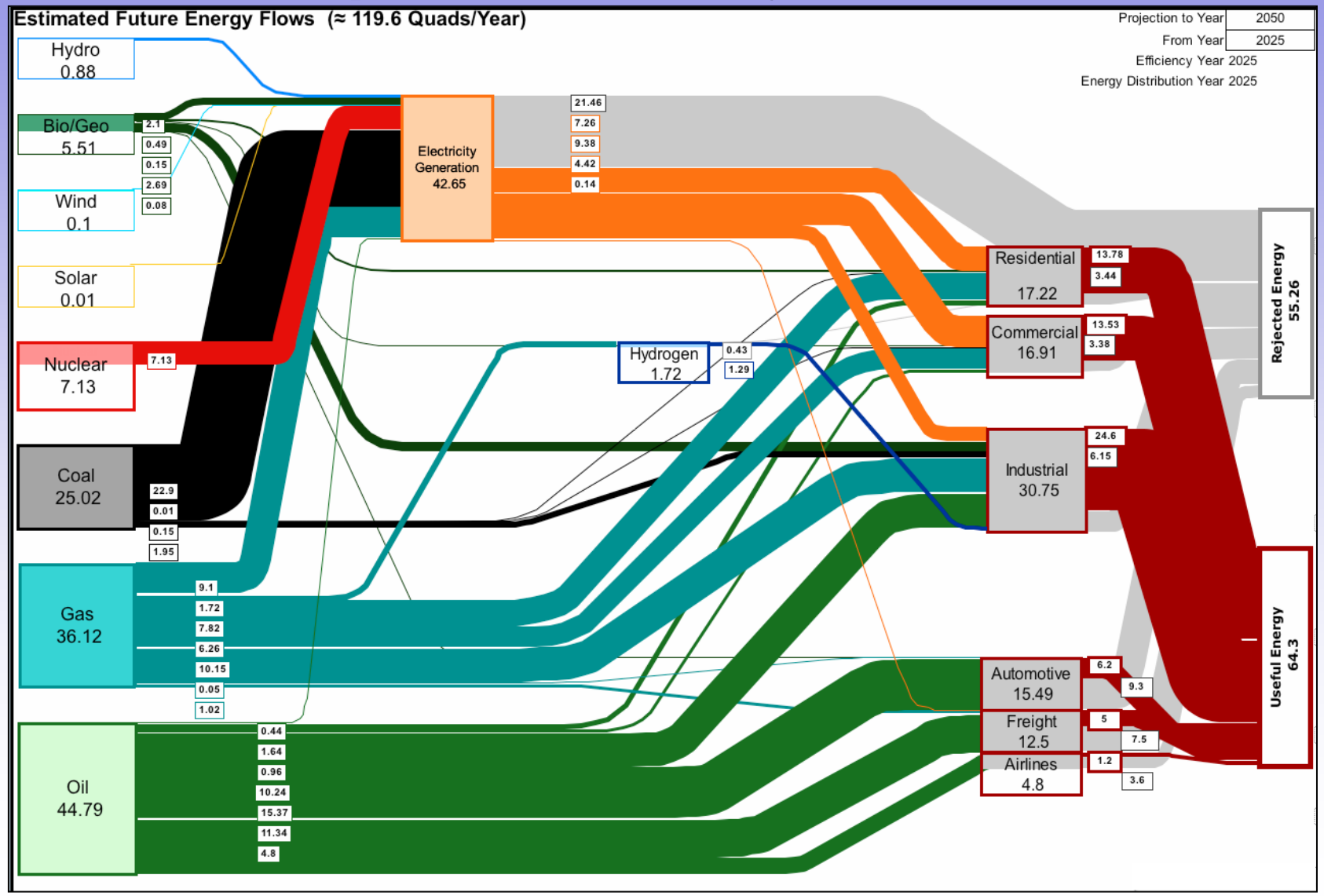
Linear extrapolation from 2020-2025 EIA reference case to 2050
- U.S. petroleum consumption ~ 40 million bbl/day?
- Natural gas grows to ~ 45 TCF?

In many ways, not a realistic scenario

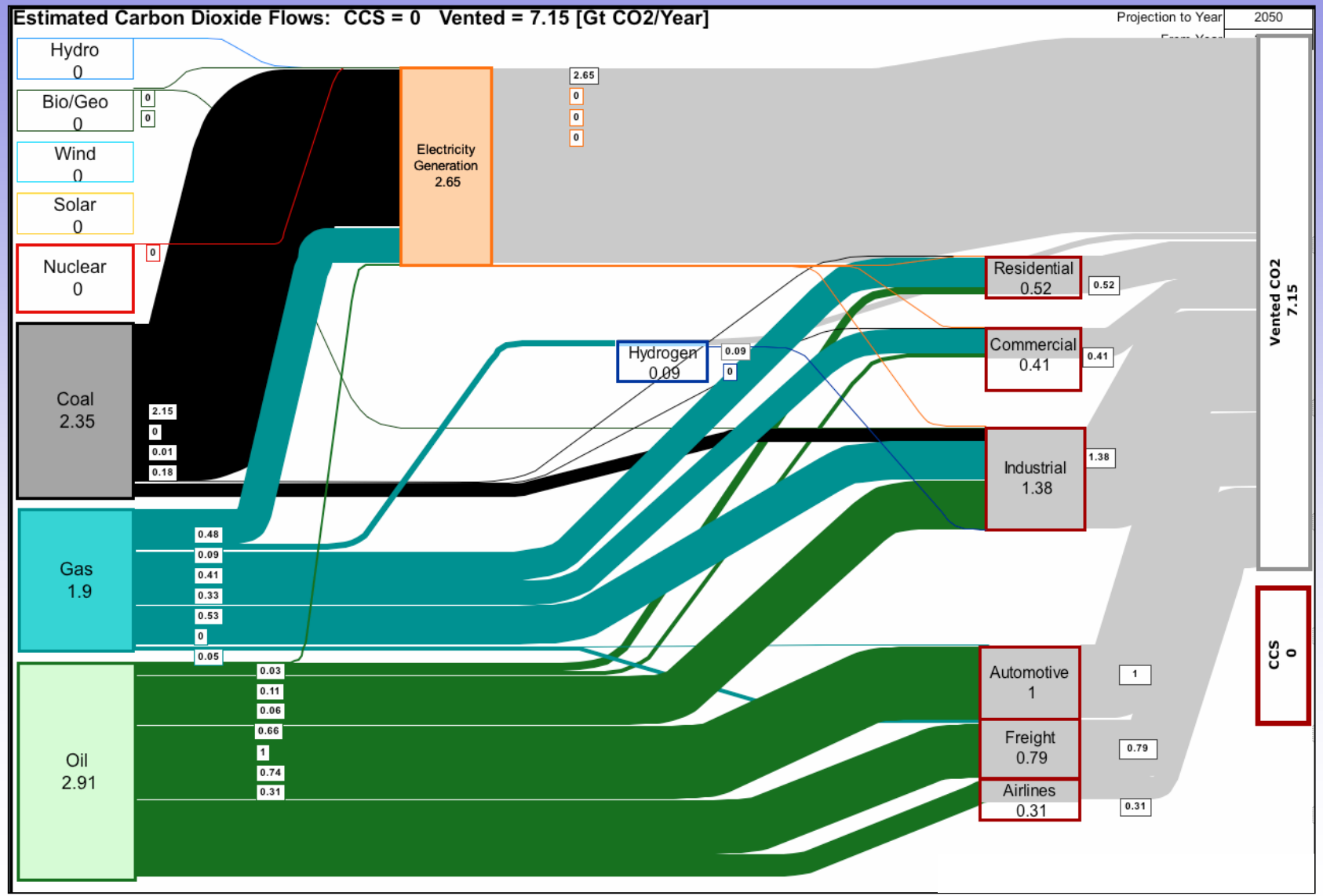


Energy flow for 2050 high-efficiency case, aggressive but more realistic:

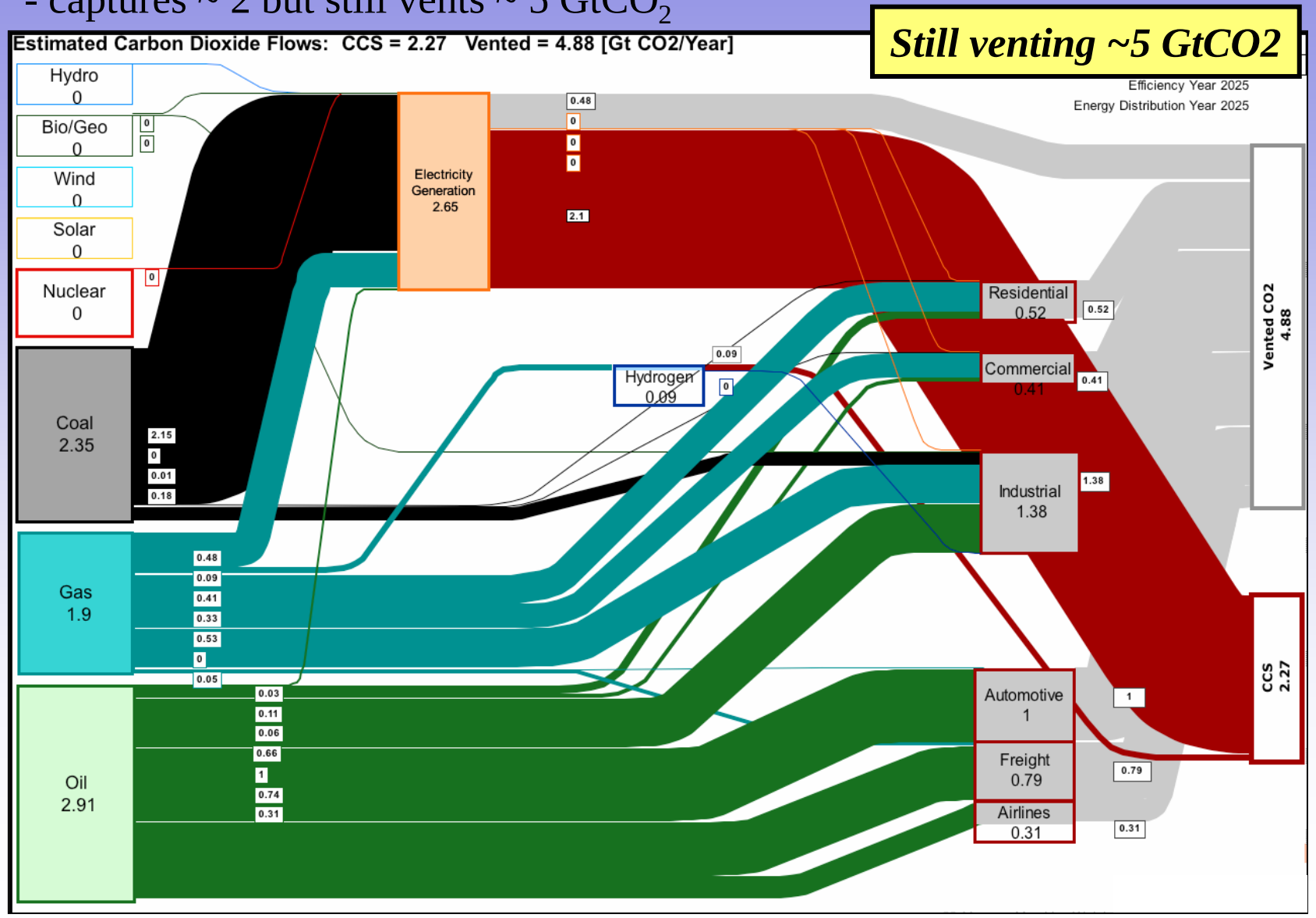
- 50% improvement in electric generation, industrial, freight and aircraft
- 50 mpg (average) US light-duty fleet
- Petroleum consumption ~ 22 million bbl/day



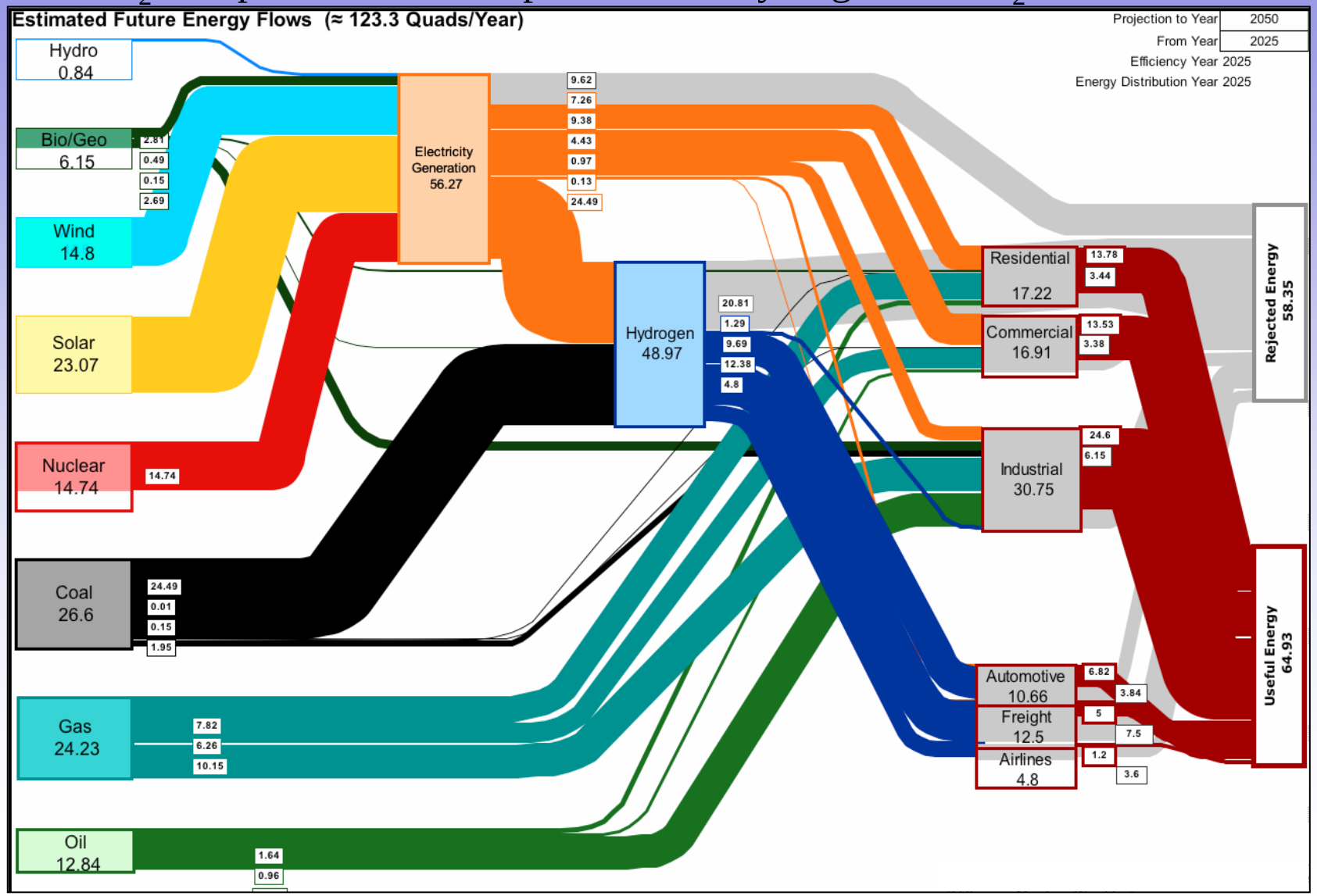
Carbon flow for 2050 energy efficiency case restrains emissions to 2025 levels: ~7 $GtCO_2$/yr vented without CCS implementation



2050 efficiency carbon flow case *with* CCS (no capture energy penalty):
- coal-fired electric generation and industrial H_2
- captures ~ 2 but still vents ~ 5 $GtCO_2$

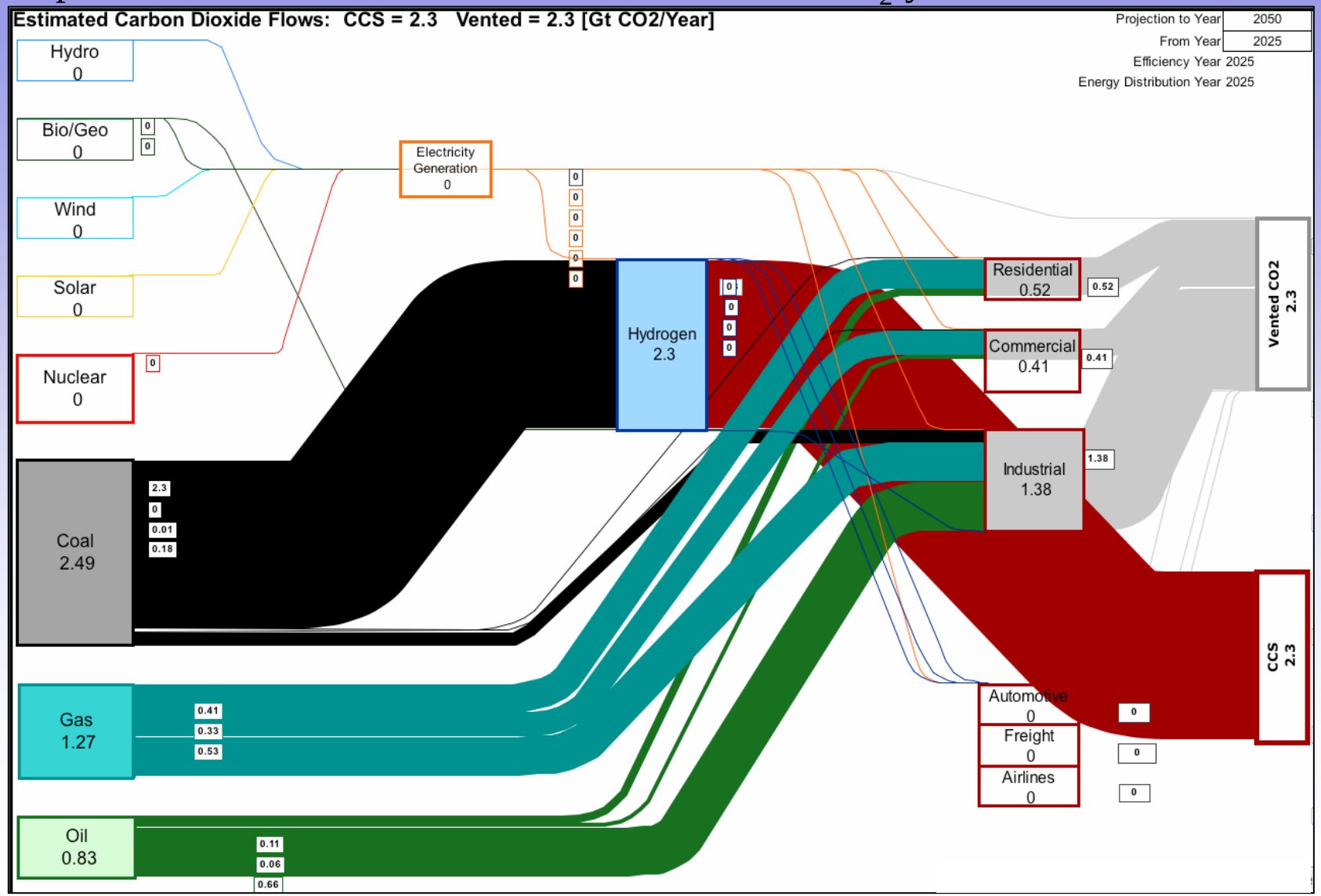


Massive carbonless electricity and transportation 2050 energy flow case:
- shifts sequestration burden from electricity generation to H_2 production
- use H_2 to replace oil and off-peak electricity to generate H_2



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

- CCS and venting equal at 2.3 $GtCO_2$/yr (~200 million bbl CO_2/d)
- optimistic nuclear and renewables avoid 2.5 $GtCO_2$/yr



Conclusions

- Energy and carbon flow charts provide a framework for complete energy system visualization naturally integrating particular future demand-driven, source, efficiency and technology scenarios
- Powerful long-range planning tool to quickly test the viability of new energy technology ideas and potentially highlight key problem areas requiring further research
- Major energy efficiency improvements, carbon capture and storage, and an aggressive renewables/hydrogen program are all needed to affect steep reductions in emissions by 2050

Bottom line: aggressive CCS enables utilization of plentiful coal to replace petroleum