Future U.S. Energy Use for 2000-2025 as Computed with Temperatures from a Global Climate Prediction Model and Energy Demand Model

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UT-BATTELLE

Multiple impacts from climate change have been identified

- Agriculture
- Natural ecosystems
- Sea-level rise
- Extreme weather
- Human health

- A little-quantified impact is that of energy use for heating and cooling

Energy/Economics/Carbon relationships

- What happens to energy use as climate changes?
- What is the regional impact on energy use and costs?
- How would this change carbon emissions?

Three components to energy analysis

- Degree days and temperature determination
- Temperature changes from climate model
- Integration into energy demand and supply model, DD-NEMS

Degree Days (DD) calculation

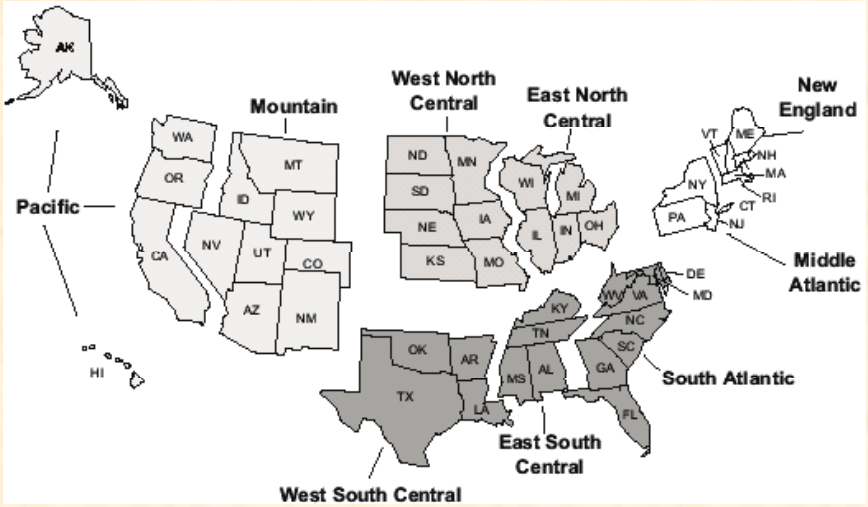
- Difference of daily average temperature from reference temperature (typically 65ºF)
- Average temperatures higher than the reference are cooling degree days (CDD)
- Average temperatures lower than the reference are heating degree days (HDD)
- Can sum the CDD and HDD over a month or year to determine heating and cooling loads

Degree Day data sources

- National Climate Data Center issues monthly heating and cooling degree days by census region
- Data available from 1931 to 2003
- Data is weighted by population to better track heating and cooling loads
- Can back-calculate average monthly temperature from HDD and CDD
  - T_{avg} = (CDD - HDD + 65 * days)/days

PCM-IBIS Global Circulation Model

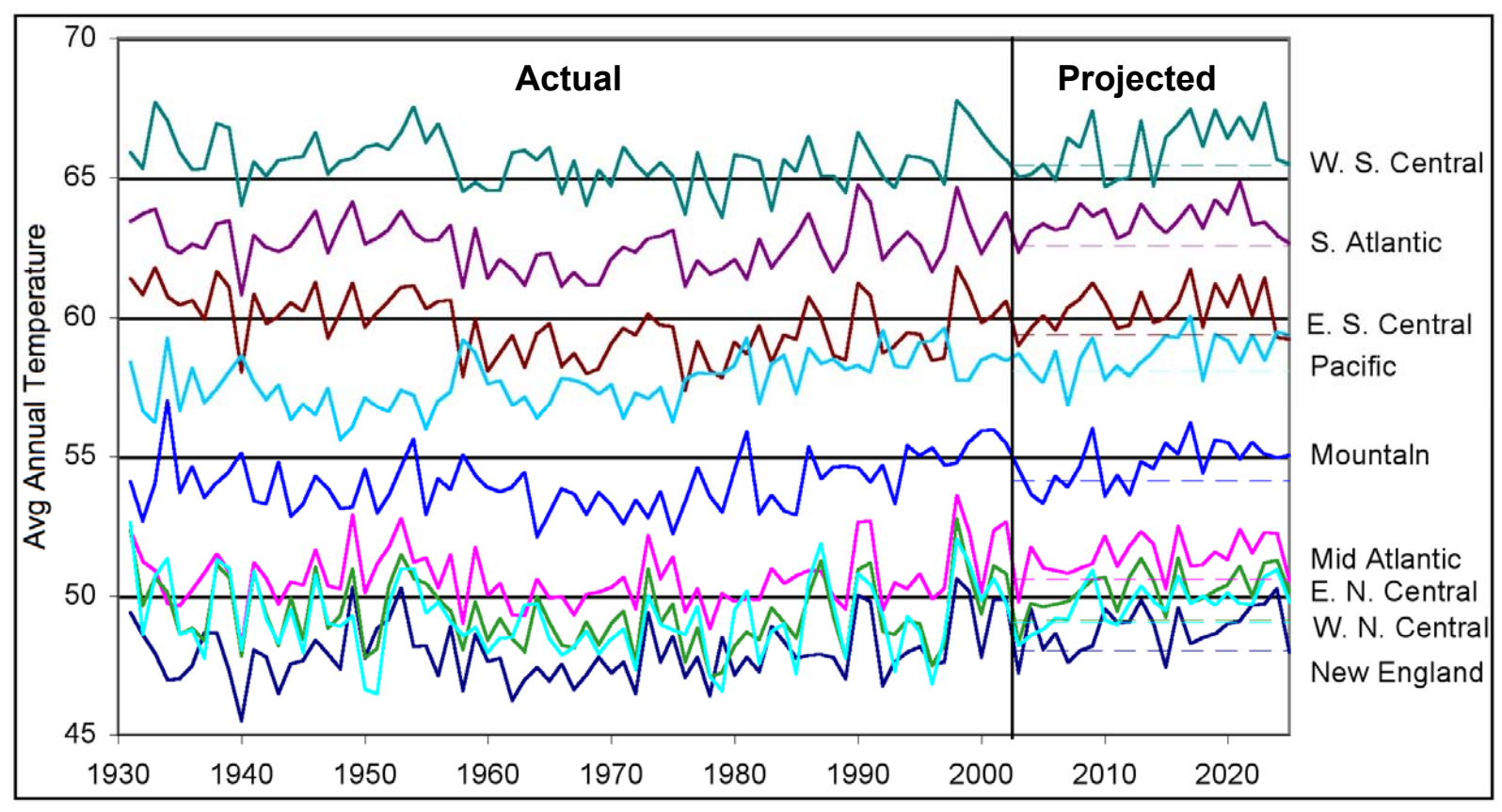
- Models global climate every 15 minutes for 1900-2100 over geographical grid of 2.5º by 2.5º
- Scenario used is based on low temperature sensitivity to greenhouse gases (2.1°C with a doubling of CO_2)



- Results were grouped by Census region and monthly temperature averages calculated for 1971-2025
- Temperatures were calibrated to population-weighted NCDC data and converted into mix of heating- and cooling-degree days

Average Temperature Profiles

- Reference case uses 1970-2000 average for 2003-2025



DD-NEMS model

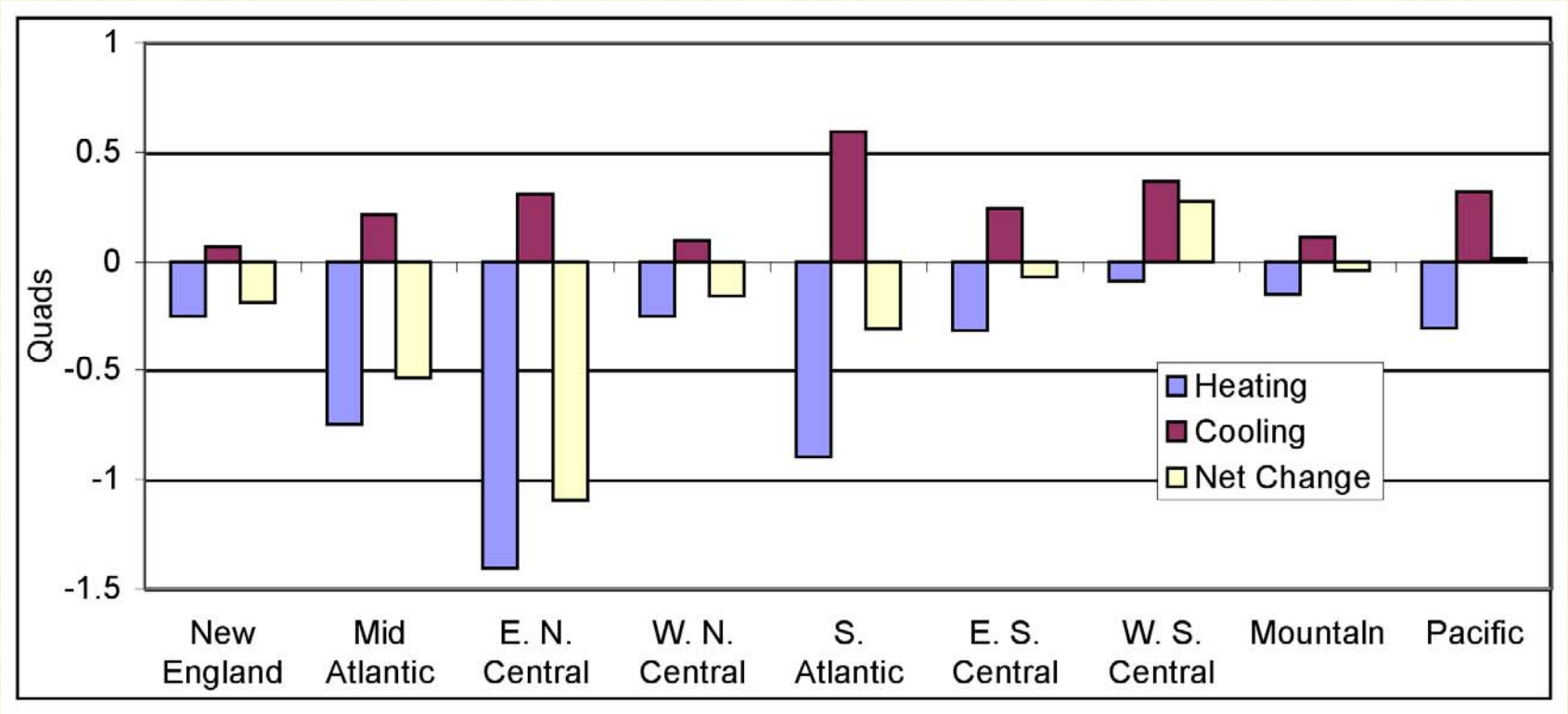
- Model based on National Energy Modeling System (NEMS) developed by DOE/EIA
- Only modification was to allow annual degree-days post-2003 in Residential and Commercial modules
- Cases based on reference NEMS run from *Annual Energy Outlook 2003* [DOE/EIA-0383 (2003)]
  - Used NCDC annual degree-day data through 2002
  - Reference scenario used NCDC historical 30 year average value for 2003-2025
  - New scenario used annual degree days based on PCM-IBIS analysis

Results analyzed

- End-use heating and cooling energy changes
- Primary heating and cooling energy changes by region
- Fuel use changes
- Electricity capacity changes
- Economic impacts by region
- Carbon emission changes

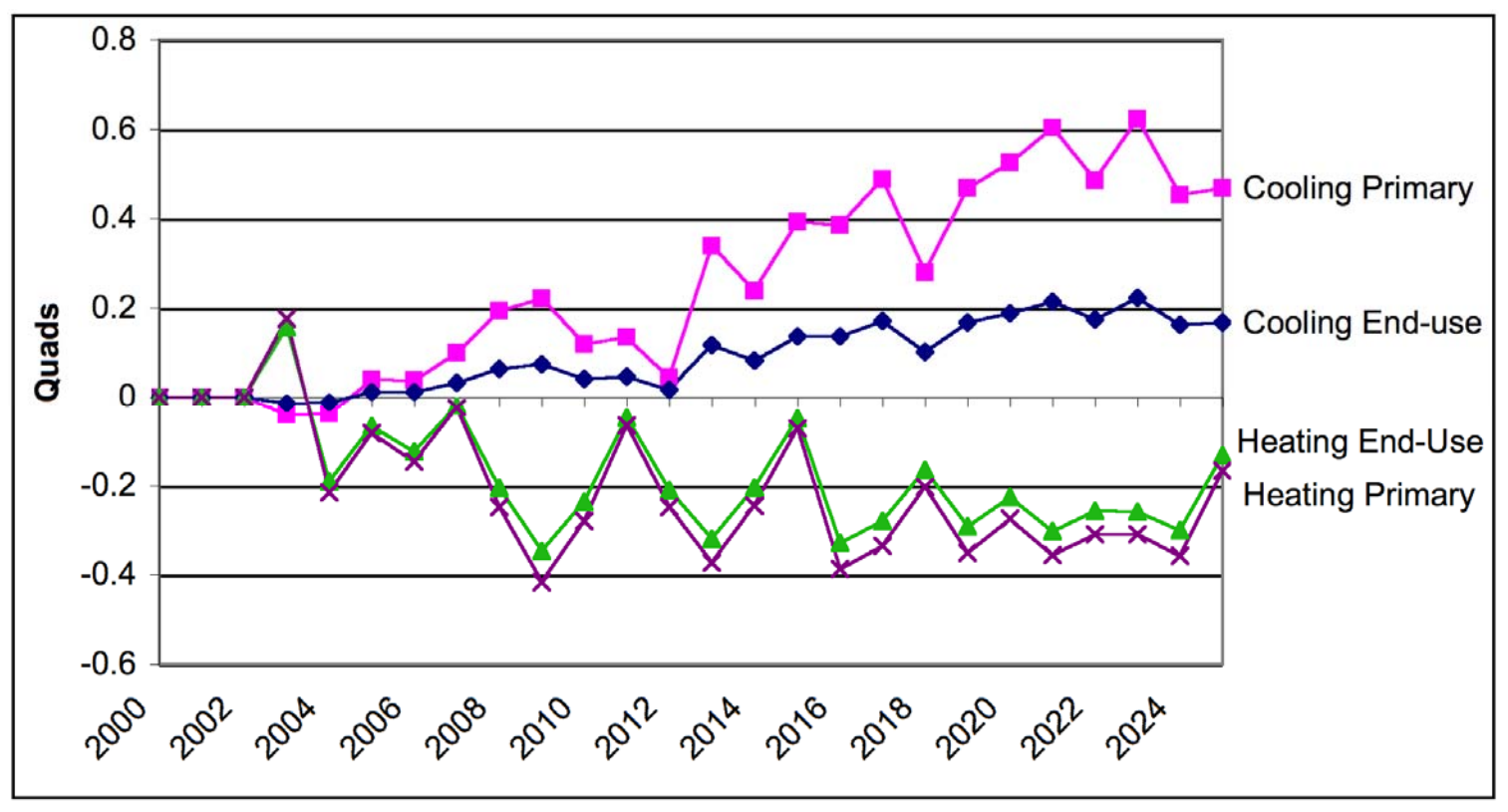
2000-2025 End-Use Heating and Cooling (H&C) Energy Change

- **Most regions show net end-use energy decline**



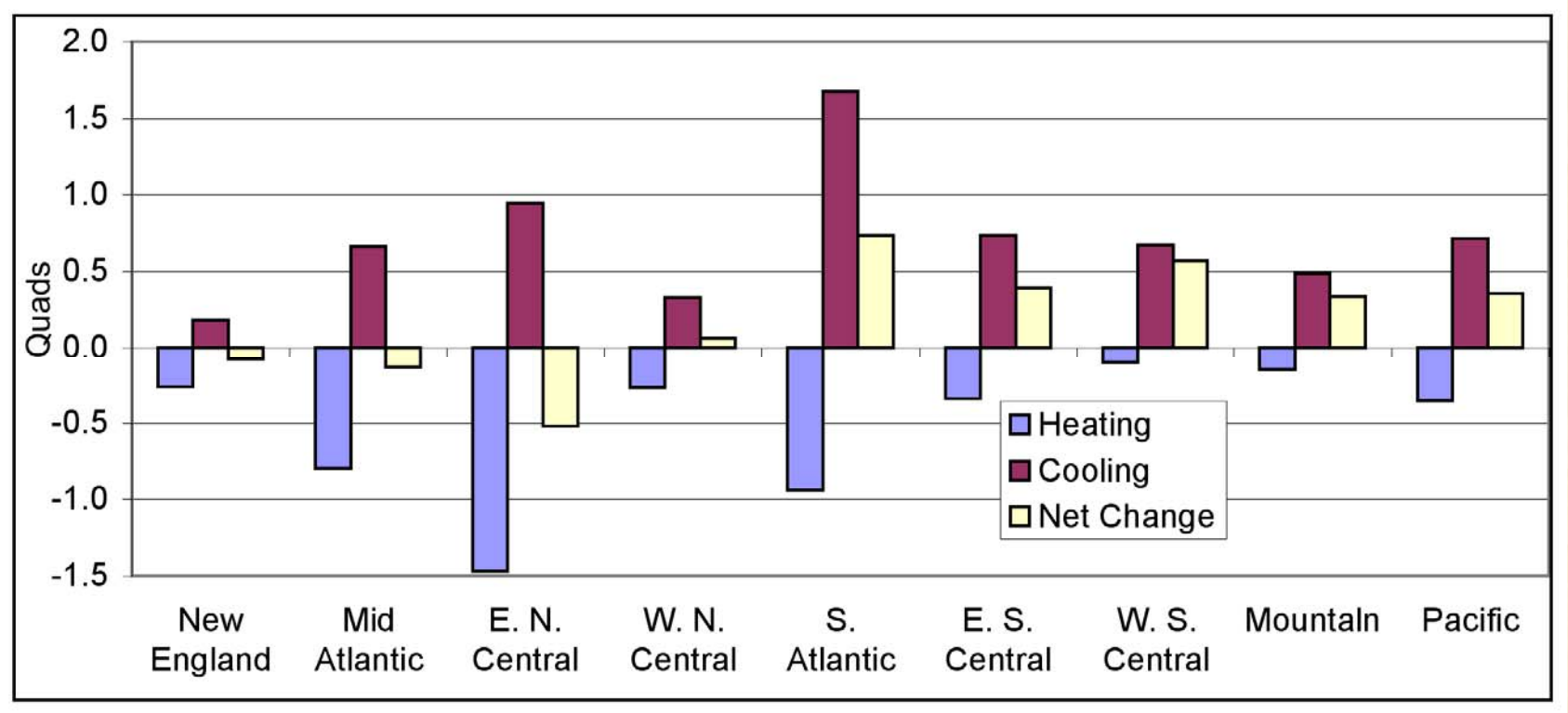
National H&C energy use change

- Conversion to primary energy affects cooling more than heating



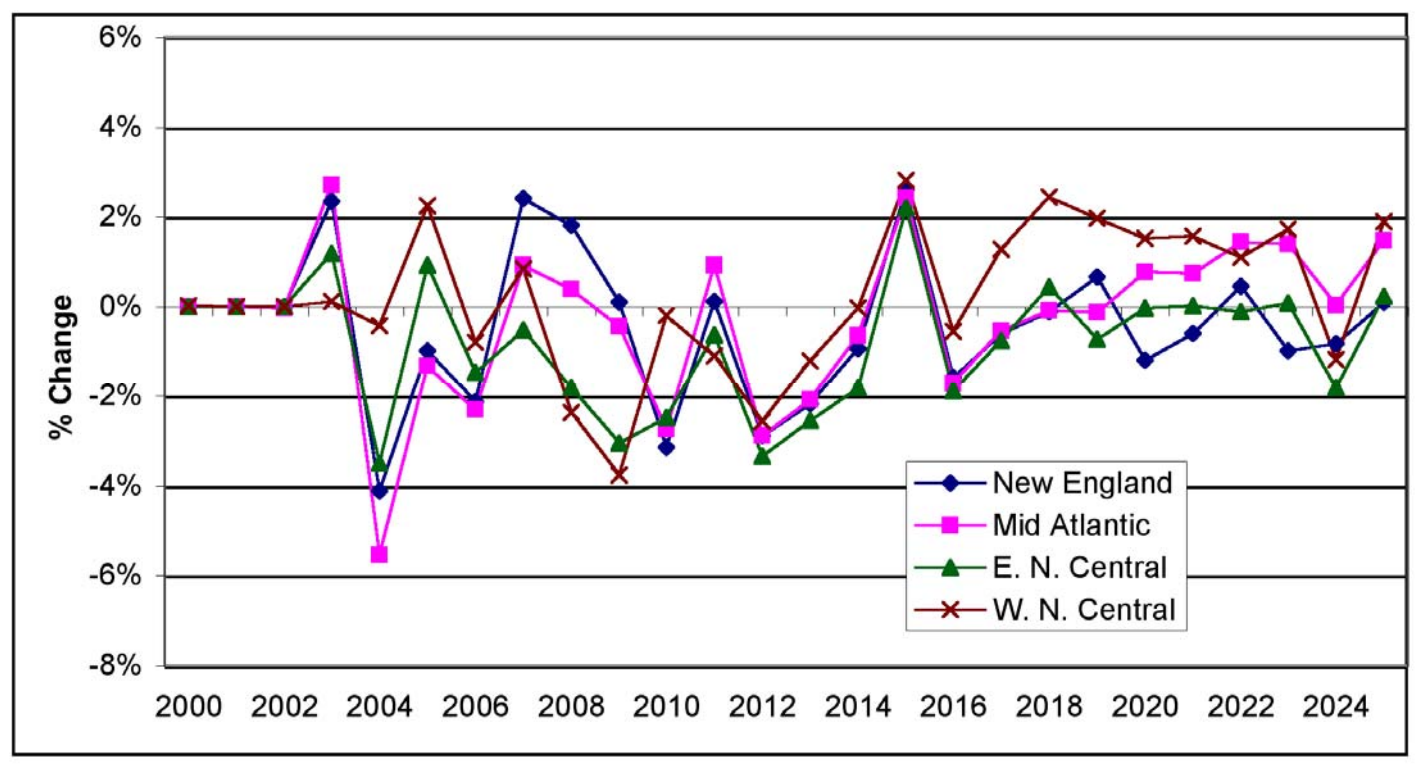
2000-2025 Primary Energy Change

- **Most regions show net primary energy increase**



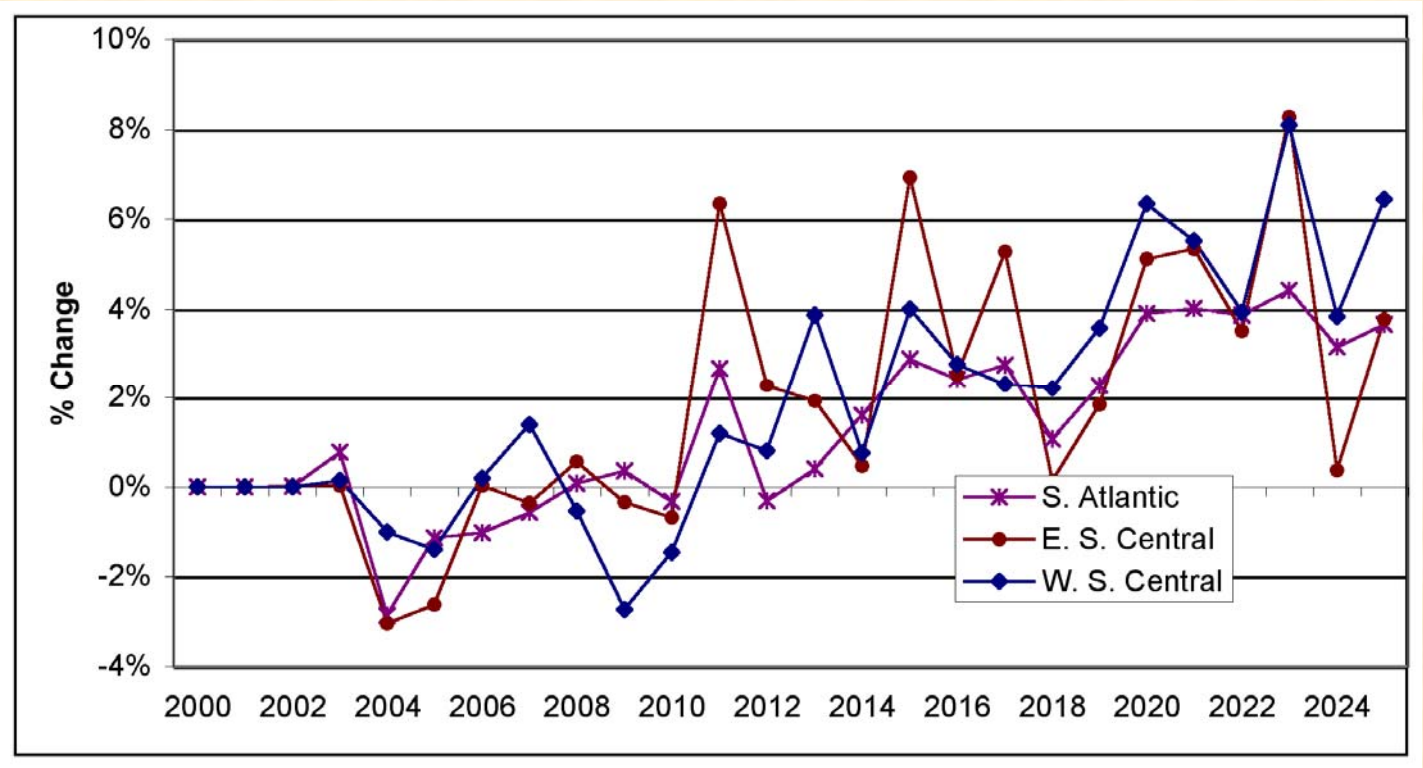
Primary H&C energy change in regions 1-4 as compared to reference

- Initial decline, max increase ~2% of demand



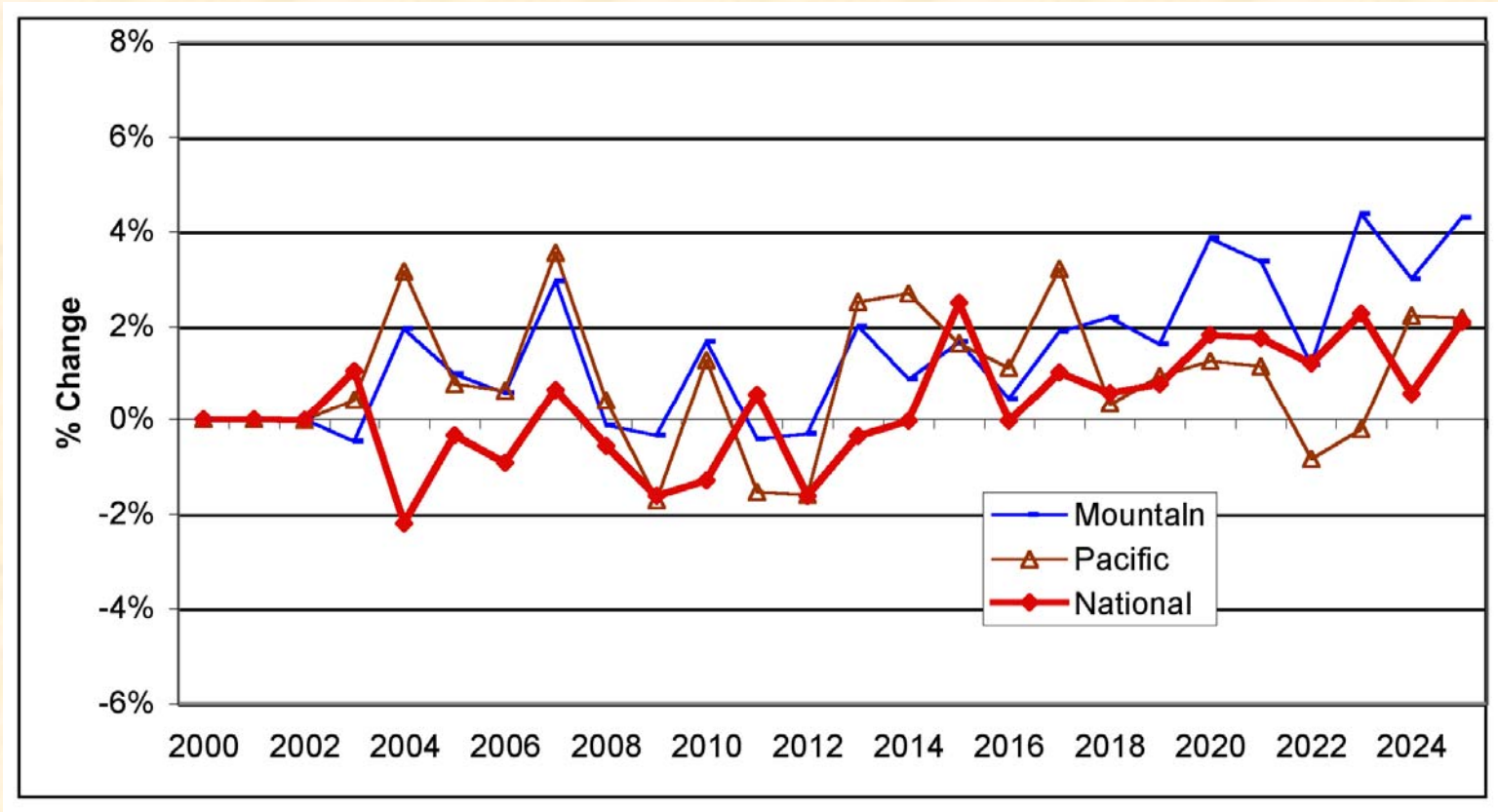
Primary H&C energy change in regions 5-7 compared to reference

- High impact, increase of up to 8% of demand

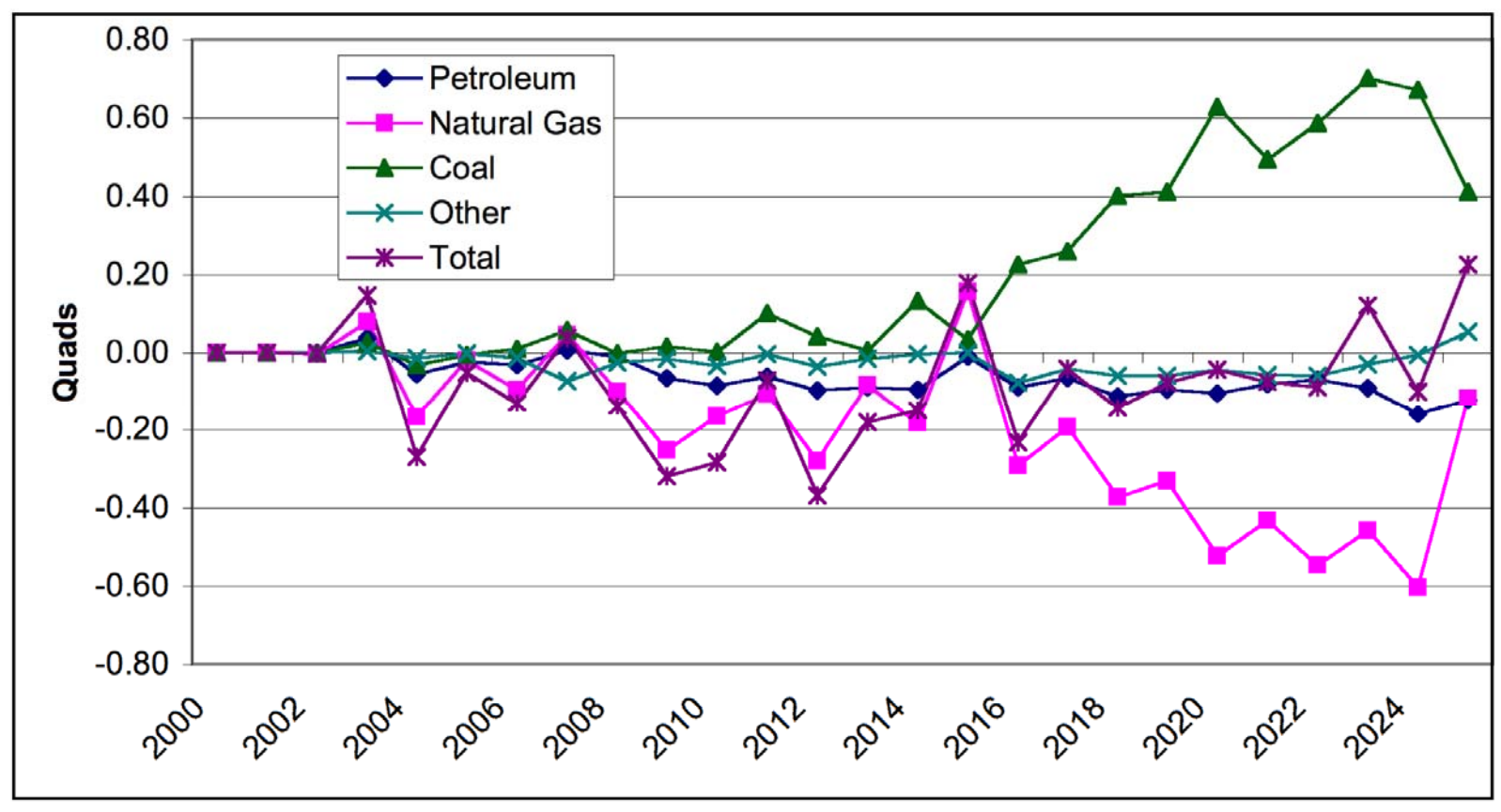


Primary H&C energy change in regions 8-9 & National compared to reference

- Modest increase over time



Coal use increases, Gas decreases

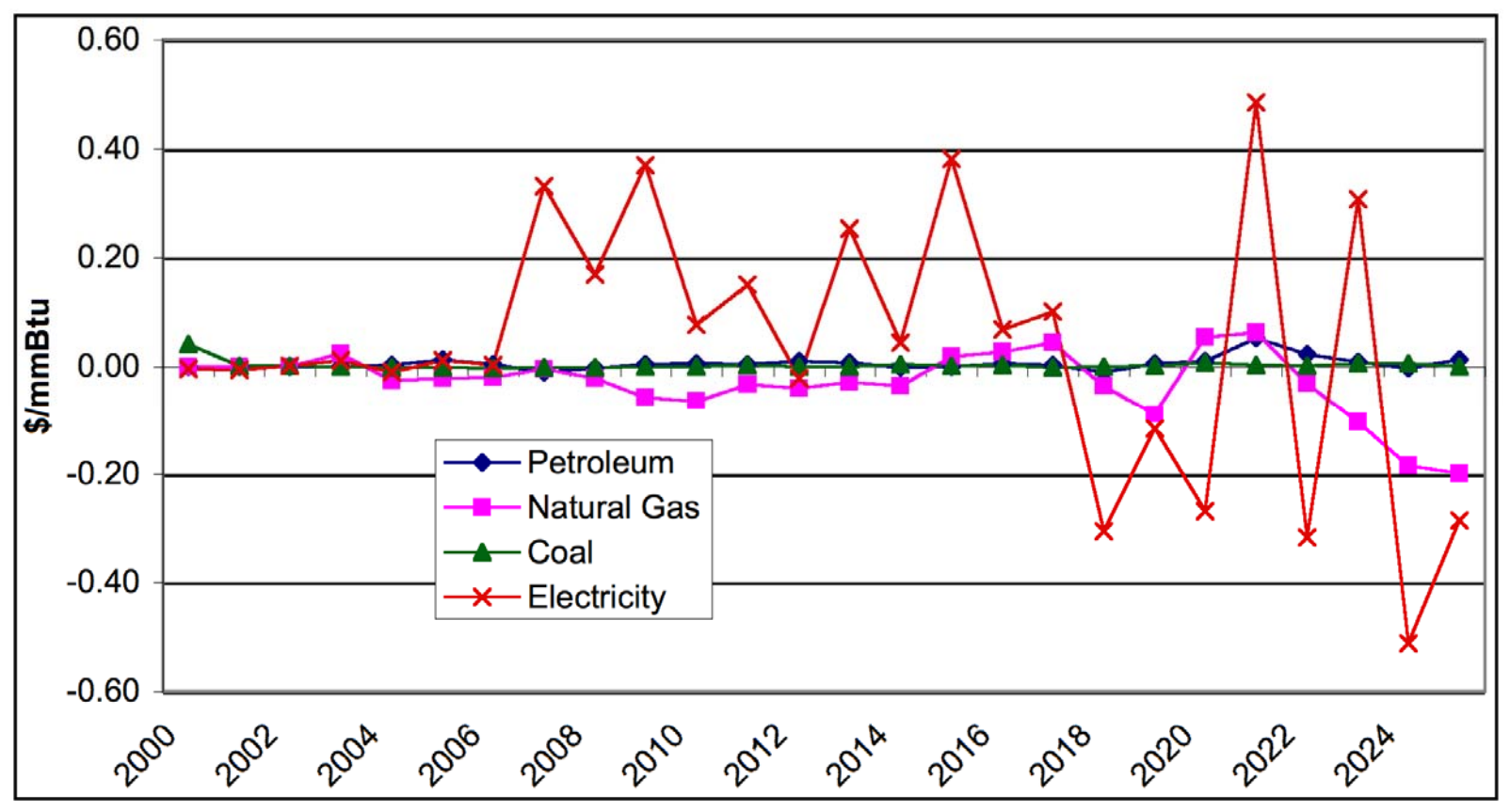


Combustion turbines are added most often

- **Variability in demand leads model to pick short lead-time capacity**

	Additions (GW)	Retirements (GW)	Net (GW)
Coal Steam	9.0	0.2	8.7
Other Fossil Steam	0.0	27.0	-27.0
Combined Cycle	5.6	0.7	4.9
Combustion Turbine/Diesel	60.5	11.1	49.4
Nuclear Power	0.0	0.0	0.0
Pumped Storage	0.0	0.0	0.0
Fuel Cells	0.0	0.0	0.0
Renewable Sources	3.2	0.0	3.2
Distributed Generation	1.3	0.0	1.3
Total	79.5	39.0	40.5

Electric price changes are most volatile

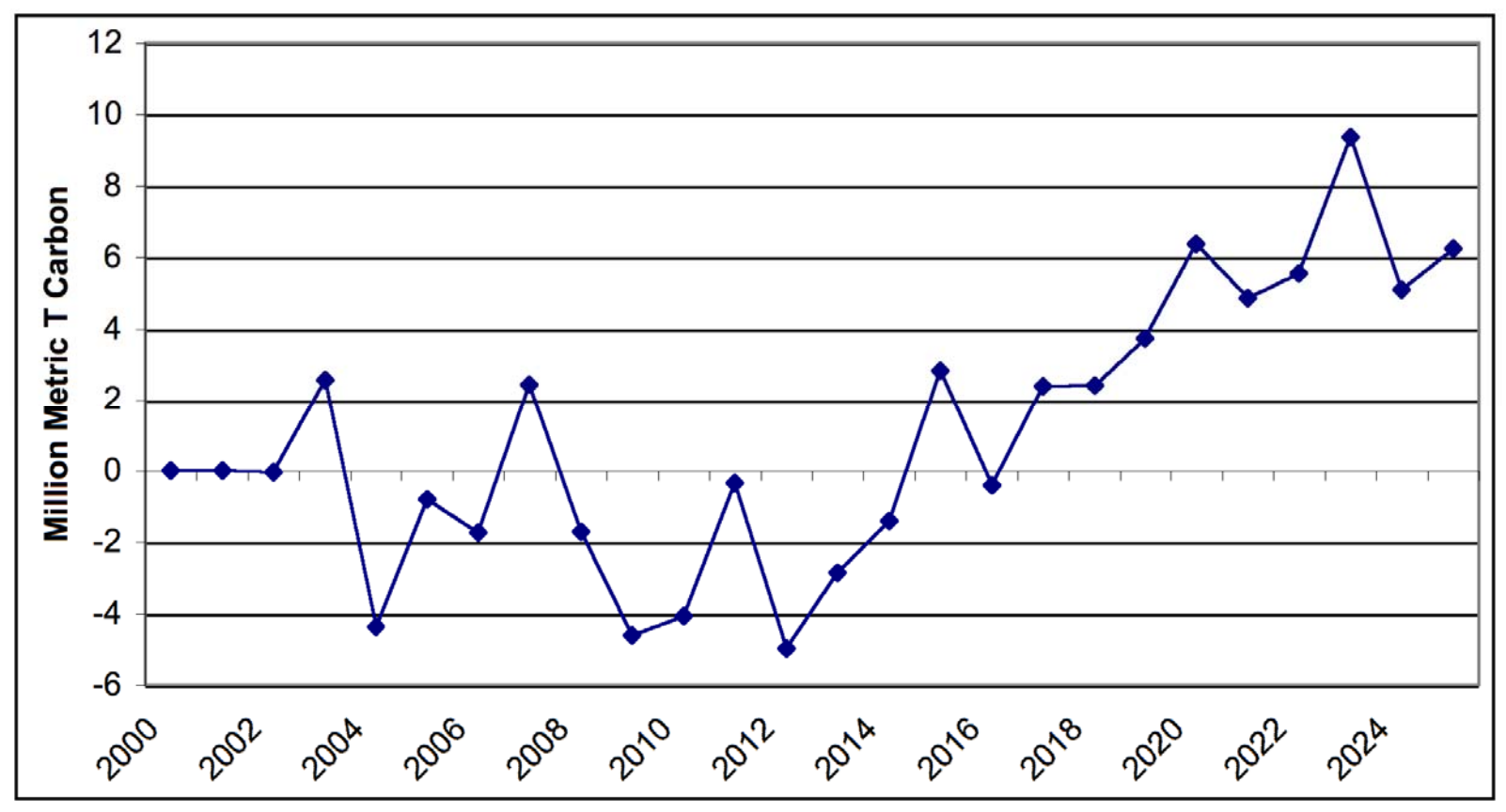


Cost changes by region (B$)

- Northern regions have cost savings
- Southern and Western regions have higher costs
- Early years have cost savings
- Later years have higher costs

	2003-2014	2015-2025	2003-2025
New England	-0.4	-0.3	-0.7
Mid Atlantic	-1.5	0.1	-1.4
E. N. Central	-3.1	-1.2	-4.3
W. N. Central	-0.7	0.8	0.1
S. Atlantic	0.4	6.5	6.9
E. S. Central	-0.0	3.2	3.2
W. S. Central	0.7	3.9	4.6
Mountain	0.2	0.6	0.8
Pacific	1.5	3.9	5.5
National	-2.9	17.6	14.8

Carbon: initial reductions but later increases

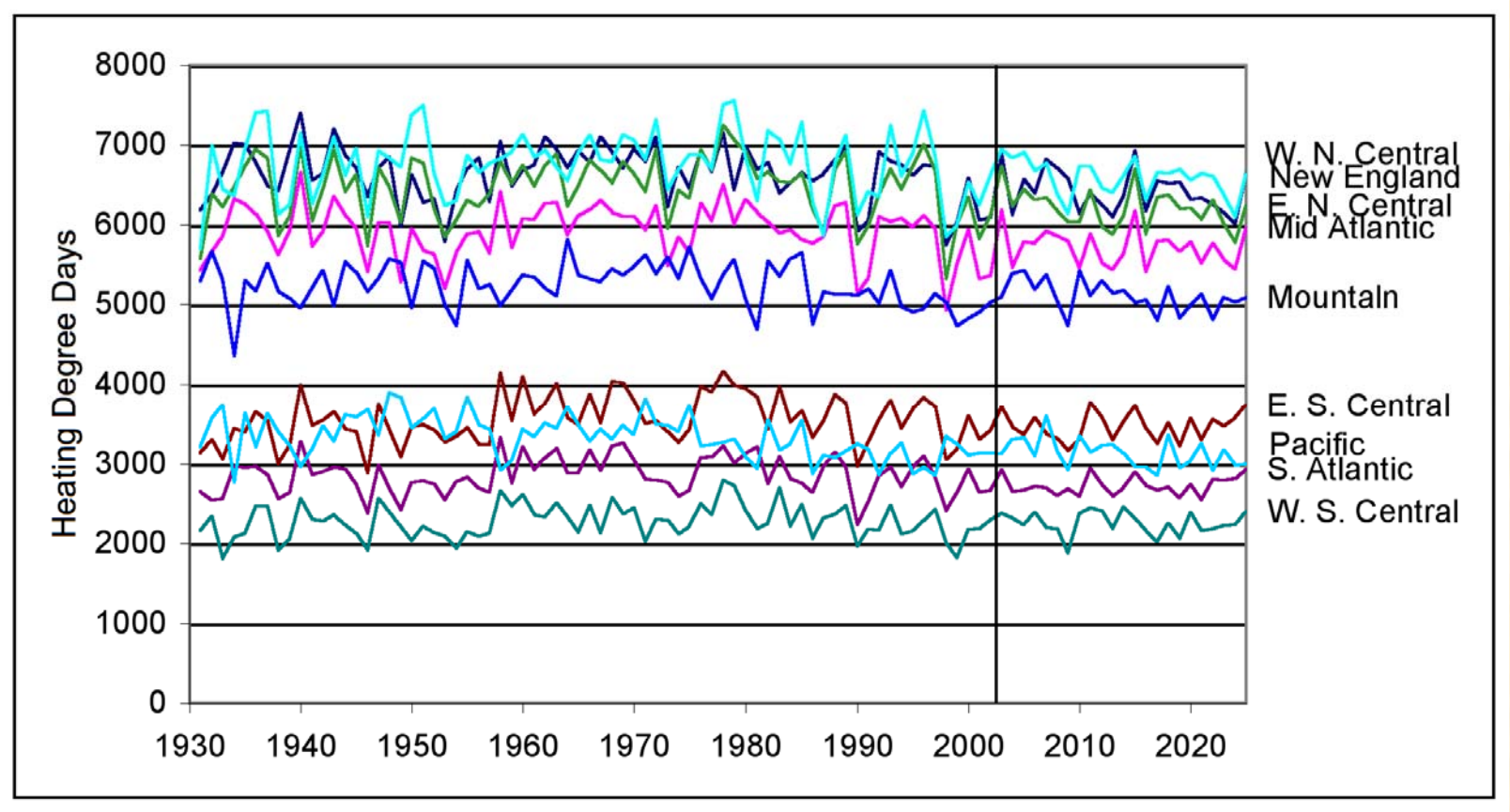


Future work possibilities

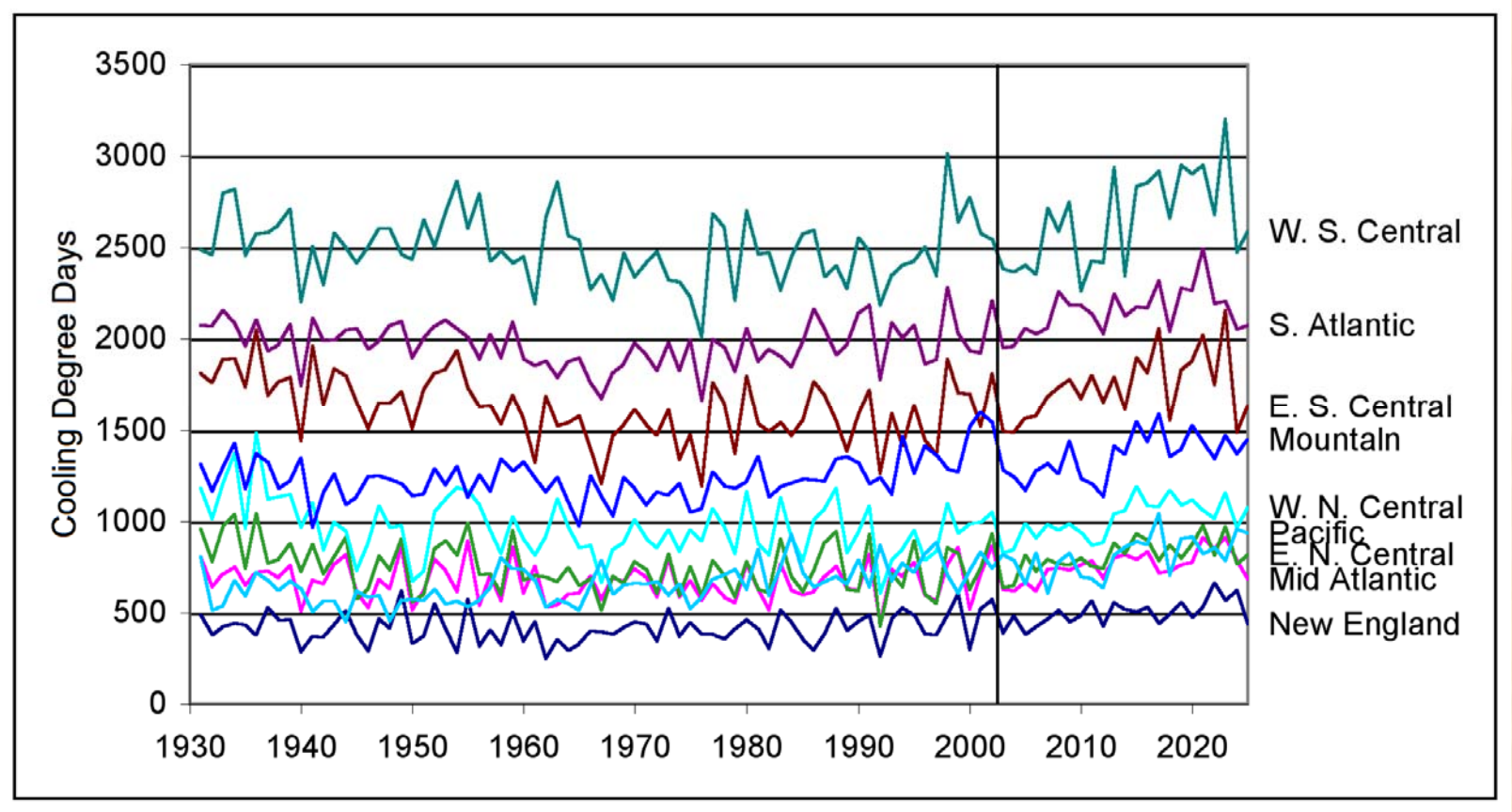
- Additional climate scenarios
  - Higher response to greenhouse gases
  - Ensembles with different temperature profiles
  - Use of other climate models
- Temperature to Degree-Day calculation
  - Daily values instead of monthly
  - Population weighting directly from PCM-IBIS data
  - Alternate set points instead of 65°F
- Changes to DD-NEMS
  - Newer version of NEMS
  - Extend to more years
  - Modify electricity capacity planning and pricing methods to reflect increased volatility in demands

Backup

Heating Degree Days

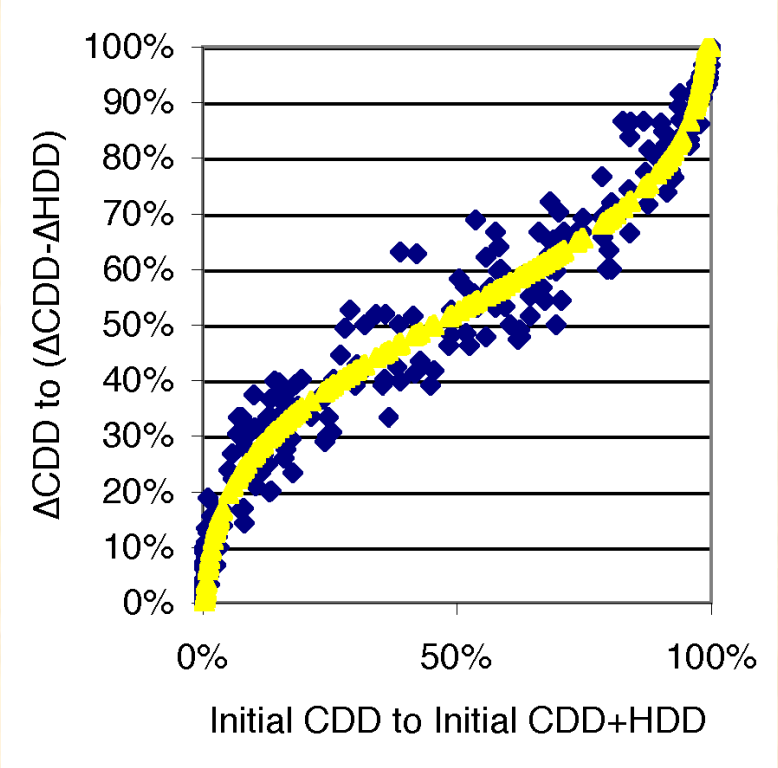


Cooling Degree Days



Changes in temperature impact on monthly values

- At extremes all DD change only affect heating or cooling
- When month has both HDD and CDD, then changes affect both
- Use random-walk simulation to find best-fit algorithm

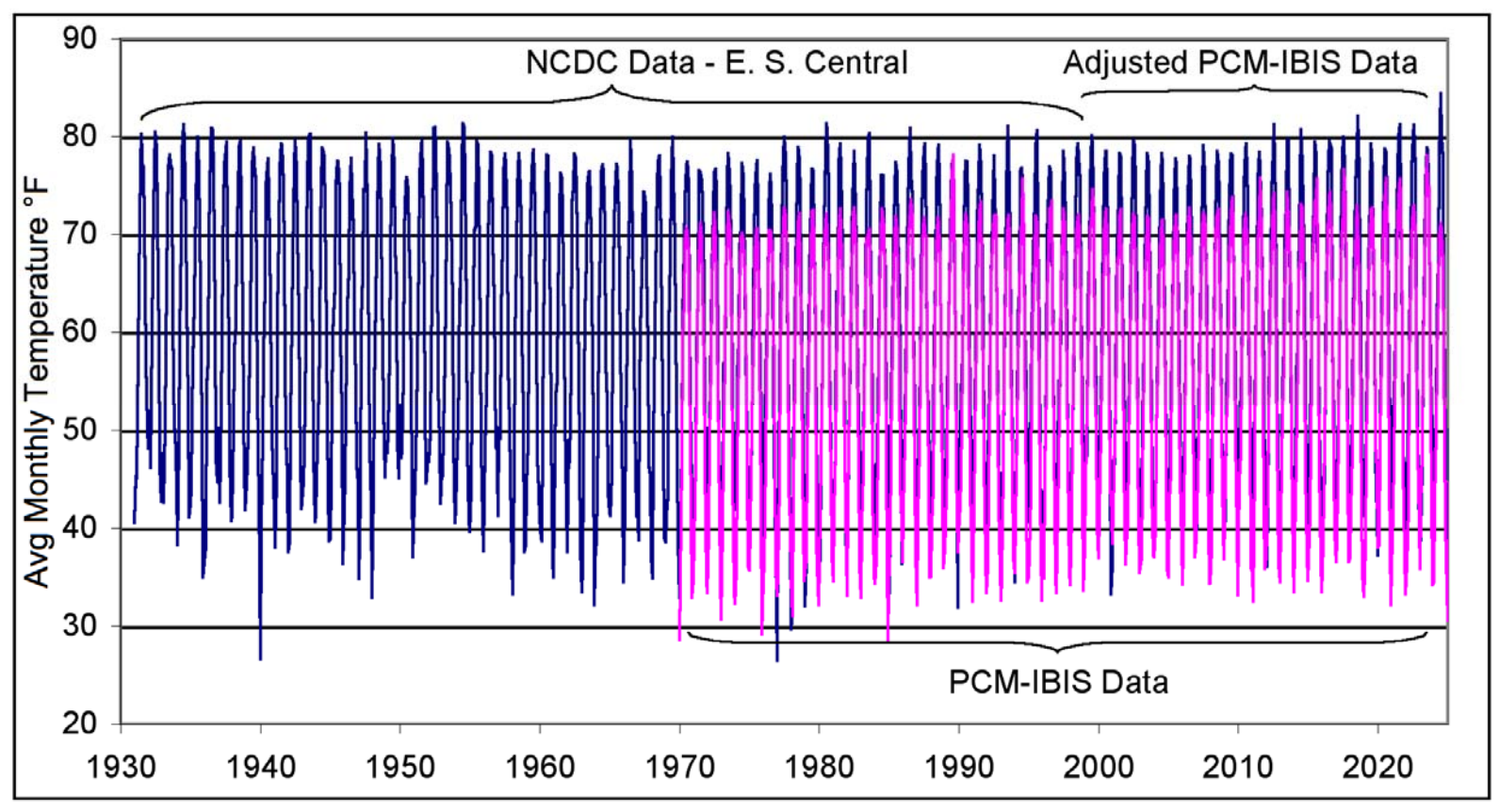


Equation background

- x = CDD/(CDD+HDD) before change
- y = ∆CDD/(∆ CDD-∆HDD)
  - = ∆ CDD/ (30*warming degrees)
- y = NORMINV(x,mean,stdev)
  - where x = CDD/(CDD+HDD)
  - mean =0.5+0.02245*warming degrees
  - stdev = 0.1923

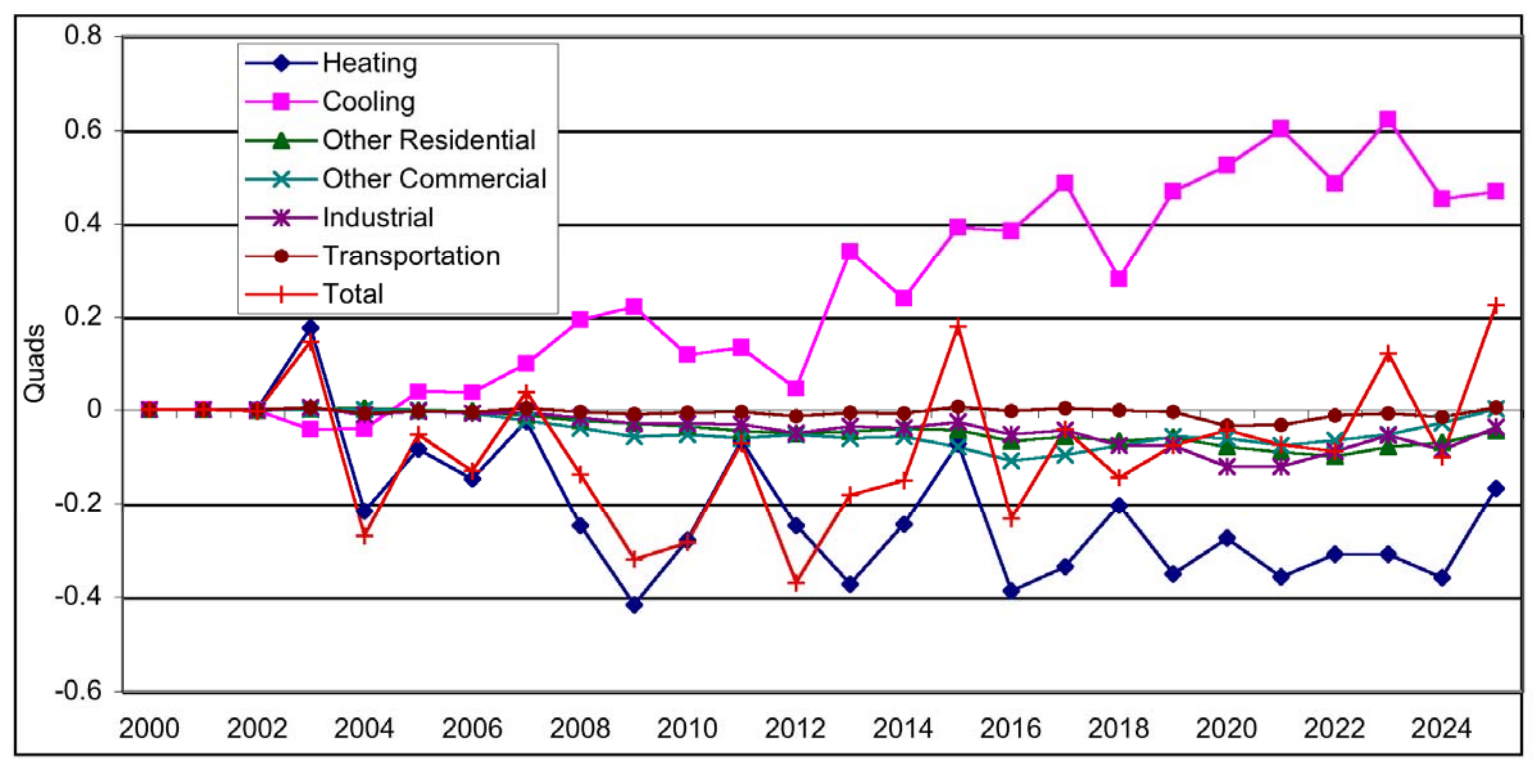
Calibrate PCM-IBIS data to NCDC

- NCDC data weighted by population



Other sectors see minor changes due to prices

- Heating and cooling are larger but cancel



Using reference prices show less volatility