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INTEGRATING CLIMATE CHANGE INTO ENERGY DEMAND FORECASTS: A COMMERCIAL SECTOR ANALYSIS

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Outline

- Background
- Methods and Data
- Results
- Conclusions
  - Impacts
  - Methodology

Contributions

- First national assessment of effects of climate change on commercial building energy use
- Advances estimation techniques

Background

- Building sector would be highly impacted by global climate change
- Previous studies have been fragmentary
- Many earlier studies using HDD and CDD find about a 2% decrease in heating requirements per 1°C rise in annual average temperature
- Comparable increases in cooling requirements

Exceptions:

- Gertis and Steimle (1989): -13 to -67% heating per 1°C
+12 to +38% cooling per 1°C
- Scott, Wrench, and Hadley (1994 in press):
-1.8% to -13% heating per 1°C
+10% to +24% cooling per 1°C

General Methodology

Four Steps:

- Estimate balance points and degree-day response coefficients
- Estimate cross-section regressions to extrapolate to full sample
- Extrapolate building sample to the year 2030
- Estimate energy consumption in the year 2030 under different temperature regimes

Building Data

Two Sources:

- 1989 Commercial Building Energy Consumption Survey (CBECS)

  (Nationally representative sample)

- Billing files for electricity and natural gas

  (Billing data converted to calendar months)

Key building characteristics:

- Building size and type
- Number of floors
- Use of energy for heating or cooling
- Energy Information Administration climate region

Weather Data and Degree Day Estimation

Local Climatological Data, Annual Summaries for 1989

- Annual from NOAA
- Contents:
  - Monthly average temperature
  - HDD and CDD (base 65°F), including 30-year normals.
- Profiles for 102 cities (weather stations)

Note: Matched cities via annual HDD and CDD

Thom Method for Computing Degree Days

Features:

- Developed by H.C.S Thom in mid-1950s.
- NOAA uses
- Statistical procedure (not true degree days)

Ideal because:

- Compute degree days for any temperature base
- Estimate the effect upon degree days from a change in average daily temperature.
- Employs only mean monthly temperatures, standard deviation

Average absolute percentage errors:

2.4% for 1989 HDD
4.2% for 1989 CDD

Building-Specific Degree Day Responses: Princeton Scorekeeping Method (PRISM)

$$E_{it} = a_i + b_i \, DD_{it}(Tbas_i)$$

Where:

E_{it} = Energy use for building i in month t

DD_{it} = Degree Days (heating or cooling) to base temperature T_{bas} in month t

Note:
(T_{bas}) defined as temperature with highest explanatory power (R^2)

Cross-sectional Analysis: Specification

- PRISM-type regressions not available for entire sample
- Cross-sectional regressions used to extrapolate to full CBECS.
- Key explanatory variables:
  - Surface/floor area
  - Vintage (Post-1979)
  - Climate Region (ClmRgn)
  - Building Type (Btype)

Cross-sectional Analysis: Major Results for Cooling (Electricity)

CDD Response Coefficients

- Key variable: surface-to-floor area ratio (coef = 0.49, t > 7)
- Weak evidence for reduction in weather sensitivity in new buildings (8%)
- High coefficients for grocery, restaurant, hospital

Balance Point Temperature

- About a 1.6°F increase in base temperature for cooling in new buildings.
- Higher setpoint temperatures in South for cooling (?)

National floorspace-weighted average: 54° F

Cross-sectional Analysis: Major Results for Heating (Natural Gas)

HDD Response Coefficients

- Key variable: surface-to-floor area ratio (coef = 0.68, t > 11)
- Post-1979 buildings show 20% lower sensitivity to HDD
- High coefficients for restaurants, hospitals, lodging

Balance Point Temperature

- New buildings appear same as old
- Higher setpoint temperatures in South (?)
- Lower in grocery stores and restaurants
- Higher in hospitals and lodging

National floorspace-weighted average: 61° F

Extrapolate Building Stock to 2030

- Extrapolated trends from DOE/EIA's Annual Energy Outlook 1993
- Adjusted sample weights in 1989 CBECS

Note: Features of Projections

- Total stock grows 90% by 2030
- 65% built after 1990

Energy Consumption Estimates

Key parameters:

- Response coefficients to heating and cooling (each CBECS building)
- Balance point temperatures (heating and cooling) (each CBECS building)
- Sampling weights: 1989 and 2030 stock of commercial buildings
- Saturation rates for heating and cooling (CBECS determines)

Note:
Natural gas results applied to other heating fuels

Cases Considered

A) Frozen empirical intensities, CBECS definitions

B) Frozen empirical intensities, Base year calibrated to 1993 _Annual Energy Outlook_ (AEO) [EIA 1993]

C) Intensities calibrated to AEO base year and projected growth rates

D) Scenario with advanced envelope for new construction

Results: Changes in Aggregate Commercial Energy Use

Year 2030, +7° F Change:

	Delivered		Primary	
	QBtu	%	QBtu	%
CBECS-only (A)	-0.7	-13	0.8	+9
Base year calbration (B)	-1.0	-14	0.8	+7
EIA projection (C)	-0.6	-12	0.8	+9
Advanced Envelope (D)	-0.6	-14	0.4	+7

Results: Changes in Commercial Energy Use

Year 2030, +7° F Change:

	Base (QBtu)	+7° F (QBtu)	%Change
EIA (AEO) Projection (C)			
Cooling	1.3	1.9	+48
Heating	3.6	2.5	-34
Delivered	4.9	4.3	-12
Primary	7.7	8.5	+10
Advanced Envelope (D)			
Cooling	0.9	1.3	+49
Heating	3.0	2.1	-32
Delivered	3.9	3.4	-14
Primary	5.9	6.3	+7

Building Energy Model Simulations

Prototype office building:

- 3-story, 48,000 square feet
- ASHRAE 90.1

Four locations:

- Seattle
- Minneapolis
- Phoenix
- Shreveport

Comparison of Regression and Simulation Results for Specific Cities

Percent Changes from a 7° F temperature increase

City	Climate Type	Heating EUI DOE2	Heating EUI Regression	Cooling EUI DOE2	Cooling EUI Regression
Seattle	Cool,Dry	-48	-45	+93	+95
Minneapolis	Cool,Wet	-26	-21	+58	+50
Phoenix	Warm,Dry	-43	-70	+36	+29
Shreveport	Warm,Wet	-46	-50	+53	+37

Conclusions (Impacts)

Total primary energy consumption in U.S. commercial buildings will rise

Absolute increase in consumption may not be large, given offsetting heating benefits (approximately 40%)

For specific scenario--2030 and 7° F rise--primary energy increase in commercial sector may be less than one QBtu (3 to 6% of total use)

Need to be aware of definitions and assumptions in any climate change analysis (delivered vs. primary energy)

Effect on electric utilities may be severe

Even advanced envelope as currently envisioned would not fully offset change with our scenario.

Conclusions (Methodology)

Balance point temperatures lower than 65° F

- precludes uses of most published NOAA degree day statistics
- percentage increase in CDD is smaller for lower temperature bases

Estimated climate change impacts will differ due to changing composition of buildings

Degree day approach appears satisfactory from heating perspective

Additional research is needed to resolve issue of humidity for cooling response

Regression results with degree days difficult to use in assessing the effect of specific energy policy

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