What Matters for Electrification?  
Evidence from 70 Years of U.S. Home Heating Choices

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University of California, Berkeley

September 2021
Motivation

U.S. households burn vast amounts of fossil fuels on-site each year for space heating.

- 2.7 trillion cubic feet of natural gas
- 2.9 billion gallons of heating oil
- 2.5 billion gallons of propane

The carbon dioxide equivalent of having 40 million cars on the road.
Policymakers Increasingly Interested in Electrification

Climate Adaptation

San Francisco Bans Natural Gas Use in New Buildings

By Mark Chediak
November 11, 2020, 10:17 AM PST  Updated on November 11, 2020, 2:29 PM PST

- Measure is strictest of its kind for large California cities
- All-electric construction required for buildings starting 2021

San Francisco will ban the use of natural gas in new buildings starting next year, becoming the latest city in California to clamp down on the heating and cooking fuel because of climate concerns.
Policy Discussion Expands Nationwide

Building gas bans and all-electric reach codes passed in California
Natural gas utility service areas as defined by California Energy Commission

Approach to limiting gas use:
- Gas ban: Prohibits gas infrastructure in certain buildings
- Electric required reach code: Requires all-electric options in new buildings (default option varies)
- Electric-preferred reach code: Requires buildings with gas systems to achieve higher energy standards
- Multi-approach: Adapts both reach code types or a gas ban and reach code

<table>
<thead>
<tr>
<th>States advancing or prohibiting building gas bans and electrification codes</th>
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<tbody>
<tr>
<td>Passed or introduced statewide prohibition against local measures to block access to utility service based on fuel type, including gas bans.</td>
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<tr>
<td>Local building gas bans and electrification codes adopted or in development.</td>
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</tbody>
</table>

S&P Global Market Intelligence
As of May 29, 2020
Map credit: Elizabeth Thomas
Source: S&P Global Market Intelligence
Cheap, Clean Electricity

Levelized Cost of Energy Comparison—Historical Renewable Energy LCOE Declines

In light of material declines in the pricing of system components and improvements in efficiency, among other factors, wind and utility-scale solar PV have exhibited dramatic LCOE declines; however, as these industries have matured, the rates of decline have diminished.

Unsubsidized Wind LCOE

Unsubsidized Solar PV LCOE

Source: Lazard estimates.

(1) Represents the average percentage decrease of the high end and low end of the LCOE range.

(2) Represents the average compounded annual rate of decline of the high end and low end of the LCOE range.
Electrification Crucial in Scenario Analyses

U.S. energy mix in five paths to net-zero emissions

Annual generation in terawatt hours, 2020 to 2050

Reproduced from Net Zero America; Chart: Axios Visuals
Proponents versus Critics

Proponents argue that electrification is critical if the United States is to sharply reduce carbon dioxide emissions from the building sector.

Critics argue that electric heating costs more than natural gas, so electrification mandates are expensive and regressive.
Percentage of U.S. Homes Heated With Electricity

Data

Determinants of Electric Heating

Electrification Mandate
1% of U.S. Homes Heated With Electricity

Electric Heat

1950
2% of U.S. Homes Heated With Electricity
8% of U.S. Homes Heated With Electricity
18% of U.S. Homes Heated With Electricity
26% of U.S. Homes Heated With Electricity

1990

Electric Heat

- 0.50+
- 0.40 – 0.50
- 0.30 – 0.40
- 0.20 – 0.30
- 0.10 – 0.20
- <0.10
30% of U.S. Homes Heated With Electricity

Electric Heat

- 0.50+
- 0.40 – 0.50
- 0.30 – 0.40
- 0.20 – 0.30
- 0.10 – 0.20
- <0.10
35% of U.S. Homes Heated With Electricity
39% of U.S. Homes Heated With Electricity

Electric Heat 2018

What Matters for Electrification?
Research Questions

(1) What Explains the Increase in Electrification of U.S. Home Heating Since 1950?

(2) How Much Would Households be WTP to Avoid an Electrification Mandate?
Summary of Results

(1) What Explains the Increase in Electrification of U.S. Home Heating Since 1950?
Changing energy prices by far the largest single explanation. Geography, climate, housing characteristics matter too. Income growth has almost zero effect.

(2) How Much Would households be WTP to Avoid an Electrification Mandate?
Households in warm states are close to indifferent between electric and natural gas heating, so would be made worse off by less than $300 annually.
Household in cold states, however, tend to strongly prefer natural gas so would be made worse off by $1000+ annually.
Related Literature

- **Economic Analyses of Home Heating** (Dubin and McFadden, 1984; Dubin, 1985; Mansur et al., 2008; Davis and Kilian, 2011)
- **Price Elasticity of Demand for Electricity** (Reiss and White, 2005, 2008; Ito, 2014)
- **Energy-Efficiency Investments** (Allcott and Greenstone, 2012; Gerarden et al., 2017; Gillingham and Palmer, 2014; Fowlie et al., 2018)
- **Cost-Effectiveness of Building Codes** (Aroonruengsawat et al., 2012; Jacobsen and Kotchen, 2013; Levinson, 2016; Kotchen, 2017)
- **Efficient Pricing of Electricity and Natural Gas** (Sherman and Visscher, 1982; Naughton, 1986; Davis and Muehlegger, 2010; Borenstein and Davis, 2012; Borenstein and Bushnell, 2018)
Household-Level Data on Home Heating Choices

- Key question "Which fuel is used most for heating this house?"
- Also know household income, age of home, and home characteristics


Heating Degree Days by State and Year from NOAA

*Merged Dataset is Restructured to Examine Choices at Time of Construction*
U.S. Residential Electricity Prices By State

Electricity

- California
- Florida
- New York
- Texas

Cents Per kWh

- 0
- 10
- 20
- 30
- 40

U.S. Residential Natural Gas Prices By State
U.S. Residential Heating Oil Prices By State

Heating Oil

California Florida New York Texas

Dollars Per Gallon


Lucas Davis (Berkeley)
Change in the Distribution of Population Since 1950s
### Descriptive Statistics

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Introduction

Data

Determinants of Electric Heating

Electrification Mandate

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What Matters for Electrification?

September 2021

25 / 40

Decrease in Heating Degree Days Since 1950

- Decrease in HDDs
- 800+
- 700 − 800
- 600 − 700
- 500 − 600
- 400 − 500
- 300 − 400
- <300

Map showing decrease in HDDs across the United States.
## Descriptive Statistics

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### Linear Probability Model, Estimates (1 of 2)

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<td><strong>Heating Oil Price, in logs</strong></td>
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### Linear Probability Model, Estimates (2 of 2)

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<td>Five+ Bedroom Home</td>
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Counterfactual Analysis: 1950s Energy Prices

- Actual
- Predicted Based on 1950 Energy Prices
Counterfactual Analysis: 1950s Distribution of Population

- Actual
- Predicted Based on 1950 Geography of New Home Construction
Counterfactual Analysis: 1950s Housing Characteristics
Counterfactual Analysis: 1950s Heating Degree Days

- Actual
- Predicted Based on 1950 Heating Degree Days
Counterfactual Analysis: 1950s Household Income

- **Actual**
- **Predicted Based on 1950 Household Income**
Decomposition Results

What Explains the Increase in Electrification of U.S. Home Heating Since 1950?

- Changing Energy Prices? **82%**
- Changing Distribution of Population? **7%**
- Changing Housing Characteristics? **4%**
- Climate Change (i.e. HDDs)? **4%**
- Rising Household Income? **-1%**
Is Electricity Priced Efficiently in the U.S.?

Estimating Willingness-to-Pay

How Much Would U.S. Households be WTP to Avoid an Electrification Mandate?

A standard discrete choice model is used for this analysis.

I estimate the model using heating system choices for homes built since 1990.
Evaluating the Fit of the Discrete Choice Model

A. Actual

B. Predicted

Proportion Electric

- >0.75
- 0.65 – 0.75
- 0.55 – 0.65
- 0.45 – 0.55
- 0.35 – 0.45
- 0.25 – 0.35
- <0.25

Proportion Electric

- >0.75
- 0.65 – 0.75
- 0.55 – 0.65
- 0.45 – 0.55
- 0.35 – 0.45
- 0.25 – 0.35
- <0.25
Willingness-to-Pay to Avoid Electrification Mandate

Annual Average ($)

- >$1,500
- 1,200 – 1,500
- 900 – 1,200
- 600 – 900
- 300 – 600
- <$300
Glass Half Full, or Half Empty?

One implication of the research is that, nationally, it may be a lot easier than is generally believed to encourage electrification.

The historical trend over the last seven decades means that millions of U.S. households have already “electrified”. Moreover, the analysis identifies millions of additional households, mostly in warmer states, for whom adopting electric heating would impose relatively modest costs.

On the other hand, the analysis also underscores the significant lift it would take to electrify colder states, where the vast majority of emissions come from.
Thank You!