Modeling China’s Building Energy Use: A Long-term Perspective based on a Detailed Assessment

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Overview of China’s Building Energy Use
Trends of Final Energy Use in China
(source: China Energy Databook in 2008)
China Buildings’ Energy Use by Fuel (2005)

Note: 190 million households in urban residential and 183 million households in rural residential in 2005
The Detailed Model for China Building Energy Use

Energy Service Demand

Urban Residential Buildings
- Space Heating
- Space Cooling
- Cooking & Water Heating
- Lighting
- Others

Rural Residential Buildings
- Space Heating
- Space Cooling
- Cooking & Water Heating
- Lighting
- Others

Commercial Buildings
- Space Heating
- Space Cooling
- Lighting
- Others

Energy Service Supply

Furnace, Boiler, Heat Pump & Exchanger

Cooker, Water Heater

Air Conditioner

Incandescent, Fluorescent, Solid State, Lamp

Appliances

Delivered Electricity

District Heat

Delivered Coal

Traditional Biomass

Delivered Biomass

Delivered Gas

Delivered Oil
Modeling Challenges

1. How should urban/rural population change over time?
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2. How to build a reasonable floor space expansion model?
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3. How should energy service demands per unit of floor space vary with income and prices?
Modeling Challenges

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2. How to build a reasonable floor space expansion model?

3. How should energy service demands per unit of floor space vary with income and prices?

4. How to define urban/rural preferences for individual energy service demands and fuels?
Modeling Urban and Rural China
Urbanization Assumption

- **Step 1:** Specify a relationship between urbanization rate and total income
  Based on parameters obtained by regressing data from China's statistics and UN projection
- **Urbanization mostly occurring between 2005-2050 and ultimately reaching 80% by 2095.**
Demand for Floor space
The approach to Floor Space Expansion

This is a very idealized approach that has some weaknesses when applied to floorspace.

- Urban / rural/commercial floor space expansion is not inter-related.
- Households’ preferences for floor space depends only on where they are currently located.
- There is no noticeable lag in market adjustment to price and income changes.
- Steady decline in household size is not an important factor.
- There is no sizeable technical changes in building floorspace service production.
International Comparison of Residential Building Floor Space

Per capita residential floor space for selected countries (1990-2004, IEA) vs. our projections for China (2005-2095)
Demand for Building Services
Modeling the Change in Service Demands

Demand for Space Heating Service [GJ-output/m²] :

\[ Q_{H,t} = k_H \cdot (HDD_i \cdot ShellEff_i \cdot SurfaceRatio_i - \lambda_H InternalGain_i) \cdot \left[ 1 - \exp \left( - \frac{\ln 2}{\alpha_H} \cdot \frac{Y_i}{P_{H,t}} \right) \right] \]

Space Heating Requirement

Demand for Space Cooling Service [GJ-output/m²]

\[ Q_{C,t} = k_C \cdot (CDD_i \cdot ShellEff_i \cdot SurfaceRatio_i + \lambda_C InternalGain_i) \cdot \left[ 1 - \exp \left( - \frac{\ln 2}{\alpha_C} \cdot \frac{Y_i}{P_{C,t}} \right) \right] \]

Space Cooling Requirement

Demand for Other Services (water heating & cooking, lighting, other appliances):

\[ Q_t = k_i \left[ 1 - \exp \left( - \frac{\ln 2}{\alpha_i} \cdot \frac{Y_t}{P_t} \right) \right] \]
How to Represent the Income Effects on Demands

How households tend to allocate their income into different energy services, given that these services have their own satiation points.
How to Model Traditional Biomass?

- In 2005, traditional biomass (TB) accounted for 84% of energy used by rural households.
- Traditional biomass use in rural China would be gradually phased out.
- No market price but potentially huge non-market price

Our cost-accounting approach

Full cost of energy service provided by TB [$/GJ]

\[ = \text{capital cost of TB using equipment} + \text{opportunity cost of TB procurement} \]

\[ \text{opportunity cost of TB procurement} = (\text{labor cost} + \text{monetized pleasure from labor}) \times \text{procurement time $0} \]
GCAM Projection of Building Energy Use in China
Projected Energy Use Density of China Residential Buildings: International Comparison [GJ/m²]

Source: Our model calculation, Database for Energy efficiency indicators in Europe, US Building Energy Databook, and OECD stat extracts
• How would service demands in urban residential buildings develop?
• How would they respond to a carbon price?

Urban Residential Buildings

**Reference**

**Policy***

*Global Hotelling carbon price path achieving 50% of 2005 CO2 emissions by 2050*
• How would service demands in rural residential buildings develop?
• How would they respond to a carbon price?

Rural Residential Buildings

Reference

Policy*

* Global Hotelling carbon price path achieving 50% of 2005 CO2 emissions by 2050
• How would building fuel use change over time?
• How would they respond to a carbon price?

Final Energy Use in China Buildings

**Reference**

**Policy**

Building Final Energy by Fuel [EJ]

- traditional biomass
- delivered biomass
- district heat
- delivered gas
- refined liquids end use
- delivered coal
- elect td bld
• How would the fuel market respond to a carbon tax?

Prices of Fuels Delivered to China Buildings

**Reference**

**Policy**

Prices of Delivered Fuels [2005USD/GJ]
Space Heating in Urban Residential

The carbon policy substantially reduces the use of district heating for space heating.
Price effects from carbon policy would push to extend the use of traditional bioenergy.
End