Determinants of Electricity Demand in the Chinese Residential Sector

Mingquan Li
School of Economics and Management, Beihang University
June 25, 2019
China’s Electricity Demand: Far From Saturated

- China is the top producer and consumer of electricity in the world

- However, frugality of residential and commercial sectors becomes evident
  - Per capita: China is far below developed countries
  - Structure: China’s demand is mainly from the industrial sector
Existing Research in Energy Demand

**Bottom-up**

Long-range Energy Alternatives Planning System (LEAP) & National Energy Modelling System (NEMS)

Top-down

Associate electricity consumption with indicators such as economic, demographic and weather variables

Other research

High-resolution demand projections, but only as applied to short time scales, such as day-ahead

Energy demand projection enjoys popularity; long-term high-temporal resolution electricity demand projection is barely discussed

<table>
<thead>
<tr>
<th>Methodology/model</th>
<th>Author(s)</th>
<th>Forecast object</th>
<th>Selected variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPO2 RBF</td>
<td>SW Yu et al. [31]</td>
<td>Annual electricity consumption</td>
<td>GDP, population, proportion of industry in GDP, urbanization rate, share of coal energy and CPI</td>
</tr>
<tr>
<td>TIMES G5 model.</td>
<td>UK Rout et al. [32]</td>
<td>Annual energy demands and emissions</td>
<td>Population, GDP, person-kilometers, transport of goods, heat demand per unit GDP, other electric demand per unit GDP, GDP of three terms (primary, secondary, tertiary industry), consumption of rural household, consumption of urban household and consumption of government</td>
</tr>
<tr>
<td>Partial least squares</td>
<td>Meng and Niu [33]</td>
<td>Annual electricity consumption</td>
<td>GDP, industrial output, rate of motorization</td>
</tr>
<tr>
<td>Energy balance model</td>
<td>Adams et al. [34]</td>
<td>Annual electricity consumption</td>
<td>GDP, the primary industry, the secondary industry, the tertiary industry</td>
</tr>
<tr>
<td>Input output model RAS</td>
<td>He et al. [35]</td>
<td>Annual electricity consumption</td>
<td>GDP, urbanization rate, passenger-turnover and freight-turnover</td>
</tr>
<tr>
<td>method</td>
<td></td>
<td></td>
<td>GDP, energy prices</td>
</tr>
<tr>
<td>PLSR method</td>
<td>Zhang et al. [36]</td>
<td>Annual electricity consumption</td>
<td>Electricity prices, Market factors, Second industry output</td>
</tr>
<tr>
<td>Cobb-Douglas function</td>
<td>Von Hirschhausen and</td>
<td>Annual electricity consumption</td>
<td>Real fuel price, GDP, population</td>
</tr>
<tr>
<td>System dynamics model</td>
<td>Andres [37]</td>
<td></td>
<td>GDP, heavy industrial added value in GDP, the proportion of urban population, coal price index</td>
</tr>
<tr>
<td>Bayesian vector</td>
<td>Crompton and Wu [39]</td>
<td>Annual production peak of natural gas</td>
<td>GDP, total population, output value of 1st, 2nd &amp; 3rd industry, electricity price, weather and climate data</td>
</tr>
<tr>
<td>autoregressive</td>
<td></td>
<td></td>
<td>GDP, population, economic structure, urbanization rate, and energy consumption structure</td>
</tr>
<tr>
<td>Co-integration model</td>
<td>Lin et al. [40]</td>
<td>Annual electricity consumption</td>
<td>Rural economic output, number of households, electricity intensity in rural household, rural population, township and village enterprises, etc</td>
</tr>
<tr>
<td>Radial basis function</td>
<td>Xia et al. [41]</td>
<td>Annual electricity consumption</td>
<td>Temperature, relative humidity, precipitation, CPI, PPI, exports and imports, total retail sales of consumer goods, gross industrial output value, etc</td>
</tr>
<tr>
<td>neural networks</td>
<td></td>
<td></td>
<td>Temperature, population, the number of tourists, hotel room occupancy and days per month</td>
</tr>
<tr>
<td>PSO-GA</td>
<td>Yu et al. [42]</td>
<td>Annual electricity consumption</td>
<td>Vehicle population, annual average vehicle travel, fuel economy</td>
</tr>
<tr>
<td>SEDA™ V2 model</td>
<td>Yang and Yu [43]</td>
<td>Annual electricity consumption</td>
<td></td>
</tr>
<tr>
<td>Semi-parametric additive model</td>
<td>Shao et al. [9]</td>
<td>Monthly electricity consumption in rural areas in six Chinese provinces</td>
<td></td>
</tr>
<tr>
<td>Wavelet ANN</td>
<td>Lai et al. [44]</td>
<td>Monthly electricity consumption</td>
<td></td>
</tr>
<tr>
<td>LEAP Model</td>
<td>Yan and Crookes [45]</td>
<td>Annual Transport energy</td>
<td></td>
</tr>
</tbody>
</table>

Reliability of the electric power sector depends on a perfect balance of demand and supply.

Projections of the high-resolution electricity demand are necessary for identifying:

- The mix of supply resources needed (to have adequate capacity, reserves, flexibility)

Electrification will drive up fluctuation of demand:

- Residential and commercial sectors cause most of the temporal fluctuations

New trends will add to the variation of electricity consumption:

- Global warming + Penetration of electric appliances (e.g. Space heating and cooling) + New end-uses (e.g. electric vehicle)

With the increasing fluctuation of electricity demand, estimates of future electricity demand that are useful must provide information at an hourly or even intra-hourly resolution.
Objective

To develop a bottom-up framework for characterizing possible futures for China’s residential electricity demand at a high temporal (hourly) and spatial (provincial) resolution that considers the uncertainties about demand side technologies and policies

❖ To identify the determinants of electricity demand in the residential sector, and understand the mechanism by which these affect electricity consumption
❖ To develop scenarios of electricity demand drivers that will be used as key inputs to a modeling structure that generates a synthetic time series of hourly electricity demand
Outline

1. Background and Objectives
2. Modeling Framework
3. Methods, Data and Results
4. Future Work
Residential Electricity Demand Projection: Framework

Drivers

Socioeconomic Drivers
- Population
- Birth rate
- Death rate
- Household structure
- Education
- Employment
- GDP per capita
- GNI per capita
- Daily schedule

Technological Drivers
- Appliance lifetime
- Technological progress
- Appliance age status
- Building lifetime
- Insulation of building
- Building age status

Geographical and Climatic Drivers
- Longitude
- Latitude
- Global warming
- Sunny/Cloudy/
- Climatic zone
- Wind speed

Policy Drivers

Modules

Demographic Module
- Population projection
- Urbanization
- Household size

Appliance Module
- Appliance penetration
- Technology advancement

Usage Behavior Module
- ON/OFF pattern
- Appliance settings

Building Module
- Building type
  - House
  - Apartment
- Occupancy rate
- Building code
  - Length
  - Width
  - Height
  - Orientation
  - Windows/door
  - Shade
- Building stock

Climate Module
- Hourly temperature
- Solar radiation

Outputs
- Long-term: 2050 or longer
- High-resolution: hourly or sub-hourly
- By end-use

- Space heating
- Space cooling
- Lighting
- Water heating
- Cooking
- Food freezing
- Clothes washing
- Entertainment (TV, PC, etc.)
- Communications (Cellphone, etc.)
- Personal care
- Working related
- Others
Outline

1. Background and Objectives
2. Modeling Framework
3. Methods, Data and Results
4. Future Work
<table>
<thead>
<tr>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Population of Chinese provinces</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Influencing Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Uncertainties in fertility rate</td>
</tr>
<tr>
<td>• Postponement of parenthood</td>
</tr>
<tr>
<td>• Increase of life expectancy</td>
</tr>
<tr>
<td>• Gradual balancing of the sex ratio at birth</td>
</tr>
<tr>
<td>• Interprovincial or international population migration</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Provincial age and sex of population in the base year 2010</td>
</tr>
<tr>
<td>• Matrix of Interprovincial or international population migration in the base year 2010</td>
</tr>
<tr>
<td>• Provincial age and sex specific mortality rate for each year in the period 2011 to 2100</td>
</tr>
<tr>
<td>• Provincial age-specific birth-rate for women between 15 and 49 years for the period 2011 to 2100</td>
</tr>
<tr>
<td>• Provincial annual ratio of boys/girls among all births for the period 2011 to 2100</td>
</tr>
</tbody>
</table>
Fertility Matters and Provincial Differences: Revisiting China's Demographic Futures
Population Projection: Major Findings

- Population will peak before 2030 in four scenarios
- Even a replacement fertility rate cannot stop societal ageing
- Current sex-ratio distortion will gradually be eliminated
- Proportion of population in the Middle and West China will rise
Urbanization Projection

Difference in appliance saturation between urban and rural

Units per 100 households

- **Washer**
  - National: 80, 80
  - Urban: 90, 90
  - Rural: 70, 70

- **Refrigerator**
  - National: 80, 80
  - Urban: 90, 90
  - Rural: 70, 70

- **AC**
  - National: 80, 80
  - Urban: 90, 90
  - Rural: 70, 70

- **Shower Heater**
  - National: 80, 80
  - Urban: 90, 90
  - Rural: 70, 70

- **Microwave**
  - National: 80, 80
  - Urban: 90, 90
  - Rural: 70, 70

- **Electric bicycle**
  - National: 80, 80
  - Urban: 90, 90
  - Rural: 70, 70

- **Color TV Set (set)**
  - National: 80, 80
  - Urban: 90, 90
  - Rural: 70, 70

- **Vacuum Cleaner (unit)**
  - National: 80, 80
  - Urban: 90, 90
  - Rural: 70, 70

- **Computer (set)**
  - National: 80, 80
  - Urban: 90, 90
  - Rural: 70, 70
Regression model:

\[ \ln(M - y_{i,t}) - \ln y_{i,t} = \alpha x_{i,t} + \beta + \epsilon_{i,t} \]

where \(M = 80\%\).

Beijing, Tianjin, Shanghai are excluded from the regression analysis.

Panel data:

Time series: year 2005-2014; Sample: 31 provinces;
Independent variable: per capita GDP;
Dependent variable: Urbanization;

Data processing:

GDP: real GDP at 2014 price obtained from nominal GDP and GDP deflator.

Number of Households

45 scenarios of household numbers for each province in urban and rural areas up to 2050

Output: Household number

Population projection module

Urbanization projection module

Household size module

Effects of population, urbanization, household size, and income on electric appliance adoption in the Chinese residential sector towards 2050
Saturation of Electric Appliances: Regression Model

Diffusion curve for new technology adoption

\[ \ln(M - y_{i,t}) - \ln y_{i,t} = \alpha x_{i,t} + \beta + \varepsilon_{i,t} \]

\[ \ln(M - y_{i,t}) - \ln y_{i,t} = \alpha \ln x_{i,t} + \beta + \varepsilon_{i,t} \]

Rural vs. Urban

Because of lifestyle difference, rural and urban households present different saturation curves

Panel data analysis

Time series: 2000-2012; Sample: rural and urban households in 31 provinces
Regression model: Random or Fixed effect; Individual effect

Different appliances have different characters (i.e., different sensitivities with income)

- Washing machine \((M=1.1)\)
- Refrigerator \((M=1.1)\)
- Air conditioner \((M=1.9 \text{ (N)}; 2.5 \text{ (S)})\)
- Personal computer \((M=2.0)\)
- Microwave oven \((M=1.0)\)
- Television \((M=2.0)\)

**Panel data analysis**

Time series: 2000-2012; Sample: rural and urban households in 31 provinces
Regression model: Random or Fixed effect; Individual effect

**Appliances**

Differences in appliance adoption due to lifestyle differences between rural and urban households result in distinct saturation curves.

**Value Addition**

The regression model captures the impact of population, urbanization, household size, and income on electric appliance adoption in the Chinese residential sector towards 2050.
Saturation of Electric Appliances: Major Findings

We project scenarios of provincial penetrations for various appliances in urban and rural areas

- Growth in saturation of personal computers and air conditioning equipment will be higher
- Current differences in appliances’ penetration between urban and rural households narrow
- Current disparities in appliance penetration observed among geographic regions tend to disappear

Effects of population, urbanization, household size, and income on electric appliance adoption in the Chinese residential sector towards 2050
Effects of population, urbanization, household size, and income on electric appliance adoption in the Chinese residential sector towards 2050

- Increase in the number of PC and AC units will be higher
- Appliance will reach a peak during the period
- Higher growth rates in Central and Western China
- Most will be owned by urban households in Eastern China
Impact of Each Driver to Adoption of Appliances

Effects of population, urbanization, household size, and income on electric appliance adoption

- Positive effect: Urbanization, household downsizing, and penetration growth
  - Growth of penetration (higher income) contributes the most

- Possible negative effect: Population change
  - Low total fertility rate is the reason
Energy Performance of Major Electric Appliances

Energy performances of many models: Segment by technology and volume

Take AC as an example

<table>
<thead>
<tr>
<th>Category</th>
<th>Fixed-frequency</th>
<th>Variable-frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;=2800</td>
<td>12.5</td>
<td>8.8</td>
</tr>
<tr>
<td>2801-4500</td>
<td>13.3</td>
<td>9.4</td>
</tr>
<tr>
<td>4501-6000</td>
<td>7.0</td>
<td>4.9</td>
</tr>
<tr>
<td>&gt;=6001</td>
<td>25.8</td>
<td>18.2</td>
</tr>
</tbody>
</table>

Market share of each category

❖ Normalized Ali 1688 purchasing index
# Energy Performance of Major Electric Appliances

<table>
<thead>
<tr>
<th>End-use</th>
<th>Electric appliance</th>
<th>Indicator</th>
<th>Unit</th>
<th>Low</th>
<th>Middle</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space cooling</td>
<td>Air conditioning system</td>
<td>Energy consumption efficiency</td>
<td>Wh/Wh</td>
<td>3.77</td>
<td>3.89</td>
<td>4.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cooling power</td>
<td>W</td>
<td>1288</td>
<td>1379</td>
<td>1453</td>
</tr>
<tr>
<td></td>
<td>Fan</td>
<td>Name plate power</td>
<td>W</td>
<td>80</td>
<td>63</td>
<td>55</td>
</tr>
<tr>
<td>Water heating</td>
<td>Water heating equipment</td>
<td>Standing loss per 24 hours</td>
<td>KWh</td>
<td>0.60</td>
<td>0.55</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hot water output rate</td>
<td>%</td>
<td>0.80</td>
<td>0.85</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Name plate power</td>
<td>W</td>
<td>3000</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Kitchen appliance</td>
<td>Induction Cooker</td>
<td>Operating mode power</td>
<td>W</td>
<td>2000</td>
<td>2100</td>
<td>2200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Off mode power</td>
<td>W</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Rice cooker</td>
<td>Operating mode power</td>
<td>W</td>
<td>1425</td>
<td>896</td>
<td>645</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heat-preserving mode power</td>
<td>W</td>
<td>75</td>
<td>61</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Microwave Oven</td>
<td>Operating mode power</td>
<td>W</td>
<td>1075</td>
<td>954</td>
<td>850</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Off mode power</td>
<td>W</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Cook Vent</td>
<td>Name plate power</td>
<td>W</td>
<td>224</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Food preserving</td>
<td>Refrigerator</td>
<td>Annual electricity consumption</td>
<td>KWh</td>
<td>158</td>
<td>143</td>
<td>105</td>
</tr>
<tr>
<td>Clothes Washing</td>
<td>Clothes washing machine</td>
<td>Electricity consumption per cycle</td>
<td>KWh/time</td>
<td>0.72</td>
<td>0.61</td>
<td>0.55</td>
</tr>
<tr>
<td>TV watching</td>
<td>Television</td>
<td>Operating mode power</td>
<td>W</td>
<td>119</td>
<td>90</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Off mode power</td>
<td>W</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>TV receiver</td>
<td>Operating mode power</td>
<td>W</td>
<td>4.4</td>
<td>4.2</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Off mode power</td>
<td>W</td>
<td>0.8</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>PC playing</td>
<td>Laptop and desktop</td>
<td>Operating mode power</td>
<td>W</td>
<td>163</td>
<td>130</td>
<td>113</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Standby mode power</td>
<td>W</td>
<td>4.1</td>
<td>3.3</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Off mode power</td>
<td>W</td>
<td>2.7</td>
<td>2.1</td>
<td>1.8</td>
</tr>
<tr>
<td>Lighting</td>
<td>Lightbulbs</td>
<td>Energy consumption per hour (Workday)</td>
<td>W</td>
<td>350.85</td>
<td>173.14</td>
<td>74.64</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy consumption per hour (Weekend)</td>
<td>Unit</td>
<td>372.81</td>
<td>184.30</td>
<td>78.88</td>
</tr>
</tbody>
</table>
Understanding and Segmenting Electricity Usage Behavior in the Chinese Residential Sector: based on Survey Instruments and Machine Learning Algorithms (In preparation)

Typical Usage Archetypes of Each End-use

Survey Instruments

❖ Residential survey in 124 households, covers all districts in Beijing city (summer 2017)

Take washing machine as an example

<table>
<thead>
<tr>
<th>ID</th>
<th>Times</th>
<th>Frequency</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
<th>Sunday</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>...</th>
<th>21</th>
<th>22</th>
<th>23</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>...</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>85</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>84</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- daily = 1
- weekly = 2
- monthly = 3
- seasonally = 4
- annually = 5
- never = 6

Yes = 1
No = 0
Typical Usage Archetypes of Each End-use

Non-supervised Machine Learning Algorithms

- Hierarchical clustering
- K-means clustering

Take washing machine as an example

Usage archetypes in each season

- Information of each household
  - Times: e.g., 3 times
  - Hourly Schedule: e.g., 10pm & 11pm
  - Weekly Schedule: e.g., Tue & Fri

- Information of each cluster
  - Probability in washing hours: e.g., 3/2/2 = 75%

Weekly Schedule

Hierarchical & K-means

Clusters

Output: Typical usage pattern of each cluster

- e.g. usage probability in 7*24 hours of each cluster

Understanding and Segmenting Electricity Usage Behavior in the Chinese Residential Sector: based on Survey Instruments and Machine Learning Algorithms (In preparation)
Typical Usage Archetypes of Each End-use

- Two types of households
  - Every single day
  - Every other day

- Two-peak shape
  - Morning (6-10am)
  - Evening (7-9pm)

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Daily user</th>
<th>Light user</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring</td>
<td>36.9</td>
<td>63.1</td>
</tr>
<tr>
<td>Summer</td>
<td>39.3</td>
<td>60.7</td>
</tr>
<tr>
<td>Fall</td>
<td>45.2</td>
<td>54.8</td>
</tr>
<tr>
<td>Winter</td>
<td>33.3</td>
<td>66.7</td>
</tr>
</tbody>
</table>
Residential Electricity Demand: Bottom-up Method

Usage pattern

Total number of households

Proportion of each usage cluster

Usage pattern of each cluster

Energy efficiency of each electric appliance

Number of household belonging to each usage behavior

Penetration of each electric appliance

Electricity consumption if owning one electric appliance

Electricity consumption of each cluster

Stacked electricity consumption

Simulating Residential Electricity Demand in Beijing Based on a Bottom-up Model (In preparation)
Electricity Demand of Each Usage Archetype

Electricity consumption of one typical clothes washing machine

Electricity consumption for clothes washing in summer under the middle level of energy performance in Beijing

Simulating Residential Electricity Demand in Beijing Based on a Bottom-up Model (In preparation)
Simulating Residential Electricity Demand in Beijing Based on a Bottom-up Model (In preparation)

Residential Electricity Demand: Bottom-up Results

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
<th>Winter</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air conditioner</td>
<td>-</td>
<td>-</td>
<td>4427.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water heater</td>
<td>59.7</td>
<td>60.3</td>
<td>59.7</td>
<td>57.1</td>
<td>3078.6</td>
</tr>
<tr>
<td>Lighting</td>
<td>56.6</td>
<td>52.4</td>
<td>49.4</td>
<td>58.0</td>
<td>2813.3</td>
</tr>
<tr>
<td>Cooking</td>
<td>30.1</td>
<td>30.1</td>
<td>30.4</td>
<td>31.9</td>
<td>1593.4</td>
</tr>
<tr>
<td>Washer</td>
<td>22.1</td>
<td>21.7</td>
<td>24.1</td>
<td>19.8</td>
<td>1139.5</td>
</tr>
<tr>
<td>PC</td>
<td>19.8</td>
<td>19.9</td>
<td>19.8</td>
<td>19.8</td>
<td>1032.0</td>
</tr>
<tr>
<td>TV</td>
<td>22.8</td>
<td>23.2</td>
<td>22.7</td>
<td>22.7</td>
<td>1188.3</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>23.5</td>
<td>23.5</td>
<td>23.5</td>
<td>23.5</td>
<td>1223.0</td>
</tr>
</tbody>
</table>

- Peak of demand
  - Space cooling
  - Water heating
  - Lighting

Simulating Residential Electricity Demand in Beijing Based on a Bottom-up Model (In preparation)
Outline

1. Background and Objectives
2. Modeling Framework
3. Methods, Data and Results
4. Future Work
Future Works

❖ To expand samples/household surveys
  ❑ Pilot surveys -> ~ 1000 surveys
  ❑ Understanding the behavior, attitudes, and beliefs of residential users

❖ To validate results by comparing with metering information
  ❑ Understanding the performance of bottom-up model
  ❑ Calibrating the bottom-up results
THANKS!