China's Electricity Future: A Provincial Scenario Analysis towards 2050
Mingquan Li, Rui Shan, Mauricio Hernandez, Varun Mallampalli & Dalia Patiño-Echeverri
Duke University, Durham, NC, USA

Introduction
- Providing affordable, reliable, clean electricity in China requires a robust planning process that accounts for uncertainties.
- Robust capacity planning in the power system requires characterizing the uncertainty on future electricity demand.
- Electricity demand from the residential sector is growing fast.
- There is an urgent need to identify and understand the drivers of future electricity demand in the residential sector.
- This research directly contributes to projection of future electricity demand in the residential sector from the bottom-up.

Objective
To project China's electricity demand from the residential sector for the 2015-2050 period at a provincial level, under different demographic and socio-economic scenarios:
- Saturation: Penetration of household electric appliances per household.
- Total end-use equipment: Total number of units of each appliance in a province.

Method
- Framework
  - Population Module
    - Base year input: Men by age group, Women by age group.
    - Independent variables: Economic development, Urbanization.
    - Dependent variable: Population change.
  - Appliance Penetration Module
    - Dependent variable: Penetration rate.
  - Urbanization Module
    - Independent variables: Birth rate, Death rate, Sex ratio.
    - Dependent variable: Urbanization rate.

Data
- Module | Variable | Year | Source
- Population | Population | 2010 | 6th Population Census of the People's Republic of China
- Population | Death rate | 2010 | 6th Population Census of the People's Republic of China
- Population | Birth rate | 2010 | 6th Population Census of the People's Republic of China

Scenarios
- Module | Variable | Number
- Population | National TFR and allocated to provinces | 4
- Urbanization | Per capita GDP growth | 3
- Household size | Household size | 3
- Penetration | Per capita income growth | 3

Decomposition model
Log mean Divisia index (LMDI) method
\[ \Delta E = \Delta E_{00} + \Delta E_{UR} + \Delta E_{SE} + \Delta E_{PG} \]
\[ \Delta E = \sum_{i} \sum_{j} \left( \frac{W \times \ln \left( \frac{E_{ij}}{E_{0ij}} \right)}{E_{0ij}} \right), \quad W \in \{PP, UR, SZ, PE\} \]
\[ W = \frac{E_{ij,Area}}{E_{0ij,Area}} \]

Results
- Penetration of appliances per household
- Total appliances owned
- Impact of each driver
  - Appliance penetration growth will be led by adoption of ACs and PCs.
  - Current disparities between regions will tend to disappear.
  - Penetration of appliances (as function of income) has a higher impact than population, urbanization, or household size on the estimated total number of appliances.
  - Reductions in ownership are due to population decline.

Conclusion
- Develop a bottom-up framework to characterize electricity demand scenarios.
- Create a tool to forecast long-term electricity demand at the hourly temporal scale.

Future work
- Most appliances will be owned by urban households.
- Appliance ownership will be concentrated in Eastern China.
- Under some possible future scenarios, appliance ownership will reach a peak during the analysis period.
- PCs owned by households in 2050 will almost triple.

Impact of drivers
- Differences between urban and rural regions will narrow.
- Penetration of appliances will be led by adoption of ACs and PCs.
- Current disparities between regions will tend to disappear.
- Penetration of appliances (as function of income) has a higher impact than population, urbanization, or household size on the estimated total number of appliances.
- Reductions in ownership are due to population decline.