Long-Term Evolution of Building Energy Demand for India: Disaggregating end use energy services in an integrated assessment modeling framework

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Some recent efforts using GCAM- IIM version:


- Shukla PR and Chaturvedi V. Low carbon and clean energy scenarios for India: A targeted approach. Under review

- Chaturvedi V, Eom J, Clarke LE and Shukla PR. Modeling long term building energy demand for India.
Background

- High economic growth expected for India, more than 8-9% in the near future (Assumptions based on GoI documents)
- Population more than 1.2 Bn
- Rapid urbanization
- Managing energy demand and ensuring adequate and reliable energy supply important challenges for Indian policy
Modeling Building Energy Use:

Moving from Supply to Demand
Building energy consumption in India

- More than 45% of total final energy in India consumed in the building sector in 2005
- High reliance on traditional biomass
- Significant difference in rural and urban energy consumption profiles
India Buildings’ Energy Consumption (2005)

Energy Consumption on 2005 (EJ)

- Urban
- Rural
- Commercial

Source: IEA (2007)
The Detailed Model for Building Energy Use in India

- Model framework based on Eom et al. (2011)
- Has been applied earlier to model China building energy demand
The approach to Floor Space Expansion

Demand, \( D_t = k_D P_t^{\varepsilon_D} I_t^{\varepsilon_I} \)

Supply, \( S_t = k_S P_t^{\varepsilon_S} P_{t-1}^{\varepsilon_{S,t-1}} \)

Floor space price [$ / m^2]

Demand increases with income

Floor space per capita [m^2 per capita]

Parameters estimated based on National Sample Survey Organization (NSSO) data
Drivers of energy consumption

Increasing population in urban areas to drive floor space and energy service demands

Per capita income gap assumed to converge by 2200
Demand for Building Services
Modeling the Change in Service Demands

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

\[ Q_{H,t} = k_H \cdot (HDD_t \cdot ShellEff_t \cdot SurfaceRatio_t - \lambda_H \cdot InternalGain_t) \cdot \left[ 1 - \exp\left( -\frac{\ln 2}{\alpha_H} \cdot \left( \frac{Y_t}{P_{H,t}} \right) \right) \right] \]

Space Heating Requirement (satiated demand) Economic Behavior

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

\[ Q_{C,t} = k_C \cdot (CDD_t \cdot ShellEff_t \cdot SurfaceRatio_t + \lambda_C \cdot InternalGain_t) \cdot \left[ 1 - \exp\left( -\frac{\ln 2}{\alpha_C} \cdot \left( \frac{Y_t}{P_{C,t}} \right) \right) \right] \]

Space Cooling Requirement (satiated demand) Economic Behavior

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

\[ Q_t = k_i \cdot \left[ 1 - \exp\left( -\frac{\ln 2}{\alpha_i} \cdot \left( \frac{Y_t}{P_t} \right) \right) \right] \]
## End Use Technologies

<table>
<thead>
<tr>
<th>Service</th>
<th>Technology</th>
<th>Fuel</th>
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<tbody>
<tr>
<td>Space Cooling</td>
<td>Air conditioner</td>
<td>Electric</td>
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<tr>
<td></td>
<td>Air cooler</td>
<td>Electric</td>
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<td>Space Heating</td>
<td>Room heater</td>
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<td>Building heater</td>
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<td>Cooking and Water Heating</td>
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<td>Gas cooker</td>
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<td>Electric cooker</td>
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<td>Coal cooker</td>
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<td>Biomass cooker</td>
<td>Commercial biomass</td>
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<td>Traditional biomass cooker</td>
<td>Traditional biomass</td>
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<tr>
<td></td>
<td>Kerosene stove</td>
<td>Kerosene</td>
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<td>Lighting</td>
<td>Incandescent bulbs</td>
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<td></td>
<td>Fluorescent bulbs</td>
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<td></td>
<td>Solid state lighting</td>
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<td></td>
<td>Oil Lamp</td>
<td>Kerosene</td>
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<tr>
<td>Appliances</td>
<td>Generic appliance technology</td>
<td>Electric</td>
</tr>
</tbody>
</table>
The Long-Term Evolution of India’s Building Energy Use
Final energy consumption by service: Rural-Urban

- Rapid expansion of cooling and appliances: results include changing degree day effect
- Significant share of cooking also in the future
Space cooling technologies

- Low penetration of space cooling technologies in the base year
- High increase in AC ownership in the urban households between 2020 and 2050
- For rural households, this increase comes after 2050
Final energy consumption by fuel: Rural-Urban

- Dominance of electricity for cooling, heating, appliances, and lighting
- Gas, predominantly LPG, for cooking, takes a significant share
- Rapid phase out of traditional biomass
Electricity and LPG

- Significant difference in urban and rural households’ consumption of electricity and LPG in 2005
- Rapid increase in per capita electricity consumption, moving towards developed country levels
- Decreasing gap: Especially LPG increase significant in rural areas
Commercial sector takes 48% share in buildings final energy consumption by century-end, similar to developed countries

Cooling, appliances, and lighting increase rapidly

Share of energy services similar to current profile of developed countries (Note: US heating and cooling have been adjusted by degree days for comparative purpose)
Impact of Climate Policy

- Low effect of carbon tax as limited substitution possibilities
- Total final energy for India decreases by 15% in 2095, Almost 8% decrease in final energy in building sector under a climate policy
- Alternative energy reduction policies important for Indian building sector
To Conclude

• Rapid increase in floor space, especially in urban areas
• Services: High growth in cooling and appliance services
• Fuels: Dominance of electricity and gas
• Phase out of traditional biomass
• Indian building energy evolves towards developed countries’ pattern
• Limited impact of an emission mitigation policy, alternative energy reduction policies hold importance
THANK YOU!