India's Residential Sector: Spatial Analysis of Air Pollution and GHG Emissions

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AIM
ASIA-PACIFIC INTEGRATED MODEL

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India Demographic Trends

- India is now the largest country in terms of population
- India had over 1.21 billion people (2011 census) and now it is 1.42 billion
- Level of urbanization increased from 27.81% in 2001 to 31.16% in 2011. Currently about 36% population is urban.

Decadal Growth Rate

- Urban - 31.8%
- Rural – 12.2%

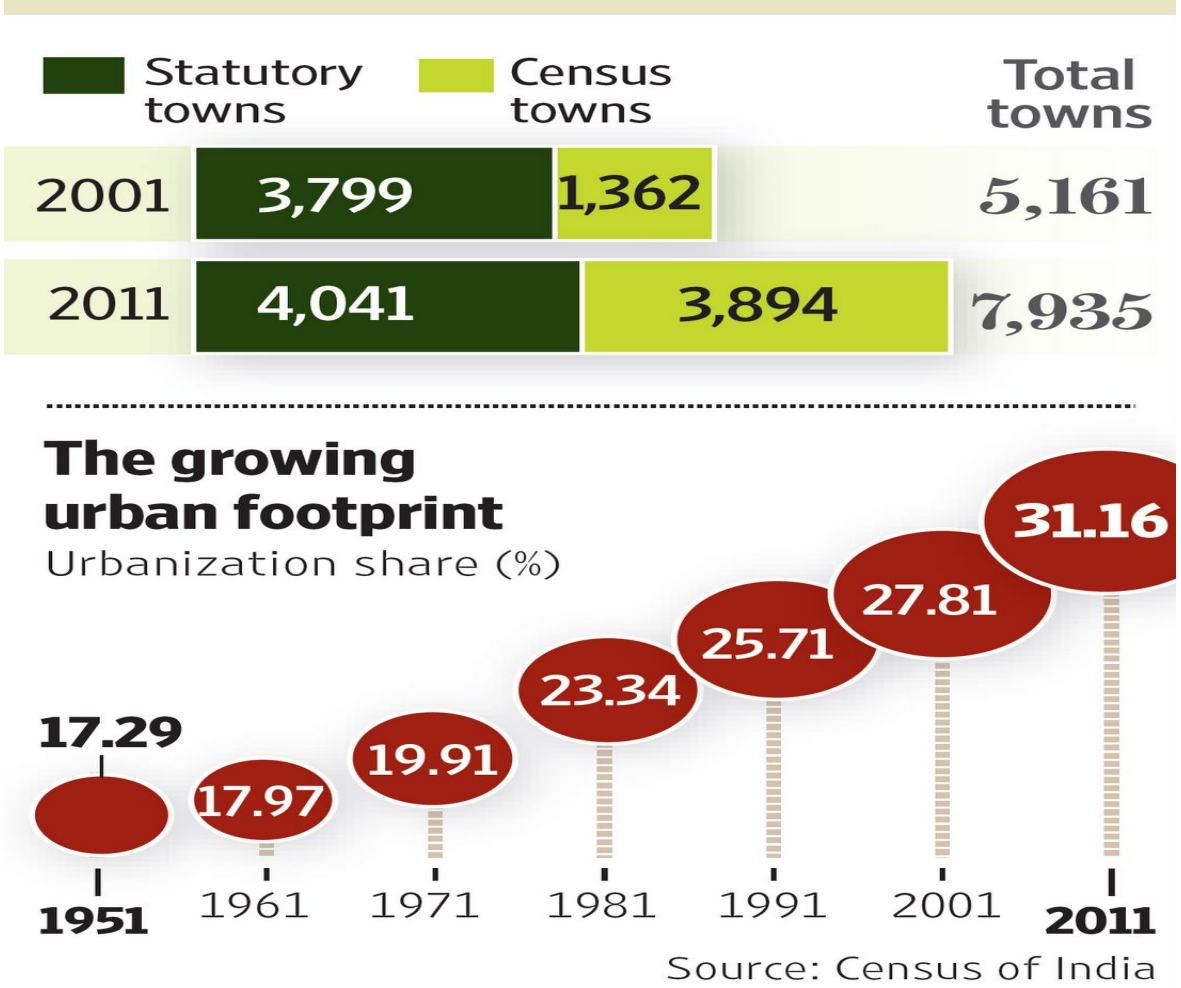
Million plus Cities (in number)

- 1991 – 23
- 2001 – 35
- 2011 – 53

Million-plus Cities and Urban Agglomerations

Challenge of Urbanization

- 33% of India's population living in urban areas - contributes 66% of India's GDP
- By 2030, urban areas are expected to house 40% of India's population and contribute 75% of India's GDP.
- **What is needed:** Comprehensive development of physical, institutional, social and economic infrastructure.
- **Goal:** Improving the quality of life and attracting people and investments to the cities. Setting in motion a cycle of growth and development.
- **Solution:** Development with climate resilience



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Direct and indirect air pollutant reductions as co-benefits of the energy transition toward carbon-neutrality in India's residential sector

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ABSTRACT

With increasing air pollution, exposure to air pollutants is becoming a critical health and environmental issue all over the world. In case of India, due to significant differences in the economic status and energy consumption characteristics, substantial variation in the air pollutant emissions is observed across Indian states in urban and rural areas. This study aims at developing a residential sector model to project CO_2 emissions up to 2070, leading India's progress towards carbon-neutrality, and evaluating the dual benefits of reducing the aforesaid emissions. A bottom-up optimization model is used to analyze these emission projections for greenhouse gases (GHGs) and air pollutants across Indian states in rural and urban areas. Further, to evaluate the effects of Indian government policy, various mitigation scenarios are analyzed, which capture the energy transition and direct and indirect emissions in India's slow, medium, and fast-developing states. Rapid energy transition in India doubles the total energy consumption in the business-*as*-usual (BAU) scenario from 2010 to 2070. Consumption of traditional biomass and coal energy sources dramatically falls, and advanced energy sources such as liquefied petroleum gas (LPG) and electricity are adopted. Energy transitions help decrease the vulnerability to harmful direct air pollutants such as black carbon (BC), organic carbon (OC) and particulate matter (PM) among rural households. There are serious tradeoffs, however, as increased usage of LPG and electricity may raise total CO_2, SO_2, and NO_X emissions. Higher LPG consumption leads to a more than two-fold increase in CO_2 emissions by 2070, compared to 2020 in residential sector. By pursuing carbon-neutrality through a renewable electricity transition, the most ambitious scenario in this study, India could reduce CO_2, SO_2, NO_X, and BC emissions by 67%, 87%, 89%, and 99%, respectively, from the 2070 BAU levels.

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End-use energy projections: Future regional disparity and energy poverty at the household level in rural and urban areas of India

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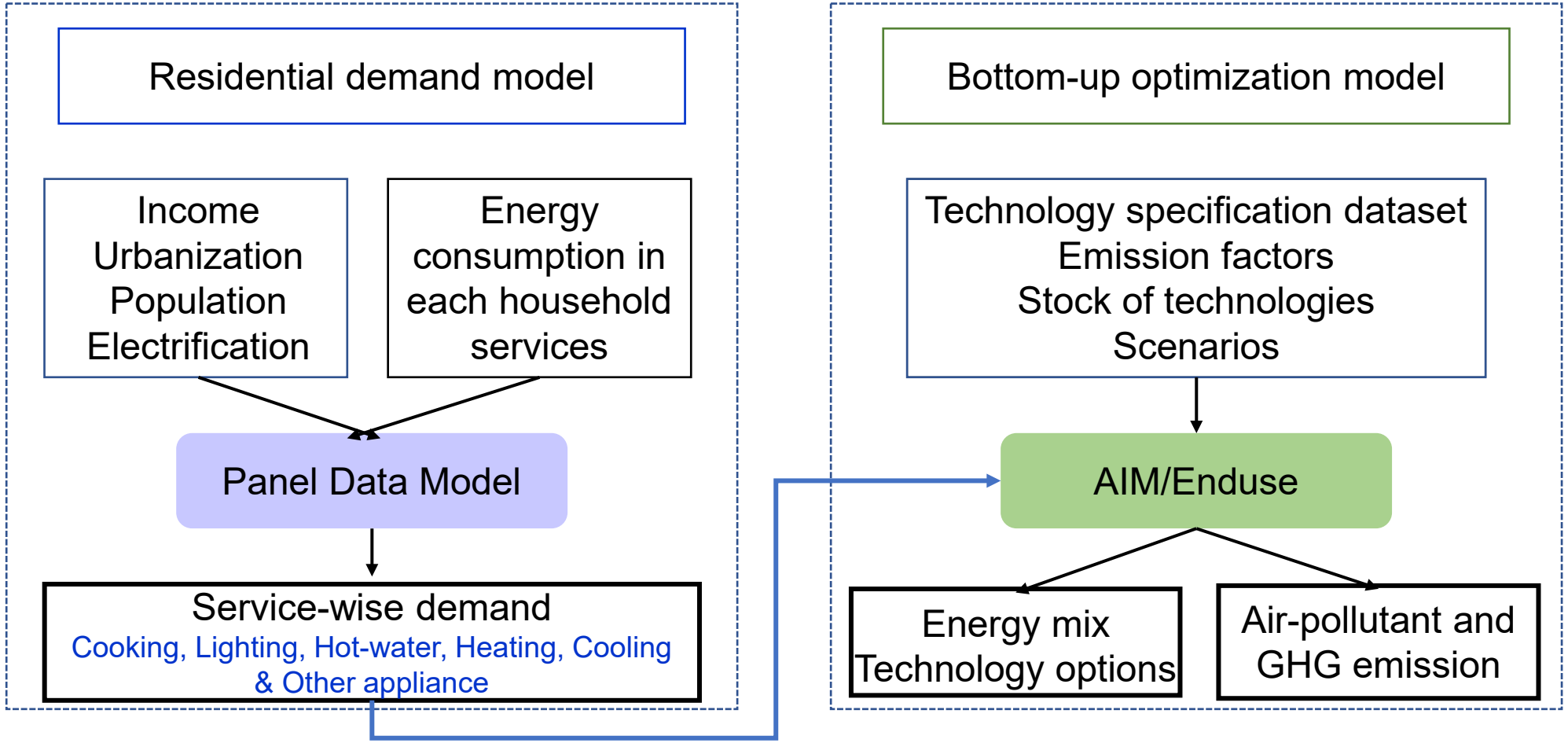
ABSTRACT

Regional disparity and energy poverty are major challenges for India on a macro-scale. In this study we explored regional disparity and energy poverty in India's future by formulating a series of unique mathematical functions while analyzing historical time-series of per-capita energy consumption (PEC). The functions formulated have important implications on India's approaches towards rapid urbanization, access to clean energy, and rural electrification. We also analyzed end-use energy consumption in low, mid and high-developing states and examined the impacts of the uncertainty of socio-economic changes. As per our estimates, energy consumption in urban areas, is likely to grow by 3.6 times from 2010 to 2070, whereas that in rural areas is likely to decrease by 0.6 times. Energy poverty among Indian states narrows by 2050, while energy consumption in the mid and high-developing states rises rapidly as urbanization and per-capita income increase. Even with this consumption growth, India's average household PEC in 2070 may remain lower than the world average recorded in 2010. The provision of advanced energy resources and technologies is therefore likely to be an important policy challenge for India, especially in the rural areas of low-developing states, as the country pursues its target of reducing energy poverty and regional disparity.

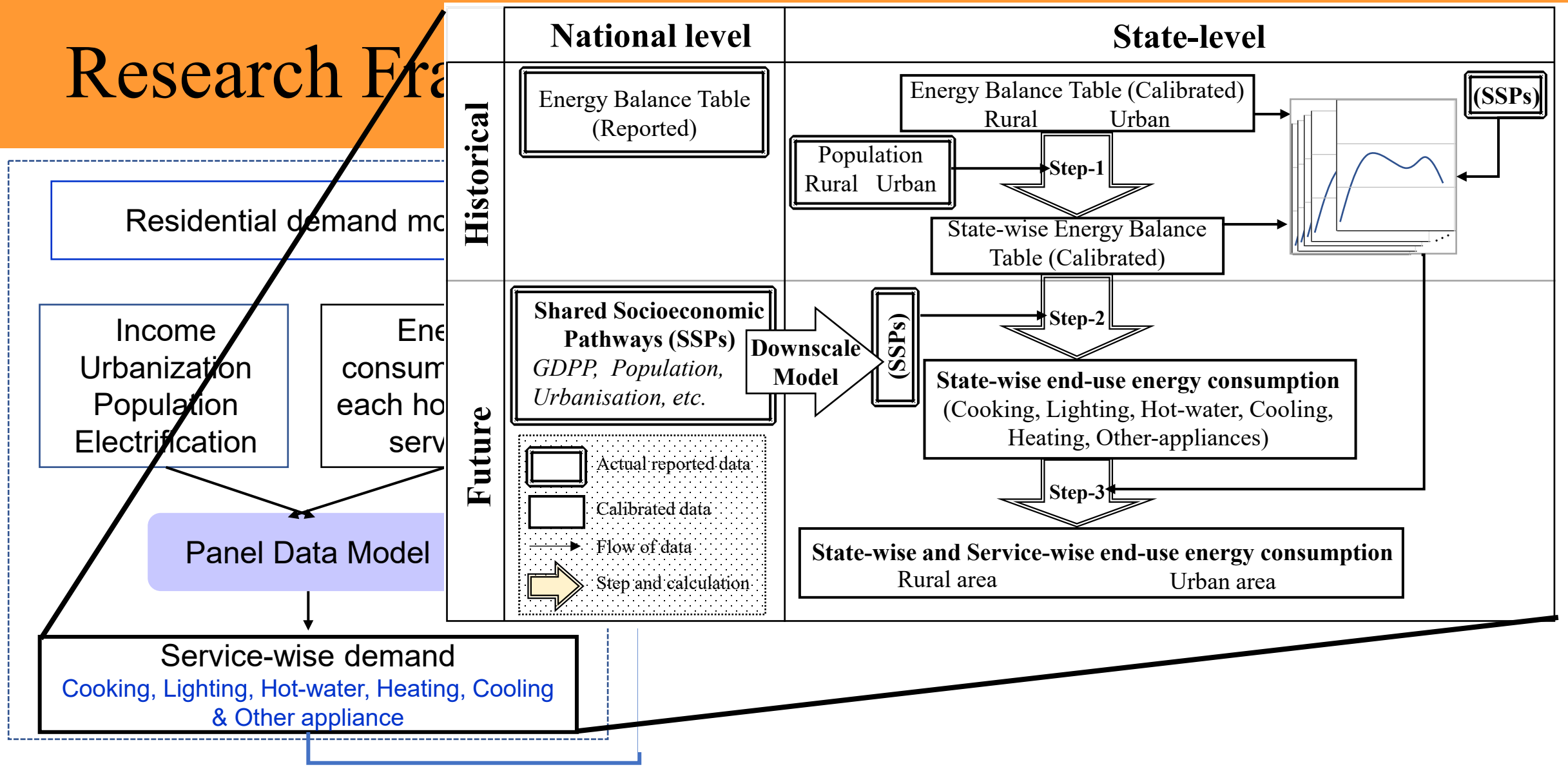
These two studies focus on -

- Detailing India into different regions and sub-regions.
- Direct (indoor) and indirect (out-door) air-pollutants and GHGs from residential sector.
- Role of residential sector in contributing to carbon-neutrality by 2070
- Co-benefits of decarbonizing on reducing direct emissions.
- Regional disparity and energy poverty among slow, medium and fast developing states in India.

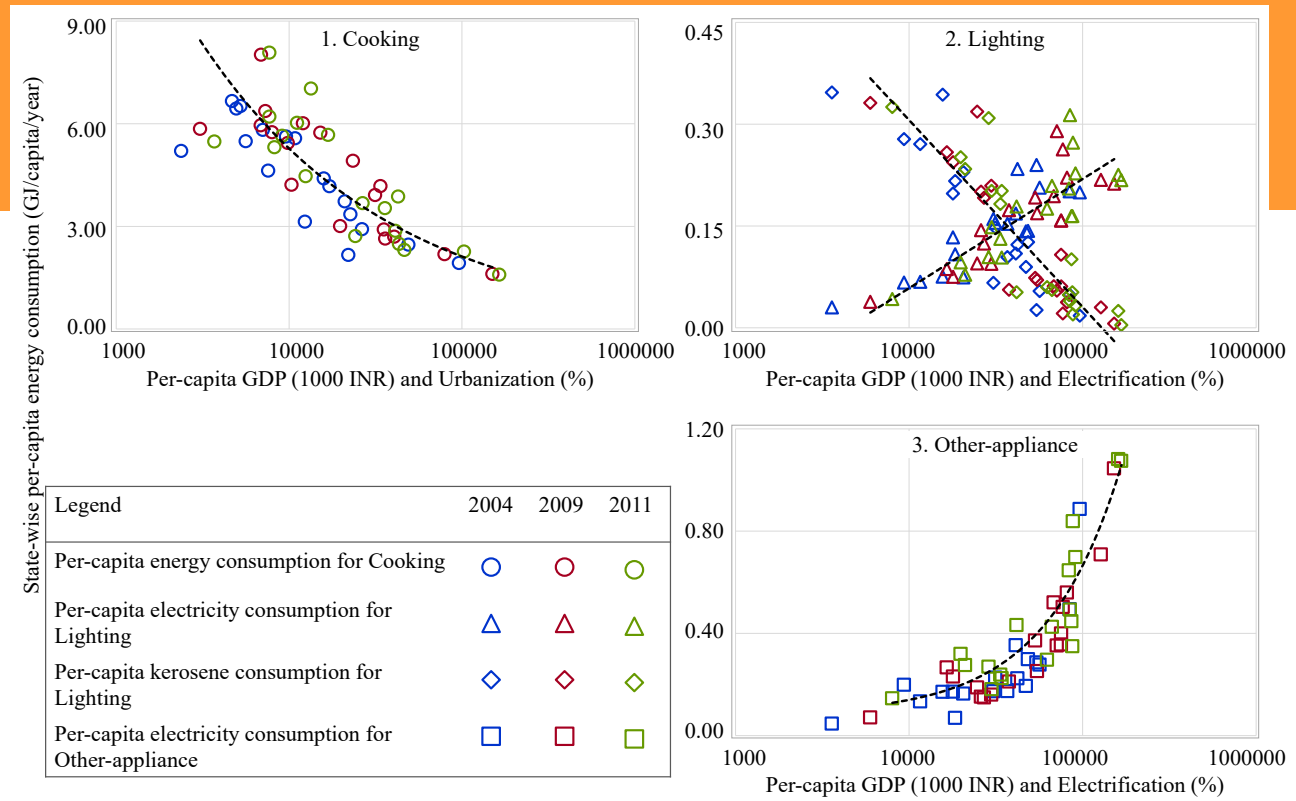
Research Framework



Research Fra



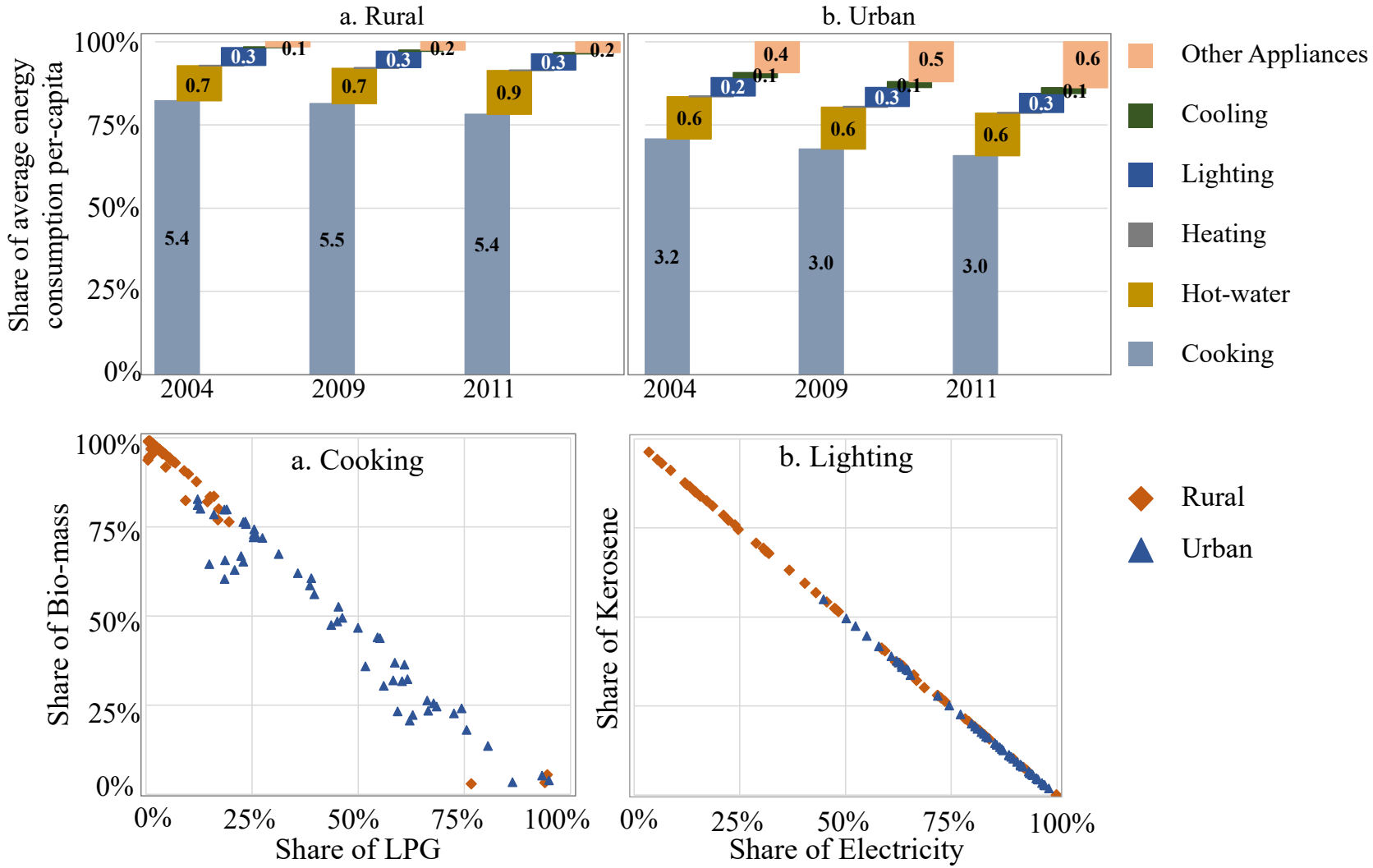
Service Demand Function



- For lighting, electricity trend is positive whereas kerosene trend is negative.
- For cooling, hot-water and heating service, climate conditions are important consideration.
- Electricity demand increases sharply due to use of cooling and other household appliances.

Household Energy Consumption in India

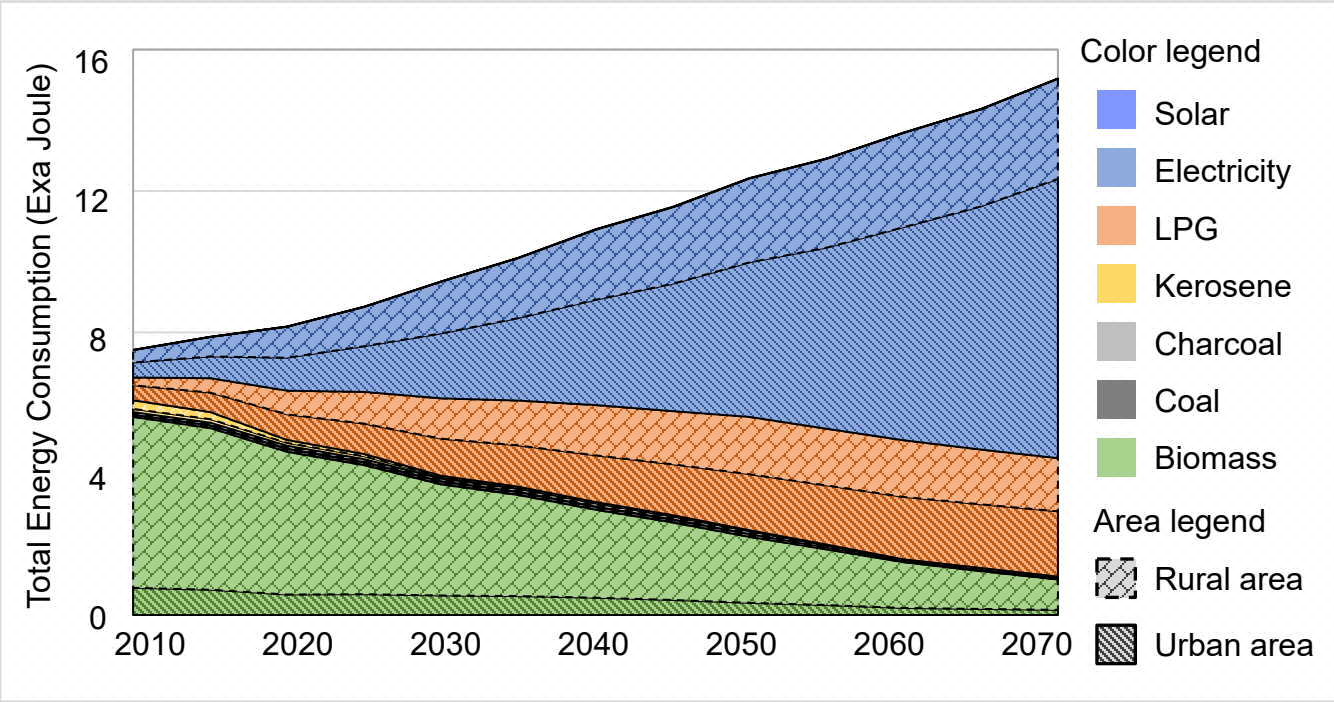
- Rural and Urban areas have substantially different energy consumption.
- Major share of energy consumption is for cooking service.
- For cooking share of Biomass is higher in rural areas and with urbanization LPG usage increases
- For lighting kerosene is still used in some rural areas and urban areas use electricity



Scenario Description

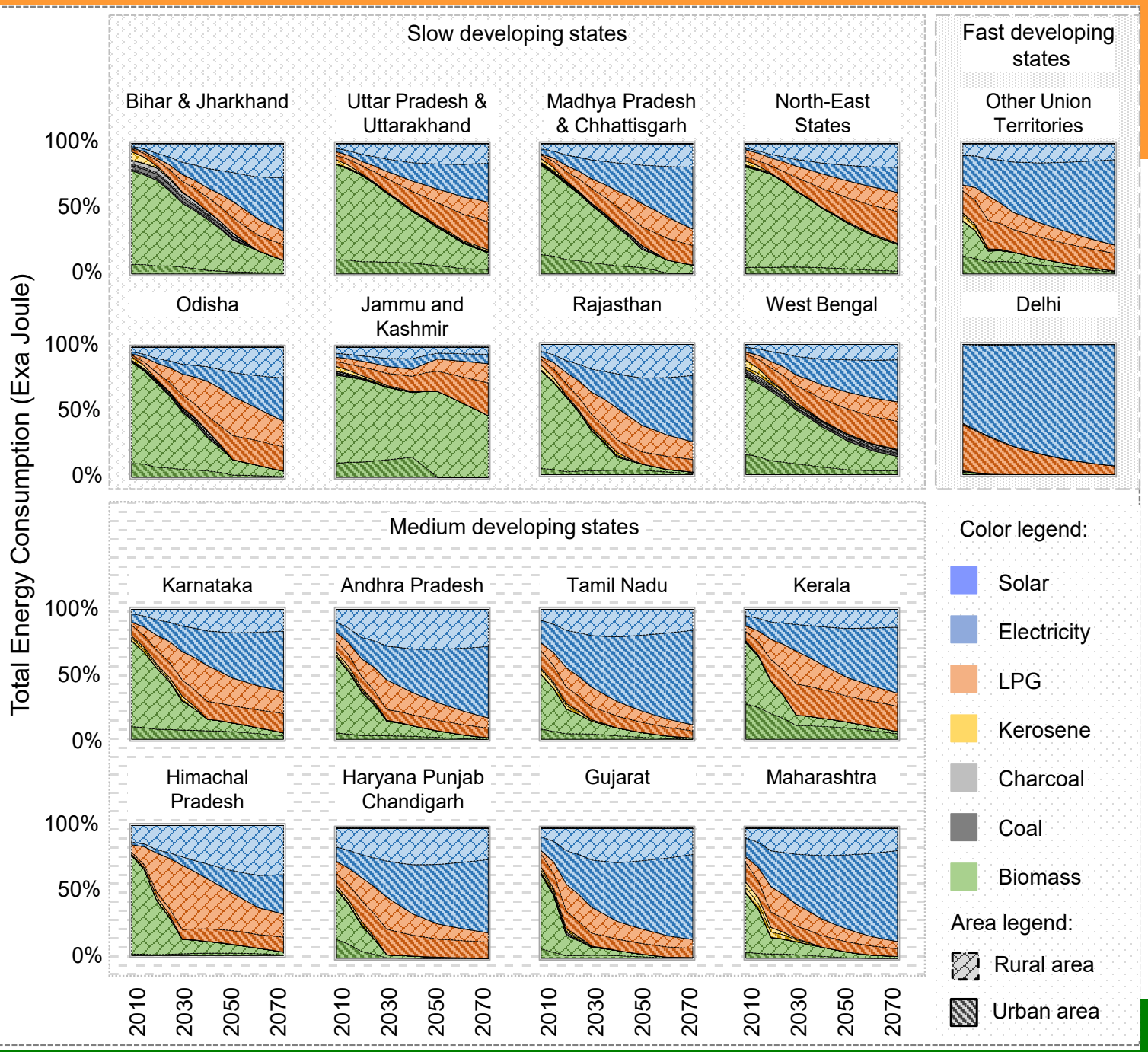
Scenario	Enhancement	Policy Options	Assumptions
Business As Usual (BAU)			The historical trends will be continued. Urban population of India would be 70% in 2070 compared to 33% in 2020.
Advance Fuel Substitution (AFS)	Advance fuel for cooking service Solar device installation at site	Supply of more LPG than demanded Enhance the solar utilization Subsidy on solar water heater, lighting and solar cooker	Enhanced clean & affordable energy. Accelerated use of solar in the residential sector. Energy access of advance fuel increases
Low Carbon Electrification (LCE)	Electricity from Renewable sources Advance fuel for cooking service	GOI plans to implement 40% of electricity from renewable source Enhancing solar utilization	Target 40% of renewable electricity by 2030 and continue till 2070.
CArbon Neutrality (CAN)	Integrate all enhancements together	Renewable electricity in India. (2030-39%; 2050-50% and 2070-70%). Household level Solar deployment	All the measures taken in advance fuel substitution and low carbon electrification are integrated. In addition, energy use in cooking service will majorly change.

Energy Consumption Trend



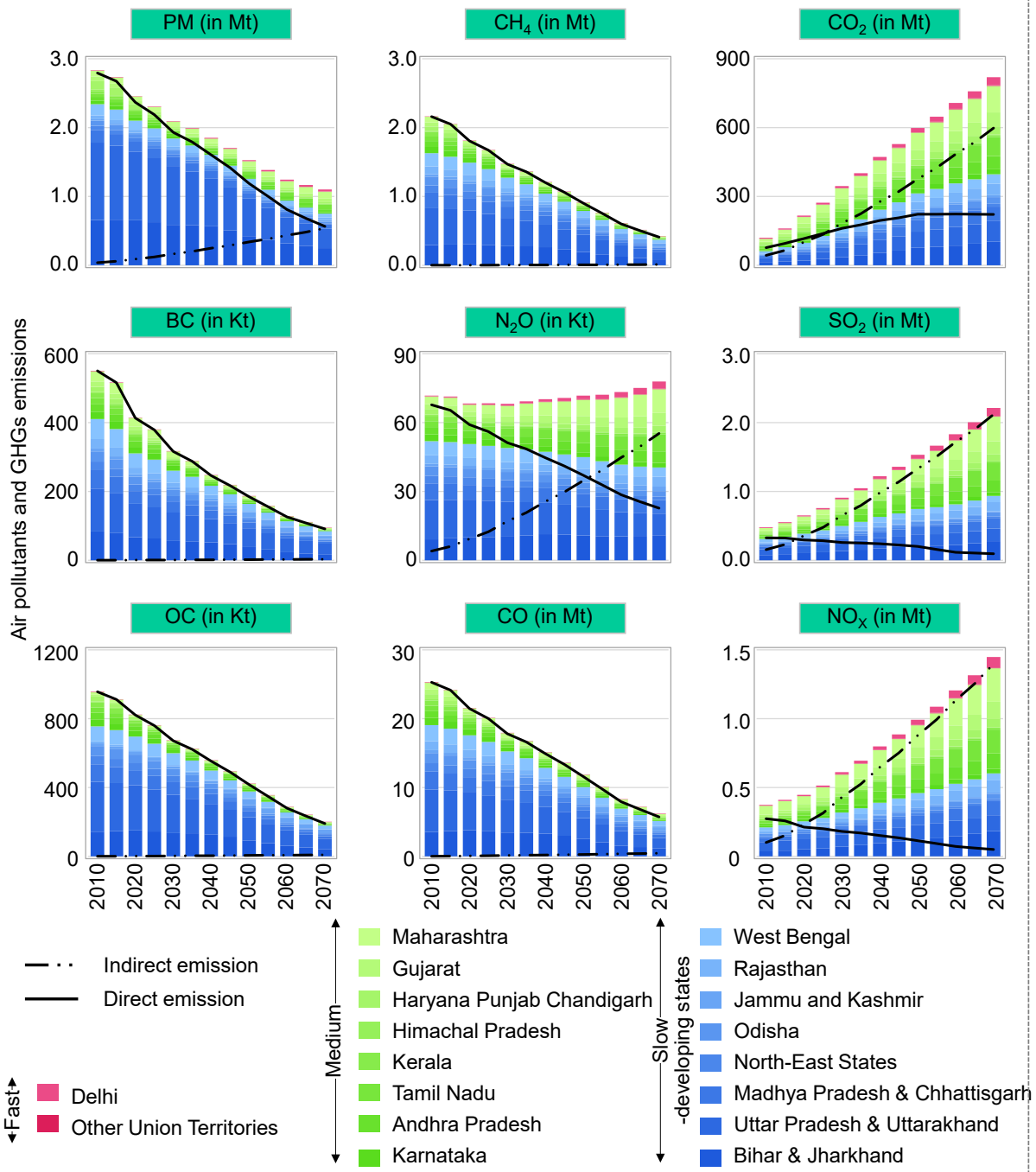
- REC will double in next half century.
- Consumption of biomass sharply decreases both in rural and urban areas.
- Consumption of electricity sharply increases due to lifestyle changes
- Kerosene will disappear from the residential sector.

State-wise Energy Consumption



- Based on per-capita GDP, we categorized Indian states among slow, medium and fast developing.
- 69% of the total energy is consumed in slow-developing states.
- Regional Diversity, Energy Disparity and Energy Access can be depicted.

State-wise Air Pollutants and GHGs



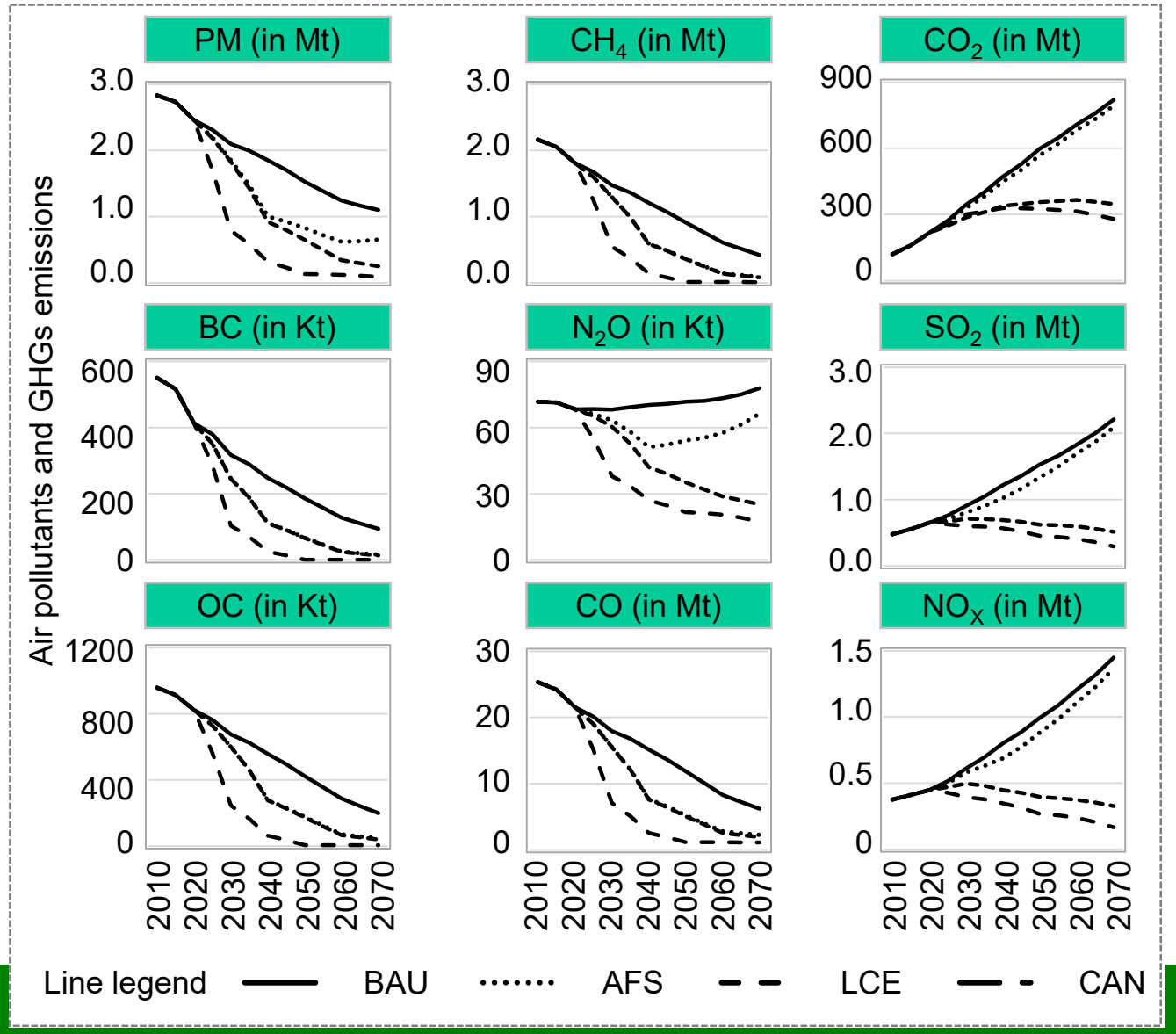
- Direct emissions (PM, BC, OC CH_4) decrease due to decrease in the consumption of Biomass.
- Indirect emissions (CO_2, NO_2, SO_2) increase due to increase in Electricity consumption.

Emission Trends in Mitigation Scenarios

- Mitigation scenarios
  - BAU-Business-as-usual
  - AFS-Advanced fuel substitution
  - LCE-Low carbon electrification
  - CAN-Carbon neutrality

- Substantial reduction in air pollutants is seen in mitigation scenarios.

- SO_2, NO_X, N_2O decreases by 90% in the CAN scenario.



Major Findings and Conclusions

- Detailing of Indian situation in regions and sub-regions is of utmost importance as common solutions may not be suitable for all the states.
- Rural areas of slow developing states consume up to six times more energy for cooking in comparison to the developed urban areas whereas the situation is opposite for electricity use the for household appliances
- There is a clear delink between local and global emissions in terms of mitigation actions.
- In some cases efforts of mitigating local pollution (a priority for government) may result in increasing GHG emissions.
- GHG emission mitigation has co-benefits which are different for urban and rural areas and for slow, medium and fast developing states.
- Provisioning of advance energy solutions in rural areas along with focus on renewable (solar and biomass) may help in reducing the gap and energy poverty in rural areas.

Thank you...

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