More with less: Insights about residential energy demand from PIER (1.5)

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Introduction

Residential energy

- Aspirations and quality of life
- Universal electrification
- Ujjwala
- Changing weather patterns

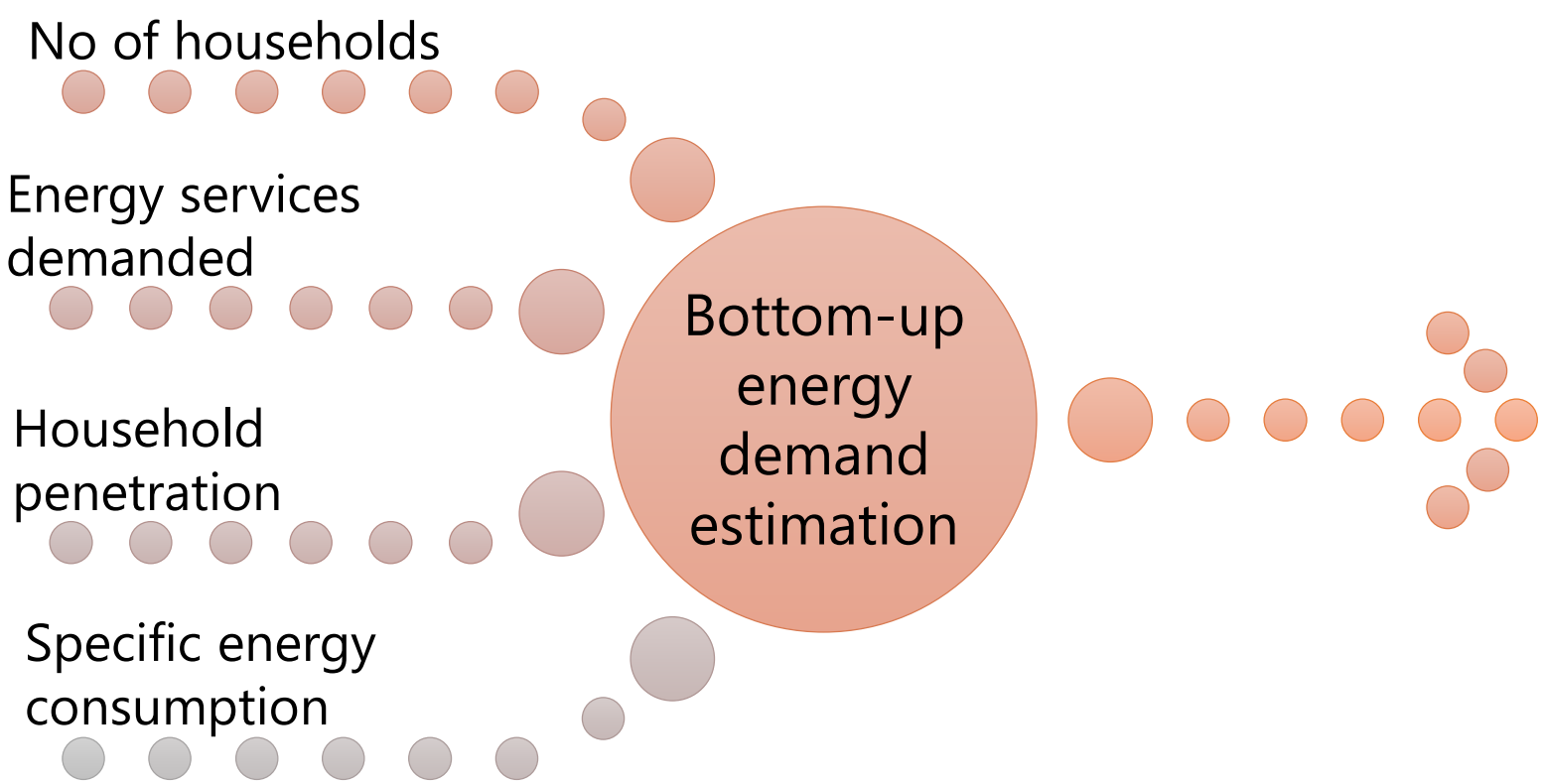
PIER

- Open-data model
- Built on open-source Rumi
- Detailed bottom-up model
- Disaggregated
- Useful policy inputs

Overview

- Model set-up
- Model results
- Interesting insights
- Presenting only national level results

Bottom-up residential energy modelling in PIER



- Electricity and cooking fuels modelled
- Time period:
  - FY 2024 – FY 2041
  - 5 seasons per year
  - 24 hours per typical day
- State level disaggregation

Residential energy services

- Bottom-up modelled energy services

Energy service	Technologies	Energy service demanded	Remarks
Lighting	LED, CFL, incandescent	Few hours in the evening + an hour in monsoon/winter mornings	All HHs use electric lighting
Space cooling	Fans, ACs, coolers	Based on temperature projections and 'trigger temperature'	• 3-star fans • 3-, 4-, 5-star ACs
Refrigeration	Direct Cool, Frost Free	Runs throughout the year	2-, 3-, 4- star for both DC and FF
Cooking	Biomass, LPG, PNG, electricity, biogas	Based on useful heat requirement per-capita and household size	
Televisions	Flat-screen only	Six hours a day as assumed in BEE regulations	3-star TVs

- Energy demand from other services (washing machines, water heaters etc.) estimated exogenously based on calibration against FY21 data
  - Bottom-up modelled services account for ~80% of electricity demand

Household penetration and Specific Energy Consumption

- Each state split into urban and rural households
  - So 50 types of households (25 states with urban-rural) modelled
- Appliance penetrations for each household type
  - Projected from NFHS-5 penetrations based on elasticity of penetration to per-capita GSDP between NFHS-4 and NFHS-5
  - Extreme values adjusted

- Specific Energy Consumption (SEC) of new appliances with mandatory efficiency standards (AC, refrigerator, TV, fan) based on trajectory of BEE notifications
- SEC of appliance stock = weighted average of SEC of new appliances and existing appliances for each household type

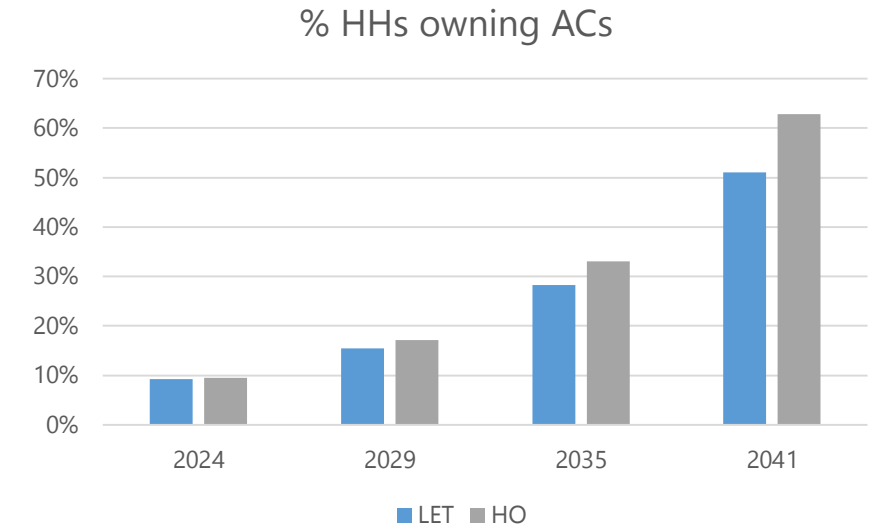
Scenarios modelled

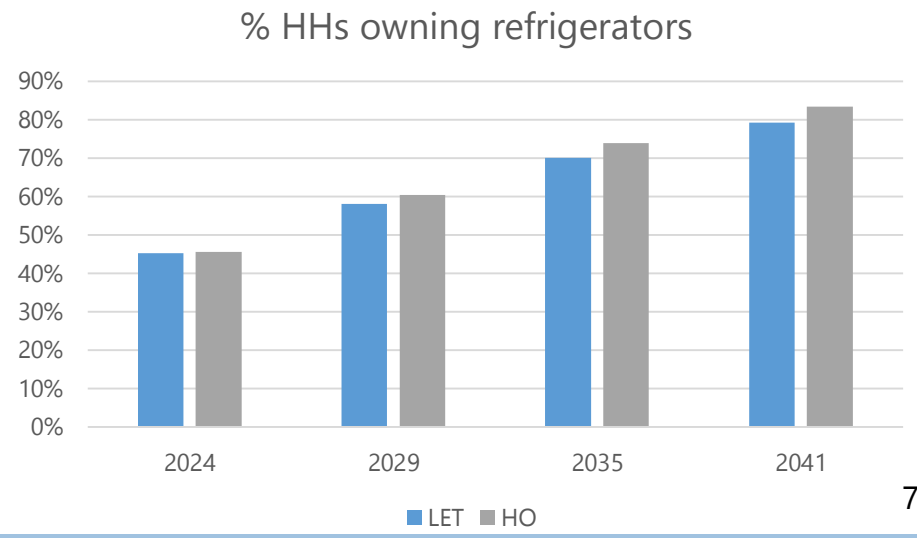
- Based on varying the 3 most critical parameters
  - SEC, appliance ownership, and usage

Scenario	SEC	Ownership	Usage
Likely Efficiency Trend (LET)	• Efficiency standards revised every 4 years for all appliances except fans (6 years) • 'Actual' appliance efficiency 60% of notified • Gradual shift to higher star-rated appliances	Standard	Standard
Desired Efficiency Trend (DET)	• All efficiency standards revised once in four years • 'Actual' appliance efficiency 80% of notified • Faster shift to higher star-rated appliances	Standard	Standard
High Ownership (HO)	Similar to Likely Efficiency Trend	Greater uptake of appliances	Standard
High Usage (HU)	Similar to Likely Efficiency Trend	Standard	Cooling appliances used 2°C earlier
High Consumption (HC)	Similar to Likely Efficiency Trend	Same as High Ownership	Same as High Usage

Significant ‘welfare’ increase by FY2041

- All HHs own fans, almost all own TVs by FY2041 in all cases
- AC penetration ↑ from ~9% in FY24 to
  - 51%-63% in FY2041 across scenarios
  - 12.1% CAGR in normal case (LET)
  - Rural ↑ from 2.4% to 34%-49%
- Refrigerator penetration
  - 79%-83% in FY2041 across scenarios





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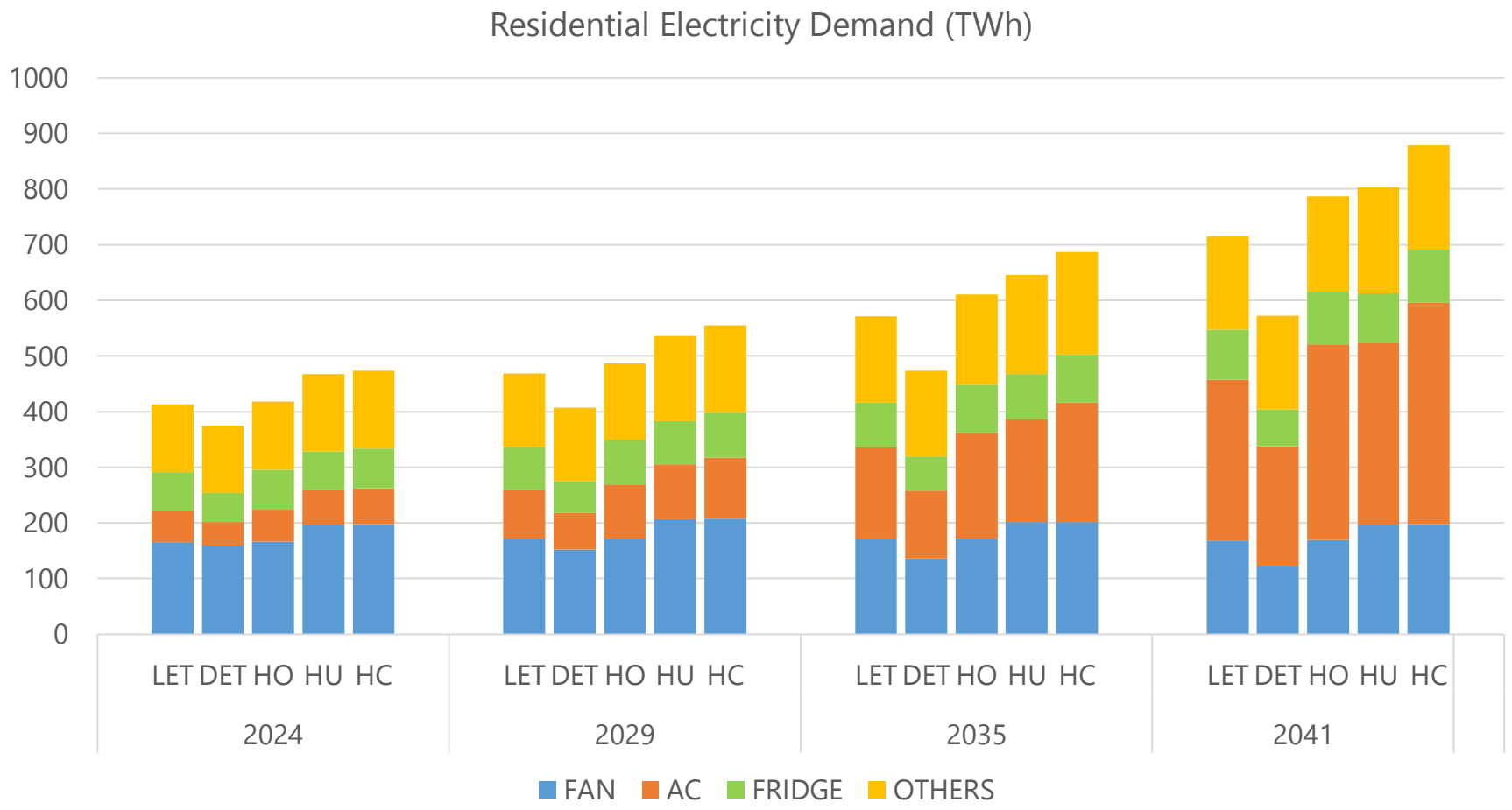
Model results #1: Electricity demand across scenarios



- DET < LET < HC
- FY2024: 375 – 413 - 473 BU
- FY2041: 572 – 715 – 878 BU
- Fan, AC, fridge share > 67%, ↑ over time

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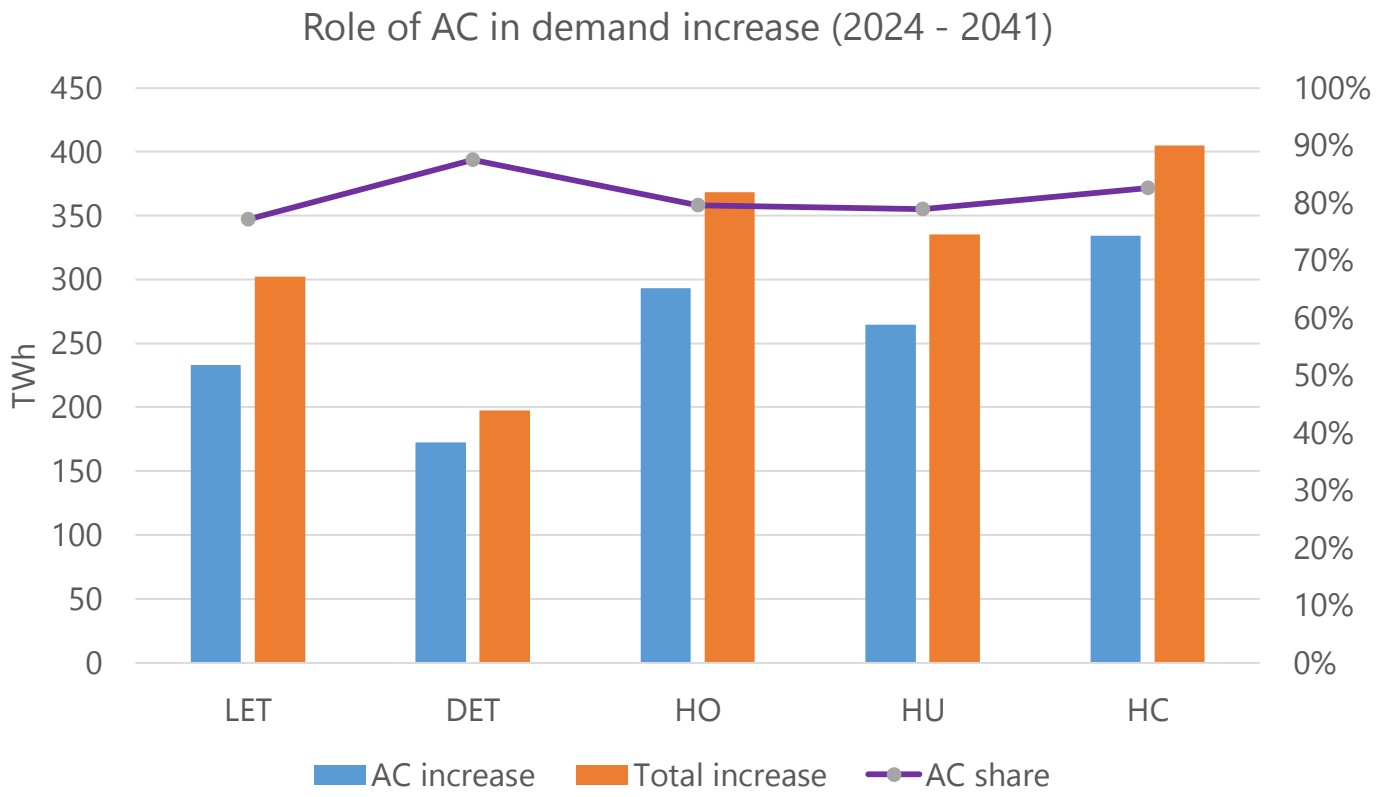
Model results #2: Role of space cooling and ACs

- Space cooling contributes to ~60-70% of residential electricity demand
- ACs contribute to 77% - 88% of the total demand increase across the years



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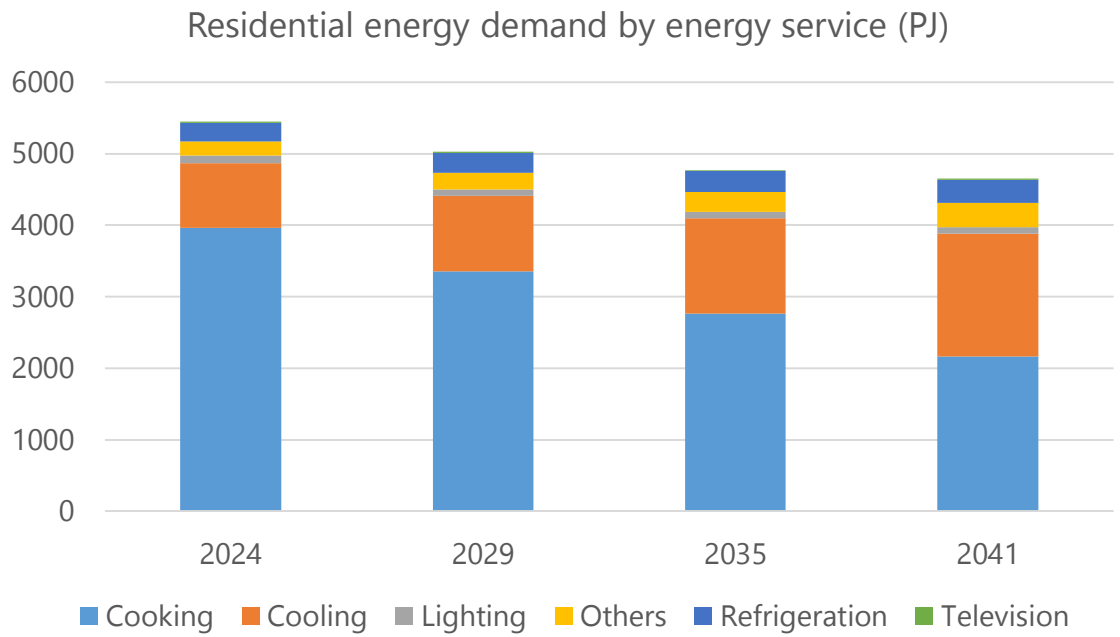
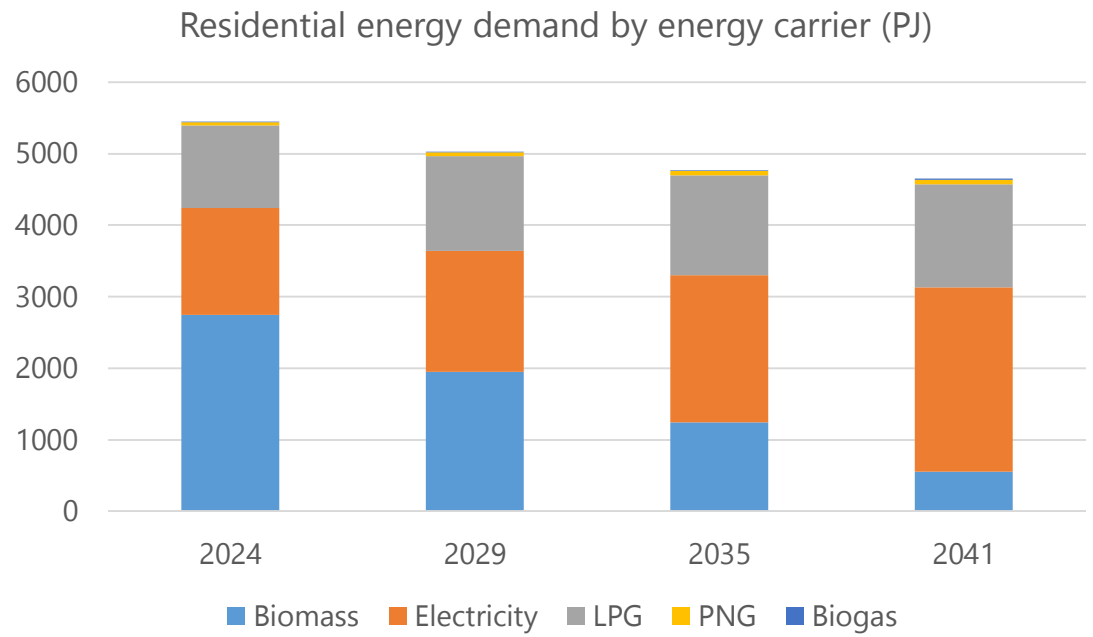
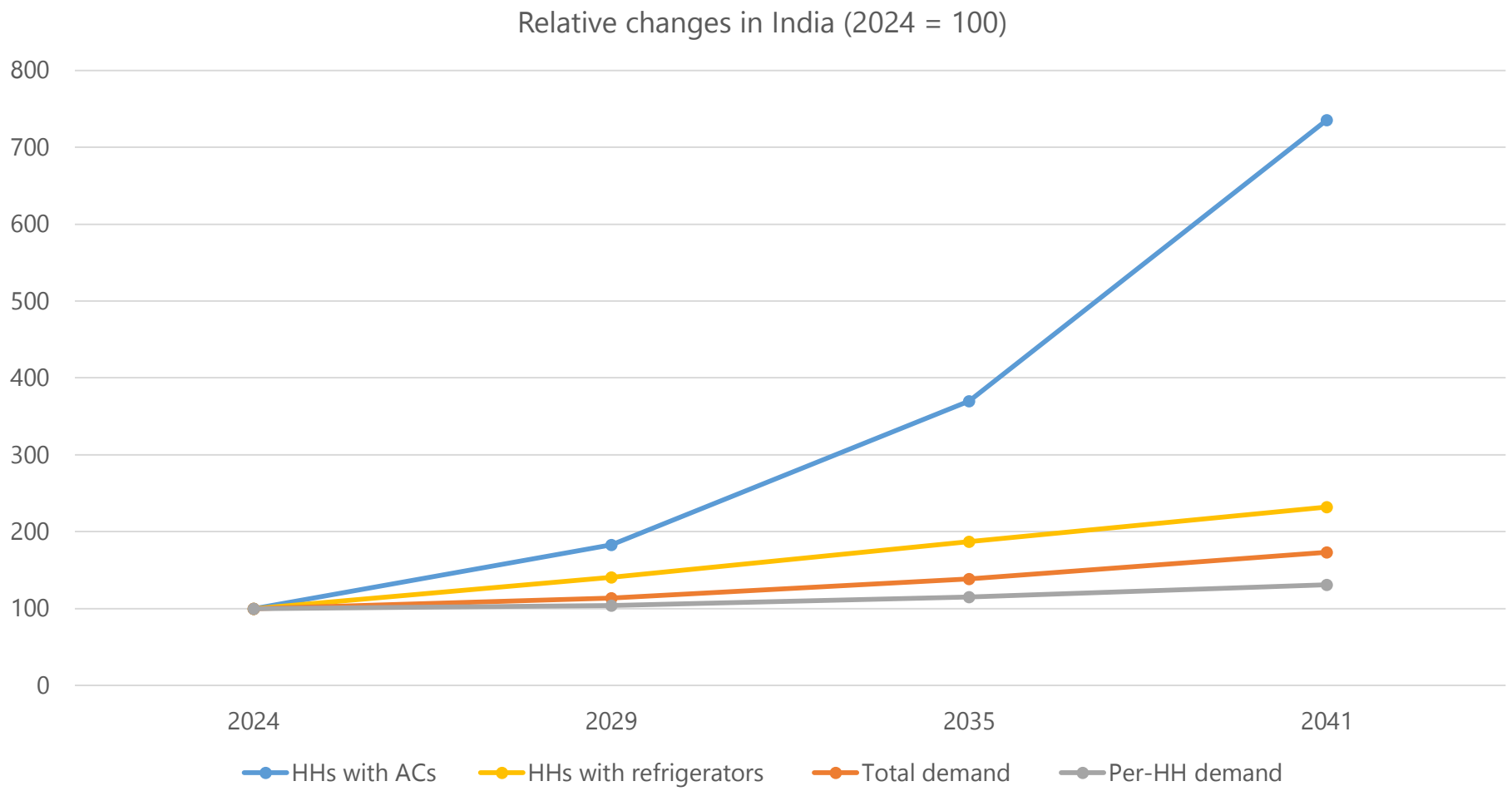
Model results #3: Total residential energy demand





- Cooking is the energy service that consumes the most energy inside HHs
- Total demand *decreases* over the years (~5450 PJ to ~4650 PJ in LET)
  - Due to huge efficiency gains from moving away from biomass cooking
- Share of biomass ↓ and share of electricity ↑

Insight #1: Increased appliance use ≠ increased electricity demand



- 7.4x ↑ in HHs with ACs
- 2.3x ↑ in HHs with fridges

- ~73% ↑ in total demand
- ~31% ↑ in per-HH demand

Demand estimation purely based on past trends is risky

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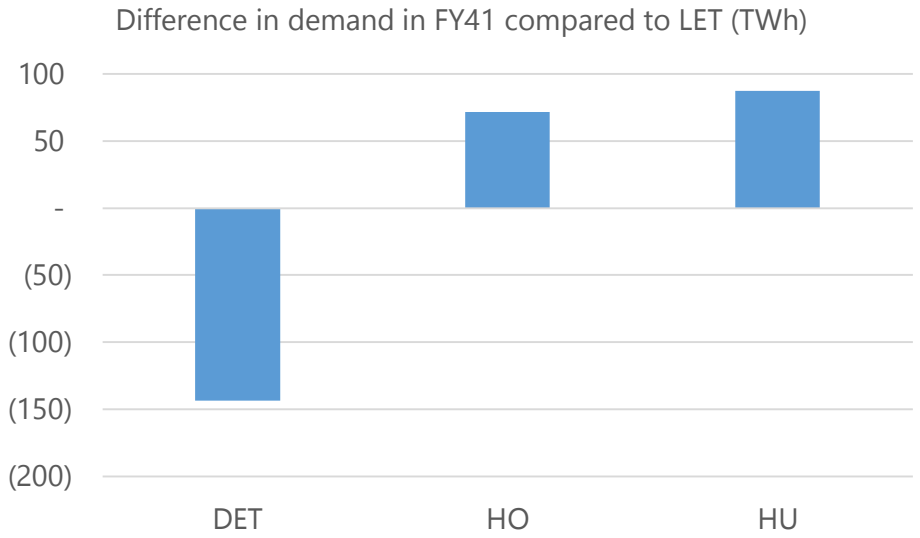
Insight #2: Energy efficiency major determinant of electricity demand

- CAGR of demand "only" 3.3% in LET scenario between FY2024 and FY2041
  - AC electricity demand CAGR > 10%
- In DET scenario , CAGR of demand is just 2.5%
- Indeed only 3.7% even in the High Consumption scenario

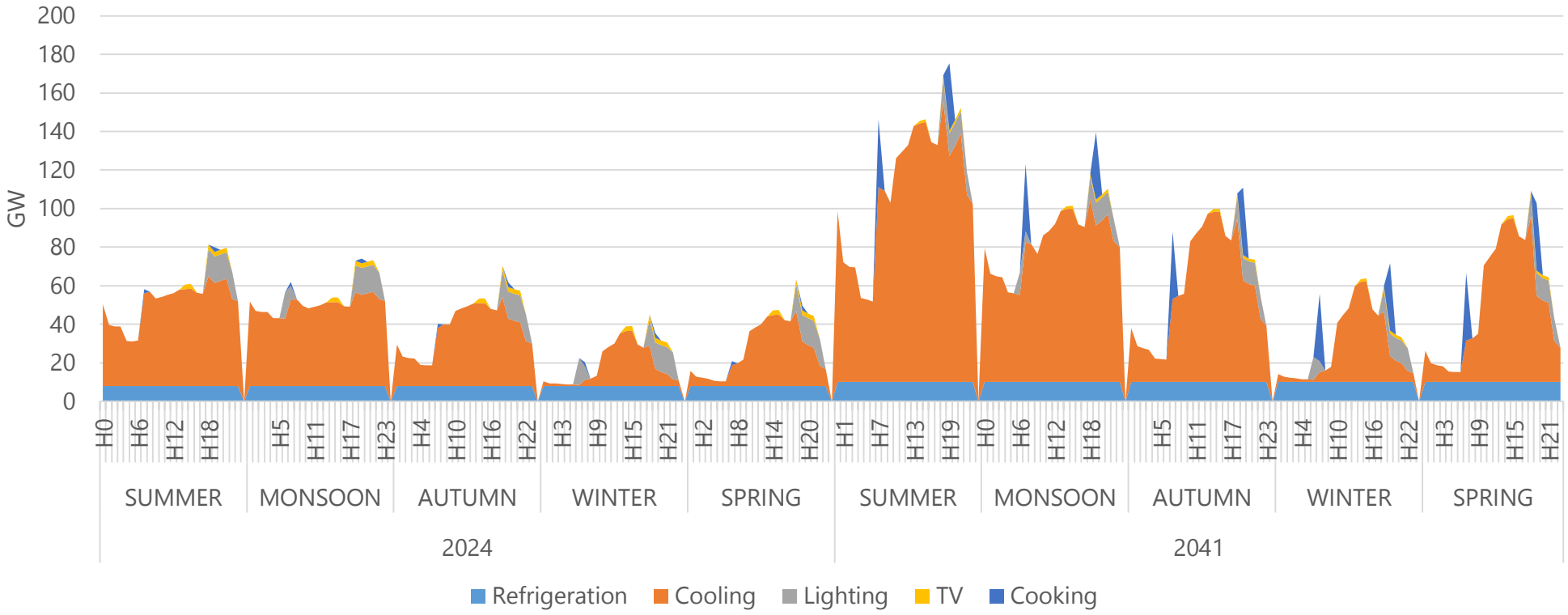


Efficiency the biggest determinant of demand compared to ownership or usage

An effective energy efficiency regime can play a vital role

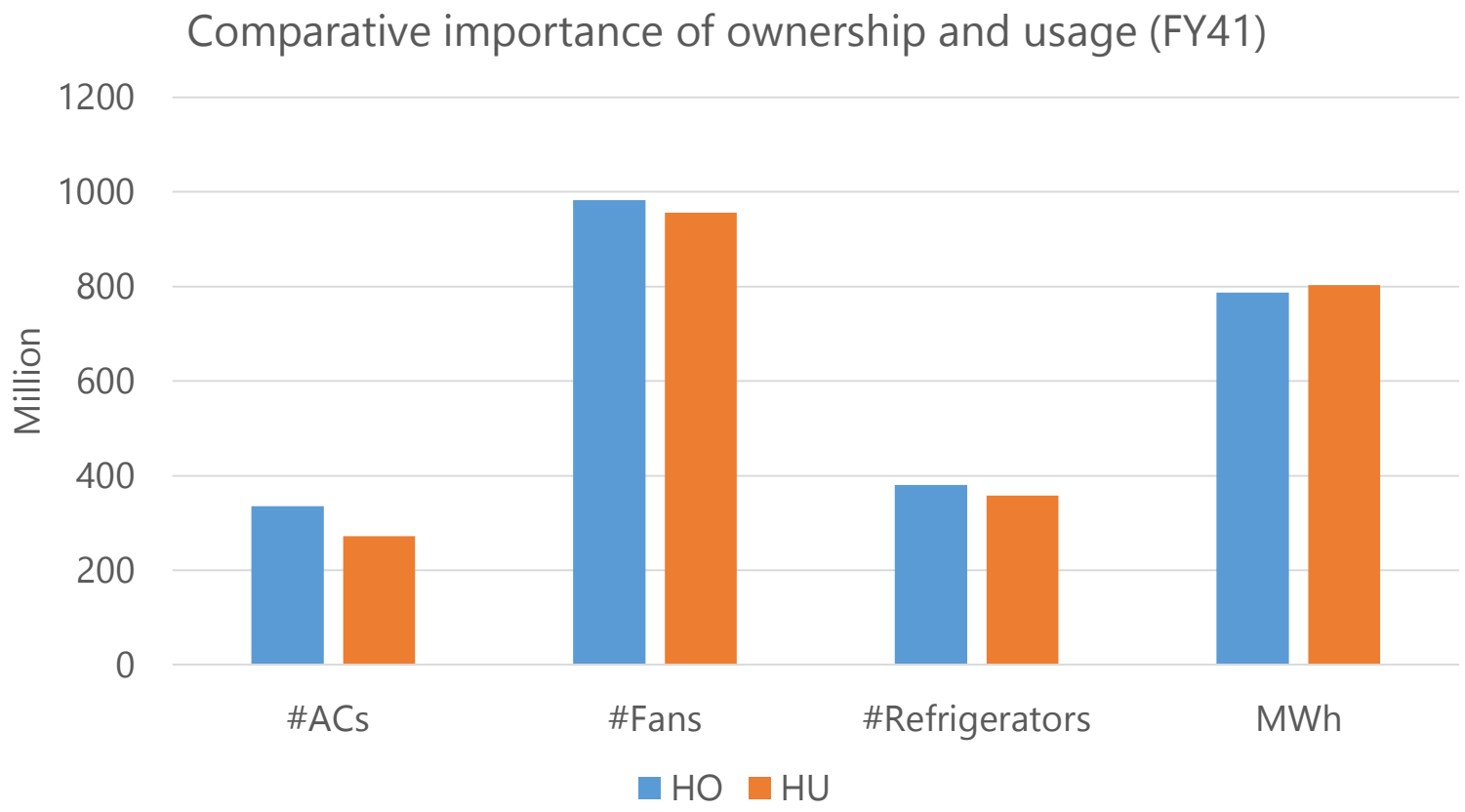
Insight #3: Residential load shapes will get peakier

- Peak load of bottom-up modelled services more than doubles from 81 GW to 175 GW
- Summer evening peak driven by ACs (and induction cooking)



Importance of power procurement, network planning and DSM strategies

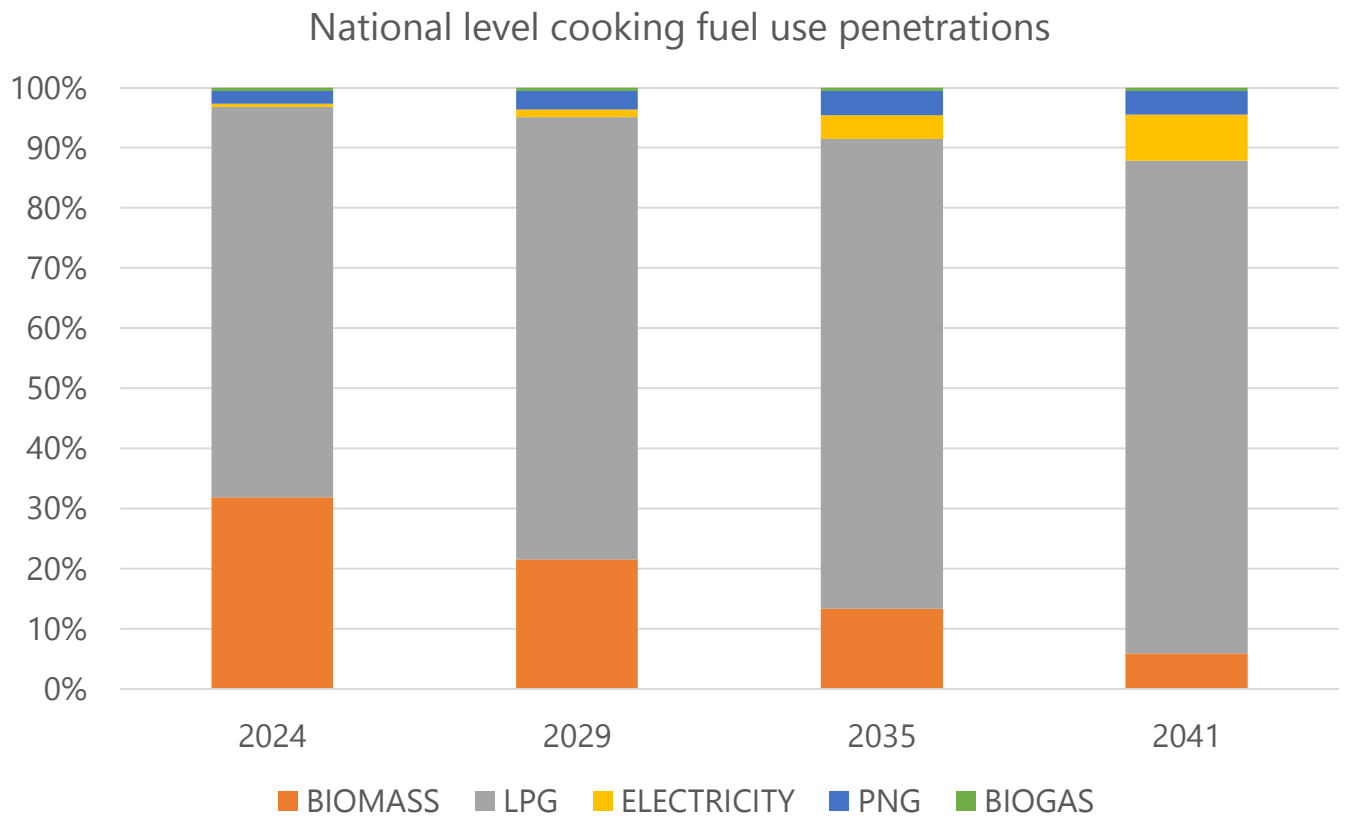
Insight #4: Behaviour > ownership as demand determinant



- ~60 million more ACs, ~25 million more fans and refrigerators in FY41 in HO
- But HU demand marginally higher than HO

Policies targeting behaviour can be a useful lever to manage demand

Insight #5: Cooking energy



- Clean cooking use ↑ from 68% in FY24 to 94% in FY41 in LET
- LPG use penetration ↑ from 65% to 82%
- Induction-based electricity has fastest growth: 0.5% to 7.6%

- 27 million HHs still use solid fuels even in FY41
  - Rural areas of 7 states

Good progress, but need for targeted interventions to improve clean cooking use

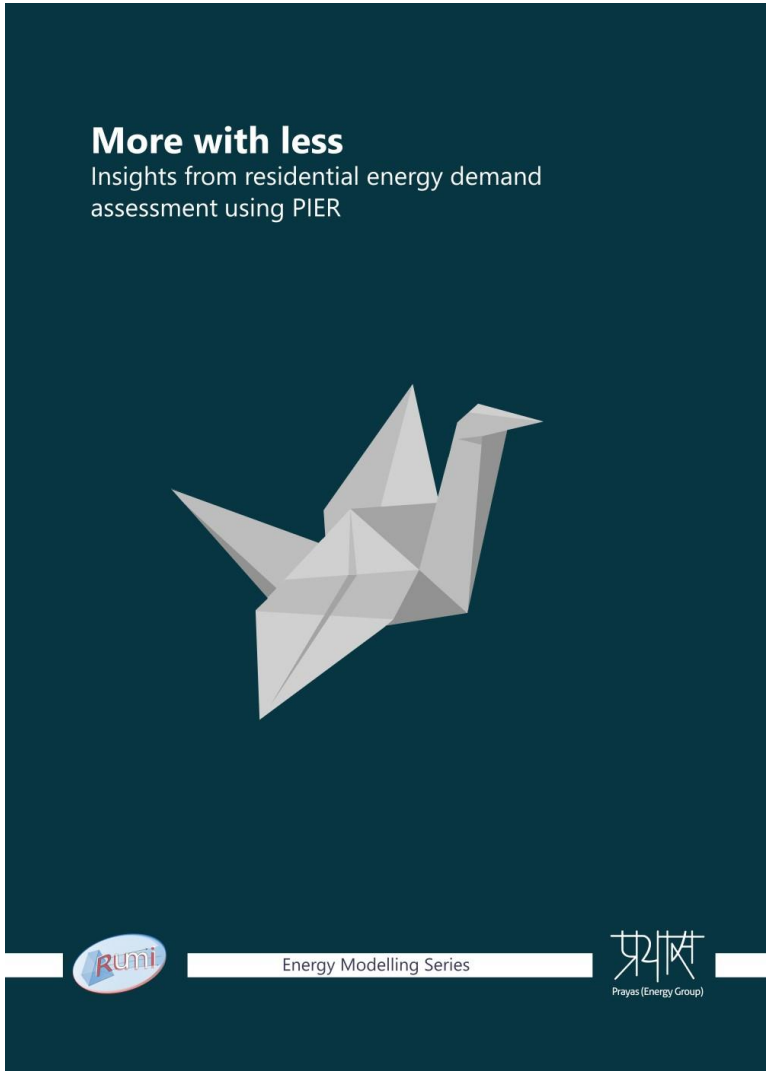
Conclusions

Useful policy insights about

- Demand estimation
- Role of efficiency
- Role of behaviour
- Peak load and clean cooking use challenges

Next steps with PIER

- Bottom-up modelling of transport and industry
- Improved time and geographic disaggregation
- Newer temperature projections
- Newer technologies



Thank You!

https://energy.prayaspune.org/our-work/research-report/more-with-less