Residential End Use Energy Consumption and Appliance Ownership Patterns in India

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Accelerating our transition to a more sustainable world

Mission to improve the energy and environmental performance of appliances and equipment we use every day, accelerating our transition to a more sustainable world
Where We Work

- National
- Regional
- National & Regional
A holistic approach to appliance energy efficiency programs

**Raise Energy Efficiency Standards**
- Market monitoring
- Standards development
- Benchmarking
- Phase out inefficient products

**Assess impacts and improve outcomes**
- Certification, monitoring, verification and enforcement
- Build test laboratory capacity

**Promote Efficient Products**
- Labeling
- Awards programs
- Financial incentives
- Influence consumer behavior

**Improve Compliance and Enforcement**
Sector Wise Electricity Consumption in India

Sector-wise Consumption of Electricity (2016)

- Industry: 39%
- Residential: 24%
- Agriculture: 19%
- Commercial: 10%
- Others: 6%
- Traction & Railways: 2%

Residential electricity consumption is projected to grow eight fold by 2050

(Source: Energy Statistics 2012, Central Statistics Office, MOSPI)
Need for reliable appliance energy use information

1. Increase in appliance purchase and use, leading to rising residential electricity consumption
2. Increase in number of domestic appliances under S&L program in the next 5 years
3. Absence of end-use baseline data to assess impacts of current and new S&L programs
4. Energy savings calculations are based solely on declared efficiencies of appliances
5. Appliance energy use, hours of use and use patterns are also based on assumptions
Residential End Use Study

- Samples represented various social, economic, cultural and climatic context across 21 cities
- First of its kind study with objectives to
  - Gather information on demographic characteristics
  - Ownership and usage pattern of appliances
  - Variation in energy consumption across various climate zones and socio-economic strata
  - Appliance purchase, technological and behavioural patterns
  - Data on the appliance inventory and age
A 3-Tier Approach – From National to Circuit level

1. Establish nation wide pattern of ownership and usage.
2. Develop sampling method.
3. User behavioral aspects
   1. Actual energy use.
   2. Representative of the national pattern.
   3. NILM for disaggregating major end-use.

1. Circuit level monitoring for spaces/end uses
2. Calibration and verification
Approach and Methodology

PHASE 1: Household survey

1. Secondary Research
2. Questionnaire Design and Sampling Plan
3. Survey and Analysis

PHASE 2: End Use monitoring

4. Households selection

PHASE 3: Data processing and analysis

5. Monitoring Infrastructure Deployment
6. Data Compilation over Cloud
7. Real-time End Use Monitoring
8. Applying NILM to Collected Datasets
9. Data Validation and Analysis
Sample distribution across 21 cities

- Climate Zone
  - Hot-Dry
  - Warm-Humid
  - Temperate
  - Composite
  - Cold

- Urban Agglomeration
  - Metropolitan cities
  - Non-metropolitan cities (Other million-plus cities)

- Socio-Economic Classification
  - High Income
    (SEC A1, A2, A3, B1)
  - Medium Income
    (SEC B2, C1, C2)
  - Low Income
    (SEC D1, D2, E1, E2, E3)

5,242 Household
(Representative Urban Sample)
Pan India Survey Findings
Appliance Ownership and Usage Pattern

Ownership (in %)
- Gas-Stove
- Cellphone-Charger
- Ceiling-Fans
- Television
- Set-Top-Box
- Refrigerator
- CFLs
- TFLs
- Mixer-Grinder
- Electric Iron
- Washing Machine
- Pump
- Desert Cooler
- Water-Purifier
- Air-Conditioner
- Voltage-Stabilizer
- Storage Water Heater
- Exhaust-Fan
- LEDs
- Inverter
- Laptops
- Microwave-Oven
- Incandescent
- Fans-Other
- Induction-Plate
- Electric-Chimney
- Music System
- Toaster
- Desktop-PC
- Routers
- Room-Heater
- Immersion-Rod
- Electric-Cooker
- Entertainment-System
- Electric-Kettle
- Vacuum-Cleaner
- Printer/Scanner
- Oven-Other
- Diesel-Genset
- Dish-Washer

Usage (in hours)
- 0% 25% 50% 75% 100%
- 2,000 4,000 6,000 8,000
<table>
<thead>
<tr>
<th>Appliance Ownership and Usage Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Home Appliances</strong></td>
</tr>
<tr>
<td>Family Size</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>No major impact</td>
</tr>
<tr>
<td><strong>Heating/Cooling</strong></td>
</tr>
<tr>
<td>Ownership increases with family size</td>
</tr>
<tr>
<td><strong>Lighting Products</strong></td>
</tr>
<tr>
<td>No significant impact</td>
</tr>
</tbody>
</table>
Energy Consumption Variation

Family size
- Increases with increase in family size
- Highest in summers across climatic zones

Socio Economic Strata
- Increases with increase in family income
- Highest in summers

Climatic Zone
- Composite and warm-humid consume highest energy in summers
- Cold climate has highest energy consumption in winters
Residential End Use Metering Results
Smart Meter Deployment across India
Installation of Metering and Monitoring Devices
Data Processing and Analysis

- Data processed and analysed using MySQL database and NILM algorithm, respectively.
- The real-time energy use data for all monitored households was collated on a cloud server.
- Includes electricity consumption, voltage, current, power factor and frequency at 30 seconds interval.
- This data was analysed using NILM algorithms to provide detailed analysis of usage and operation of appliances.
- The NILM algorithms distinguish appliance use and operation by mapping the load signature from trained datasets onto monitored data.
- Results of monitoring and survey uploaded on a dashboard www.neemdashboard.in
## Variation in energy use with seasons for AC and non AC households

<table>
<thead>
<tr>
<th>Category</th>
<th>Family Type</th>
<th>Household Size</th>
<th>Climatic Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC household</td>
<td>-Joint family had highest energy consumption throughout the year</td>
<td>-Energy consumption increases significantly with increase in the size of household</td>
<td>-Composite zone consumes highest energy consumption</td>
</tr>
<tr>
<td></td>
<td>-Nuclear with elders had high energy consumption in monsoon and winters.</td>
<td>-The variation peaks in summers.</td>
<td>-Temperate zone consumes lowest.</td>
</tr>
<tr>
<td>Non AC household</td>
<td>-Energy consumption increased with increase in family size.</td>
<td>-Energy consumption increases marginally with increase in household size.</td>
<td>-Composite zone had highest energy consumption throughout the year</td>
</tr>
<tr>
<td></td>
<td>-Joint family had highest energy consumption throughout the year.</td>
<td></td>
<td>-Particularly peaking in summers and monsoons.</td>
</tr>
</tbody>
</table>
Key Findings

- Energy consumption highest in summers owing to ACs
- Low energy use in winters but high peak demand observed due to water and room heaters
Key Findings

- Energy consumption of AC households higher throughout the year owing to higher socio-economic strata.
- AC households consume at least 50% higher energy as compared to non-AC households during summers.
Key Findings

• Energy consumption higher in summers across socio economic strata, dwelling type and socio climatic zones except cold climate.

• Space and water heating appliances are major contributors towards winter peak demand and summer peak is attributed to space cooling devices.

• Energy consumption increases with increase in family size and socio economic strata.

• Peak demand as well as energy use varies by seasons, climatic zone, socio economic strata and dwelling type.

• These can help in developing targeted demand response strategies.
Conclusions and Way Forward

• Appliance ownership and per capita energy consumption rising
• Deeper insight on appliance ownership and electricity consumption
• Behavioral insights on variations in energy consumption across climatic zones, demographic parameters and socio economic strata
• Data beneficial to academicians, think tanks, policymakers, utilities and consumers

• The data will enable-
  − Formulation of product and region specific strategies and policy interventions
  − Enable estimation of more realistic energy savings
  − Promote better understanding of future electricity demand
  − Enabling research, modelling, better planning and demand side management programs