Electricity demand

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Outline

- Characteristics of electricity demand
  - Income elasticity
  - Price elasticity
- Metering technology
  - Traditional
  - Modern
- Demand side management
  - Energy efficiency
  - Demand response
  - Smart appliances
Drivers of electricity demand

- Electricity is not consumed directly
- It is the result of demand for services provided by energy-using appliances

Main drivers:
1. price of electricity
2. consumers’ income
3. prices and availability of substitutes
4. prices of appliances (complements)
5. changes in economic structure
6. technology
7. changes in energy policy
8. weather
Income elasticity of electricity demand

- If income rises by 1 percent, by how many percentage points does electricity consumption change?
  - If household income increases, how would it affect electricity demand?
  - Do countries with higher GDP consume more? By how much?
Measuring income elasticity

1. Relationship between GDP and total electricity consumption
2. Relationship between household income and electricity consumption

- Results vary, but no significant difference: 0.2-1.1
  - More consumption with higher income, but electricity represents a smaller percentage within expenditures
  - If income elasticity is below 1:
    - More consumption, but with less intensity
    - New appliances are more energy efficient
    - Developed countries consume more services, but with greater energy efficiency

- Income effects of electricity consumption are a result of household appliance choice, rather than utilization behavior
If price rises by 1 percent, by how many percentage points does electricity consumption change?

Limited substitutability
- heating, hot water, cooking/baking
- anything else?

Derived demand of appliances
- consumption often not considered
- valuable service provided by appliance
- limited consumption adjustment possibilities
  - A/C, water heater, washing machine

Price elasticity of demand

Low elasticity
Price response increases over time

- Magnitude of demand response depends on the time available for reaction
  - Short term: changing the use of current appliances
    - e.g. turning down the air conditioner
  - Long term: changing the appliances
    - e.g. buying new appliances and changing the old ones to more energy efficient ones
Price elasticity estimates

- **Tishler 1998 Israel**
- **Tishler 1991 Us**
- **Park and Action 10 studies 1984 US**
- **Hawdon 1992 and before: US 7 studies**
- **Dufty 1980s:US 4 studies**
- **Filippini: Swiss households 1995**

**Business**
- PEAK
- OFF-PEAK

**Residential**

**Energy Cooperation between the EU, the Littoral States of the Black & Caspian Seas and their Neighbouring Countries**
Characteristics of price elasticity

- There is price response: demand for electricity is not vertical, although inelastic
- Elasticity differs for extremely high prices and average prices
- Differs in the case of low and high consumption
- Elasticity is different for price increase and price decrease
- Different for residential and non-residential users
- Different in long and short run
Artificial inelasticity created by fixed retail prices

- Consumers would respond somewhat to price changes, ...
- …if the price changes!
- With fixed retail prices, there is no incentive to cut back on consumption, even if the marginal generation cost is very high.
  - no customer reaction to short and mid-term changes in (wholesale) prices
  - cross-subsidization between peak and off-peak consumers
  - vertical demand curve also transmitted to the wholesale market
  - part of the demand inelasticity is artificial
- Main issue is metering technology
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Metering technology
Traditional meters

- Cumulative recording
- Display in kWh
  - no exact measures of current consumption
- Manual (visual) reading
- Monthly bills based on:
  - self-reporting
  - consumption estimates (payment smoothing possible)
- Infrequent reading by utility
  - 1-2 times a year
  - yearly adjustment bills
More advanced solutions

- Multiple registers for recording consumption on different times of the day
  - or multiple meters
- Retrofitting existing electromechanical meters
  - Prepayment attachment
  - Real-time display attachment
  - Communications attachment
- Electronic versions of the above
Smart metering

- Two-way communication capability
- Real time display of prices
- Automated meter reading
  - via various communication networks
- Automated meter management
  - remote changes in contracted power or price schemes
  - remote disconnection/reconnection
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Demand Side Management (DSM)

- Encouraging consumers to modify their level and pattern of electricity usage
  - planning
  - implementation
  - monitoring

- Two forms
  - Energy efficiency: change in usage level
  - Demand response (DR): change in usage patterns
DSM effects on the load curve

**Energy Efficiency**
- permanent change to demand profile
- demand reduction in all hours
- affects the energy balance

**Demand response**
- short-term changes to demand profile
- might increase consumption in some hours
- affects the power balance
Demand response

- Lower wholesale prices
- CO₂ emission reduction
- Less room for market power abuse
- Fixed retail price demand curve
- Price responsive demand curve
- Supply curve
- Bigger system flexibility and reliability
- Optimal reliability set by consumers
- Lower system costs
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Lower wholesale prices

Bigger system flexibility and reliability

Optimal reliability set by consumers

Lower system costs

ENERGY COOPERATION BETWEEN THE EU, THE LITTORAL STATES OF THE BLACK & CASPIAN SEAS AND THEIR NEIGHBOURING COUNTRIES
Types of demand response

- Incentive-based programs
  - Direct load control
  - Interruptible/curtailable rates
  - Emergency Demand Response
  - Capacity Market Programs
  - Demand Bidding/Buyback Programs

- Price-based programs
  - Time-of-Use Rates
  - Real-Time Pricing
  - Critical Peak Pricing
Incentive-based DR programs

- Contractual agreement between consumer and organizer
- Voluntary sign-up, obligation afterwards
- Payments for consumption reduction independent from the retail tariff
- Possible penalty for non-compliance
- Pre-agreed size and manner of demand reduction
- Curtailment execution by
  - program organizer (TSO/DSO)
  - consumer
- Program event definitions differ
  - every day in peak hours, high wholesale prices, system emergency events, etc
Price-based DR programs

- Consumer response is triggered by price changes that reflect variations in the underlying costs of electricity generation
- Alternative to conventional flat rates
- Enable users to reduce their electricity bills by shifting their consumption to cheaper time periods
- Actual demand response depends solely on the economic decision of the consumer
- Always voluntary
- Program types differ mainly in the frequency and predictivity of price changes
Potential Peak Load Reduction

U.S. peak load: ~750-800 GW

Source: FERC (2008)
New paradigm of flexible electricity demand
Which appliances to manage?

Typical load profile of selected household appliances

Source: Smart-A project (2009)
Assessment of the appliances

- Assessment factors
  - Total energy volume that can be shifted
  - Maximum duration of possible load shift
  - Availability
  - Consumer acceptance
- Most interesting are the already involved electric storage heating and water heaters
  - smarter management in the future
- Dishwashers
  - Low availability, could be compensated by large numbers of appliances
- Cold appliances
  - High availability, consumer acceptance, could be controlled fully automatically, but load per appliance is quite low, as well as maximum duration (15 min)
- Washing machines and dryers
  - Main problem is consumer inconvenience, combined washer-dryers could be a solution
Consumer survey on acceptance

- High general acceptance of smart appliances
- Consumers expect a perceptible economic benefit, extra investments costs up to 25$ are accepted
- Consumers are not willing to change their daily routine
- Consumers want to be able to retain full control over the appliance
- Consumers tend to be sceptical about the technical reliability – washing machines
- If the technology can be shown to be saved, and the appliance shows additional safety and comfort features consumers tend to accept even slightly higher costs
- Consumers are not too concerned about data protection

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Source: Smart-A project (2009)
Cost-benefit analysis (for 2025)

Costs

- Higher costs of appliance
  - Communication module €1.7 - €3.3
  - Additional electricity costs due to standby consumption
    - Increases the electricity consumption by 0.1% - 2%
    - Leads to additional costs: €0.02 – €1.1
- For comparability these costs were related to the unit of 1 kW of controllable load which is available throughout the year (considering patterns of operation)

Benefits

- Reduction of costs for the operation of the power system from an overall economic perspective
- Cheaper wind power integration into the system
- Reduction of fossil fuel consumption, by replacing part-loaded fossil fuel plants operating as reserves
- Reduction of CO2 allowances
Costs and benefits

Source: Smart-A project (2009)