

Evaluation and modelling of demand and generation at distribution level for Smart grid implementation

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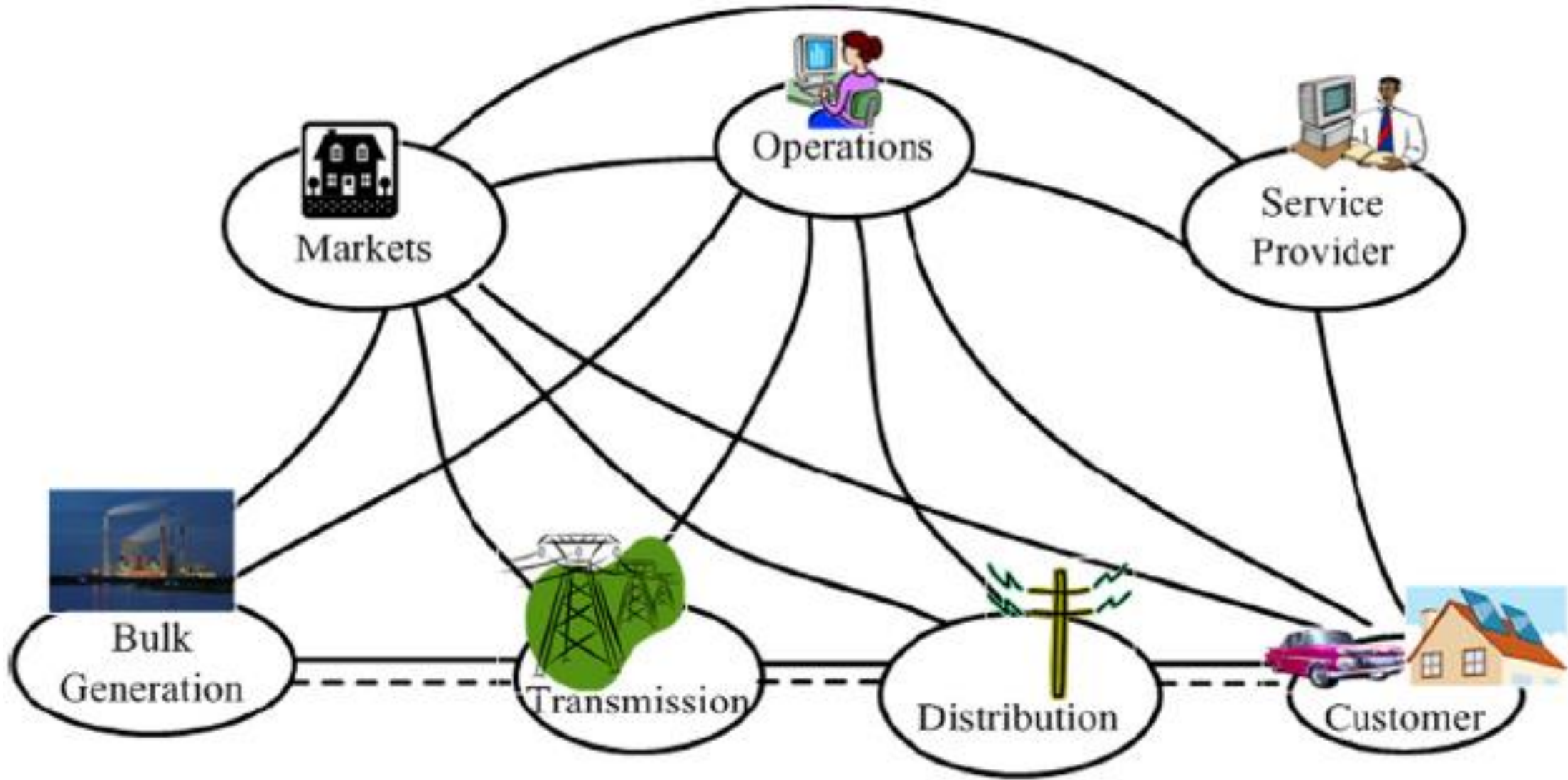
Group Expertise / Areas

- Modelling and simulation of power systems
- Artificial intelligence and heuristic optimization techniques
- Smart grid distribution technology
- Embedded Renewable Energy generation & embedded storage
- Electric vehicles integration into grid
- Wireless communication networks for smart grids
- Security in Smart grids
- Pricing strategies in deregulated energy markets
- Demand side management and demand response
- Energy policy

Structure

- Background
- Development of models
- Targeted interventions
- Pricing issue
- Development of a criteria
- Local demand under pricing schemes
- Key points

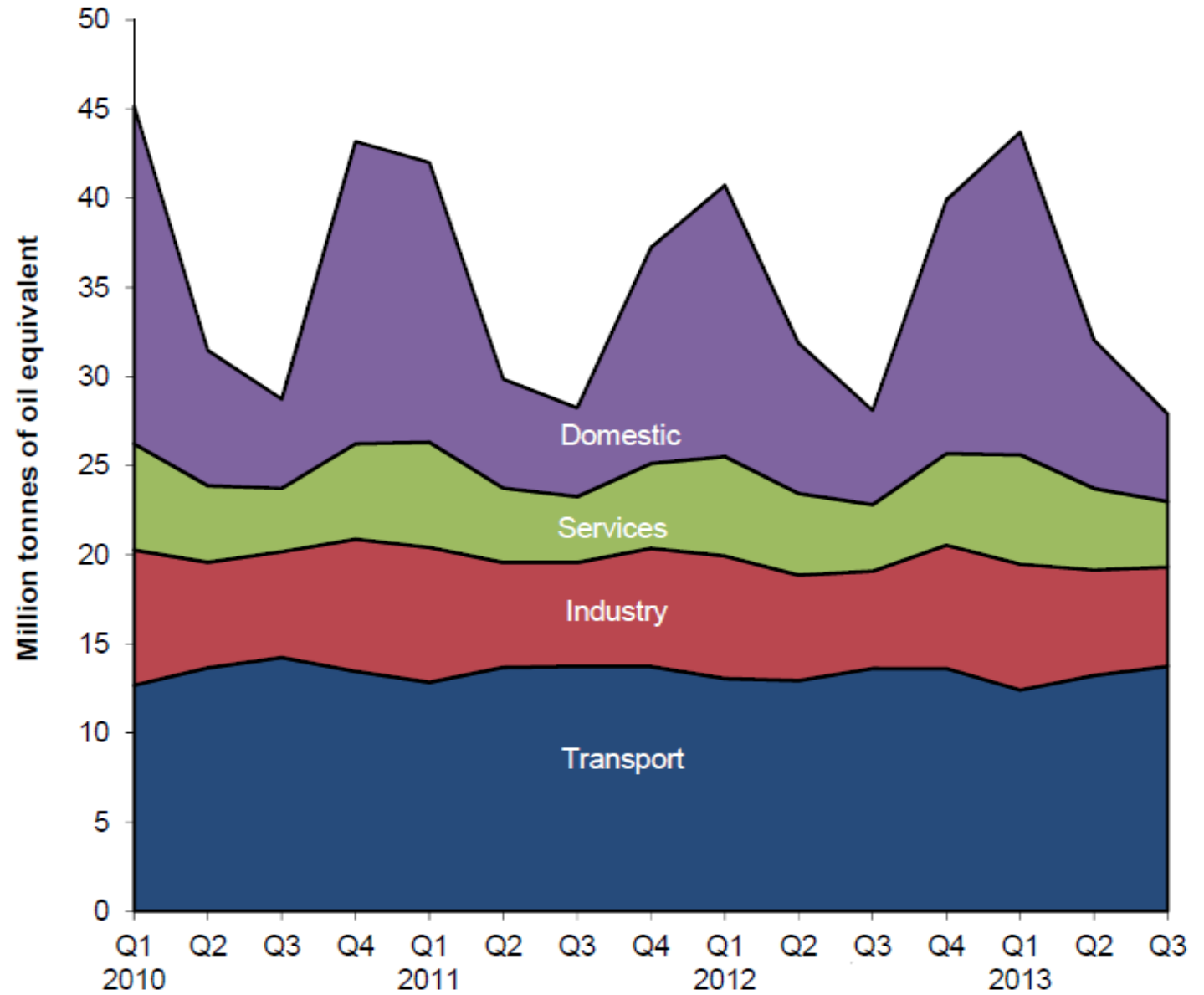
The Smart Grid



Why is there interest in distribution side?

- Deregulation of the industry – move away from single central planning unit
- Energy Security – spreading supply
- Approaches for CO2 emissions reduction targets
- Rising cost of fossil fuels – makes some of the other options feasible – renewables
- Technology developments – SMART Grid, affordable local generation options, advanced control electronics, market mechanisms
- Private investment

UK Energy consumption over time (DECC)



Distribution side aspects

- Embedding renewable energy – more common
- Embedding storage – to some extent
- Improving efficiency – much effort in insulation
- Purchasing – market leverage, green energy deals, etc
- Demand side response (DSR) – Some effort

Demand Side Response (DSR)

- Change in load characteristics on a daily basis – behaviour change
- Change in load due to sudden changes in supply e.g due to embedded generation

Drivers for Demand side response in UK

- Electric vehicles – Driverless cars being introduced in UK
- Increased embedded generation – dependent on weather
- Maximising existing infrastructure
- Heat pumps, air-conditioning on the increase globally
- Storage options developing
- Involvement of private investment
- Reduction in investment in supply provision.

UK to allow driverless cars on public roads in January

COMMENTS (47)



The BBC's Jon Ironmonger finds out how to 'drive' a driverless car

Load shifting initiatives

- Peak and off peak pricing: issues of how to change behaviour, length of time, pricing, etc
- Critical peaks: short term, not regular. Can be effective.
- Automated shifting of load: air-conditioning (USA) etc. Enabling technology is helpful. Override facility issues, food safety in fridges etc.
- No real-time Time of Use pricing.

Some aspects of Demand side response

- Consumers more likely to change behaviour in response to financial incentives (Economy 7 tariff – lower price 12-6am)
- Consumers also change behaviour with better information
- Most impact where there are flexible energy units such as electric heating, air-conditioning. (Economy 7 tariff)

Distribution side Energy research

- Simulations
 - Historical, Demographical
 - Business case – around government initiatives
- Case studies
 - Trails in different countries – USA, UK, Germany, Nordic countries etc
 - Investigating particular aspects
 - Financial incentives
 - Information / educational
 - Technology
- Technology and business development
 - Tariff schemes, capital grants etc

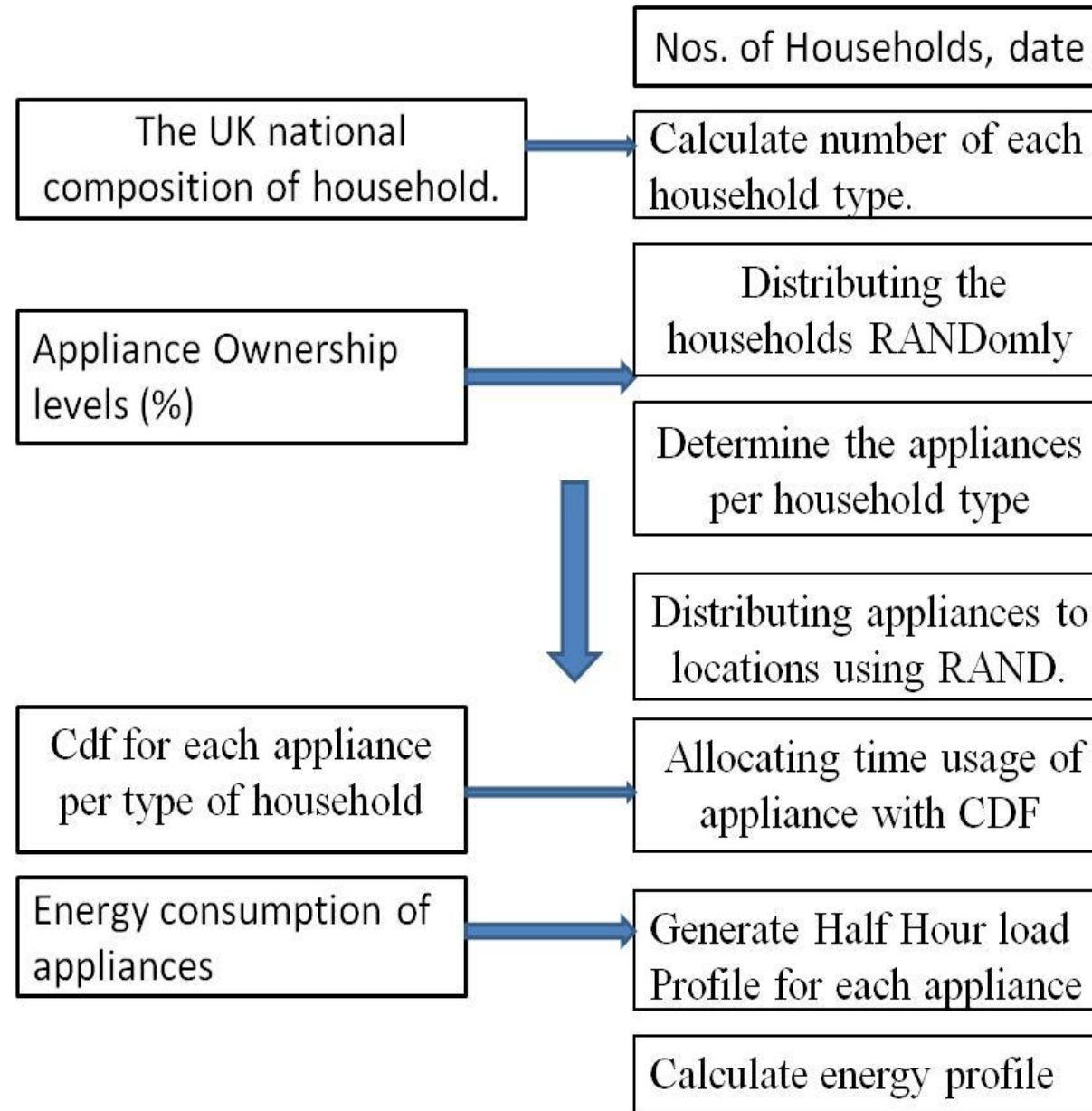
Modelling of a local load

- National projections exist based on historical consumption
 - Good for supply planning purposes
 - Lack detail
- Case studies
 - Detailed measurements of sample households
 - Metering data
 - Too detailed / not detailed enough
- Simulation models
 - Appliance characteristics
 - Behaviour patterns

Community Demand Profile Generator

- **Demographic information:**
 - The information on the type of households such as the number of adults, working people, and number of children.
- **Annual electricity consumption patterns:**
 - Includes ownership level of appliances, and total energy consumption of certain appliances.
- **Daily Occupancy information:**
 - This is the behaviour of occupants in households with respect to their usage of appliances and lighting on a daily basis.

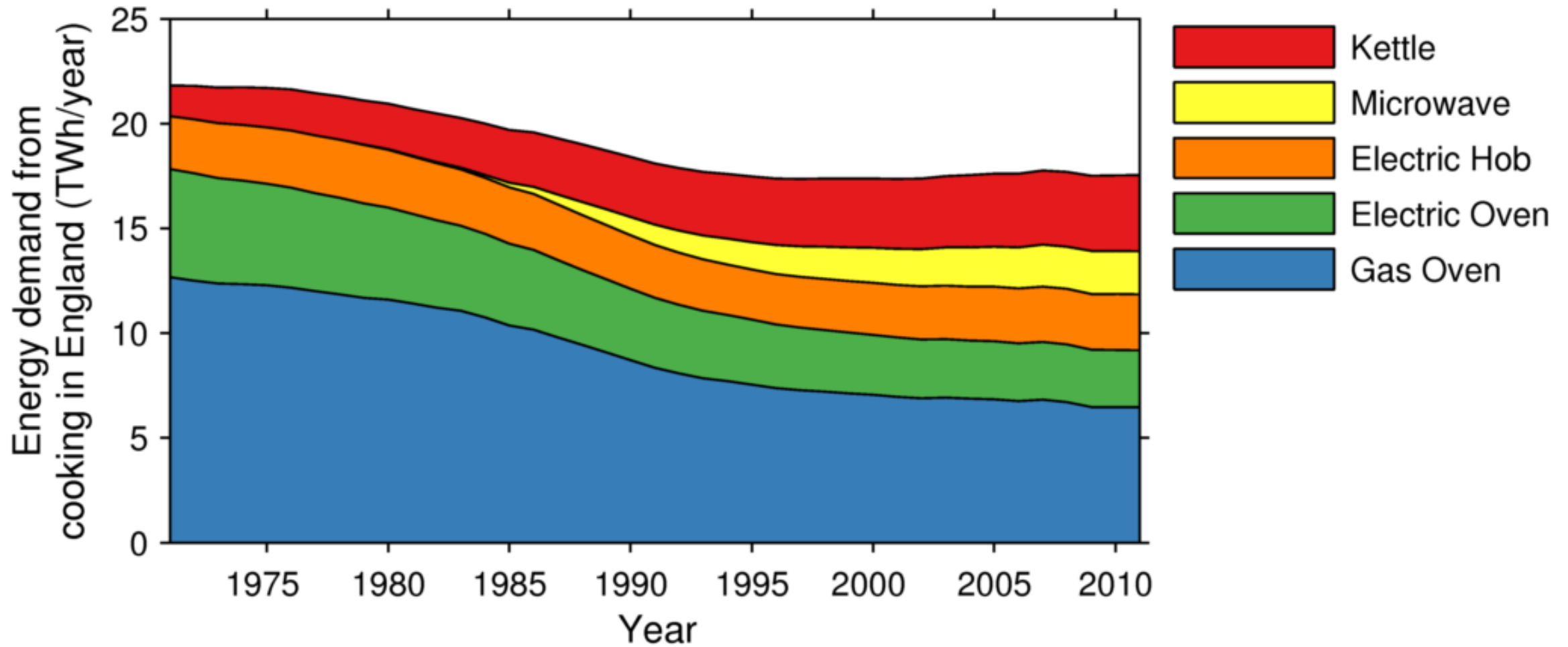
Framework



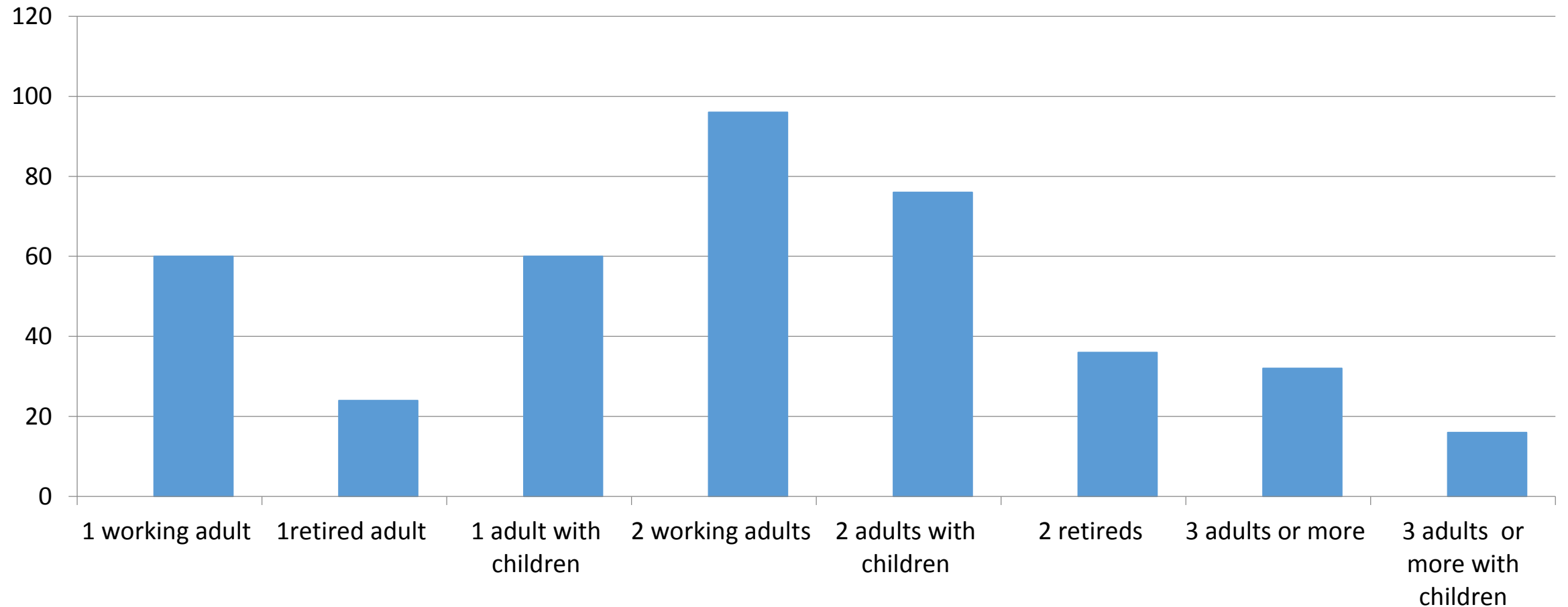
Type of Households in UK

Type of Household	Percentage Share (%)
Single adult without children	15
Single adult with children	6
Single retired adult	15
Two adults without children	24
Two adults with children	19
Two retired	9
Two adults or more without children	8
Two adults or more with children	4
Total (%)	100

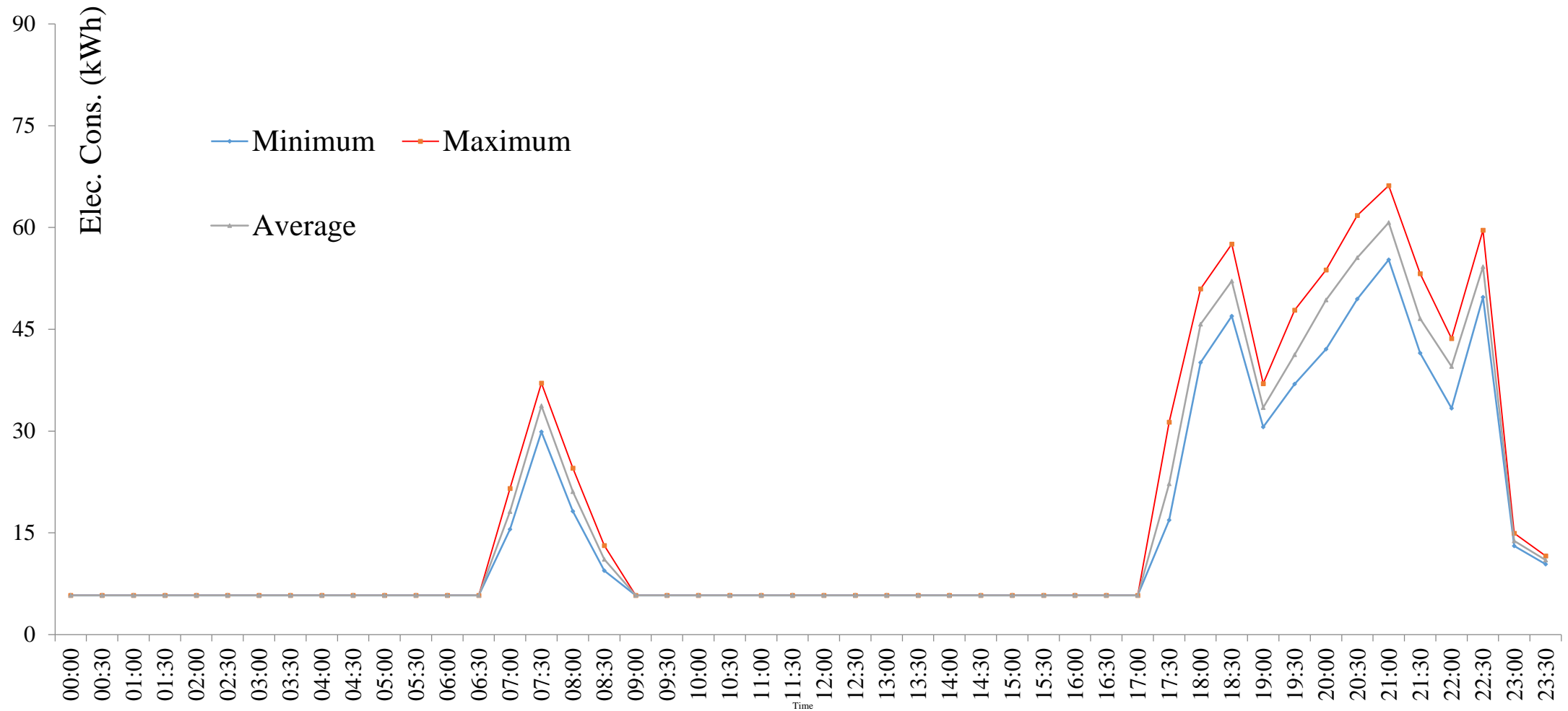
UK Appliance demand decc



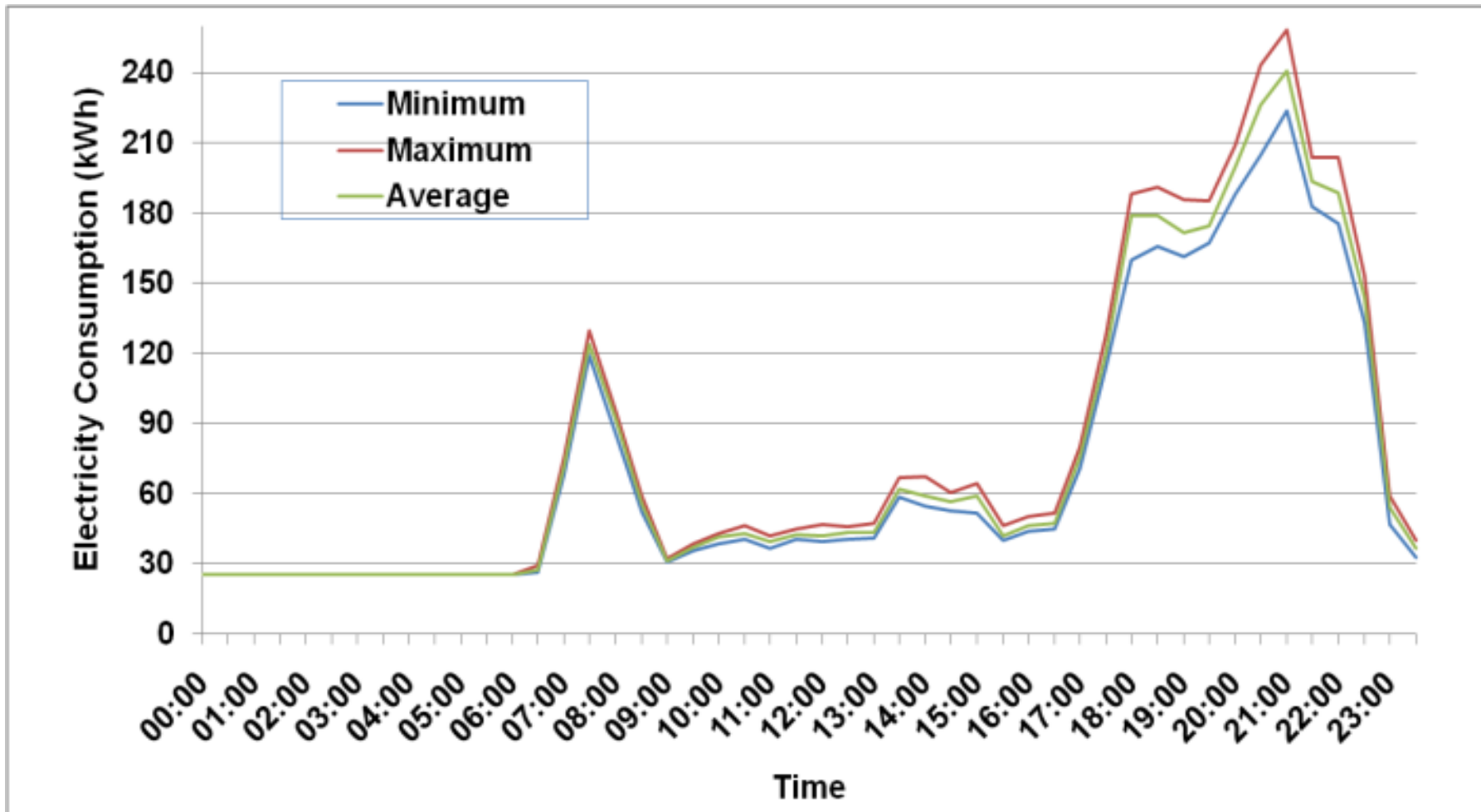
Projection of a Community (Number of households)



Daily consumption for 2 Adults, weekday



Local Community Energy usage – who contributes most?



Interventions

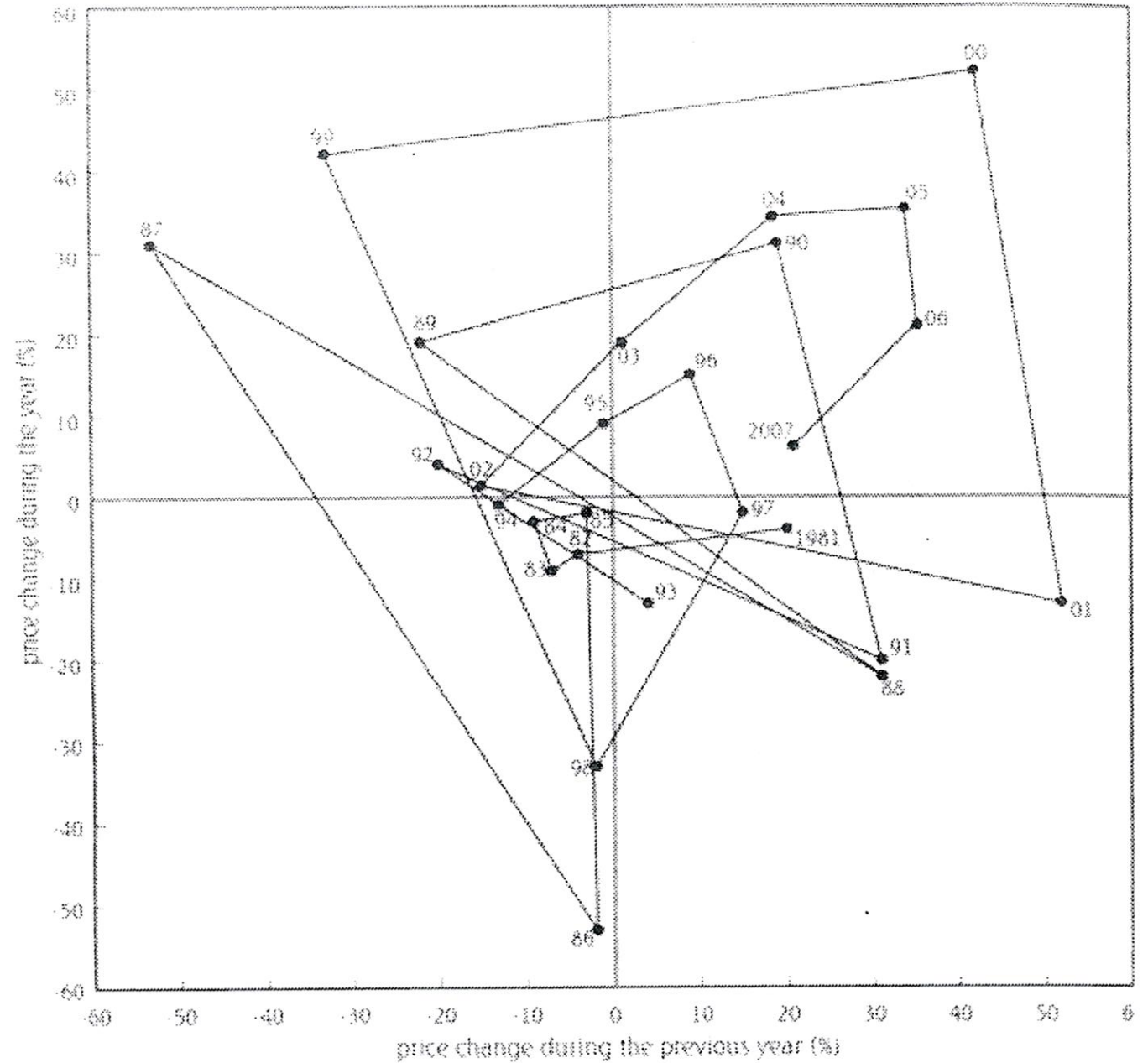
- Renewable Energy
- Storage options
- Load shifting
- Energy efficiency measures
- Behaviour modification / education

We need to understand these.

How do we evaluate?

- Standard business practice methodology.
 - Short term based on current prices
- Economic models
 - Often too lumped for a small community
 - Not able to account easily for technological changes
- Market prices – vary significantly in a free market

Oil price changes 1981 – 2007 (oil)



UK Electricity Market

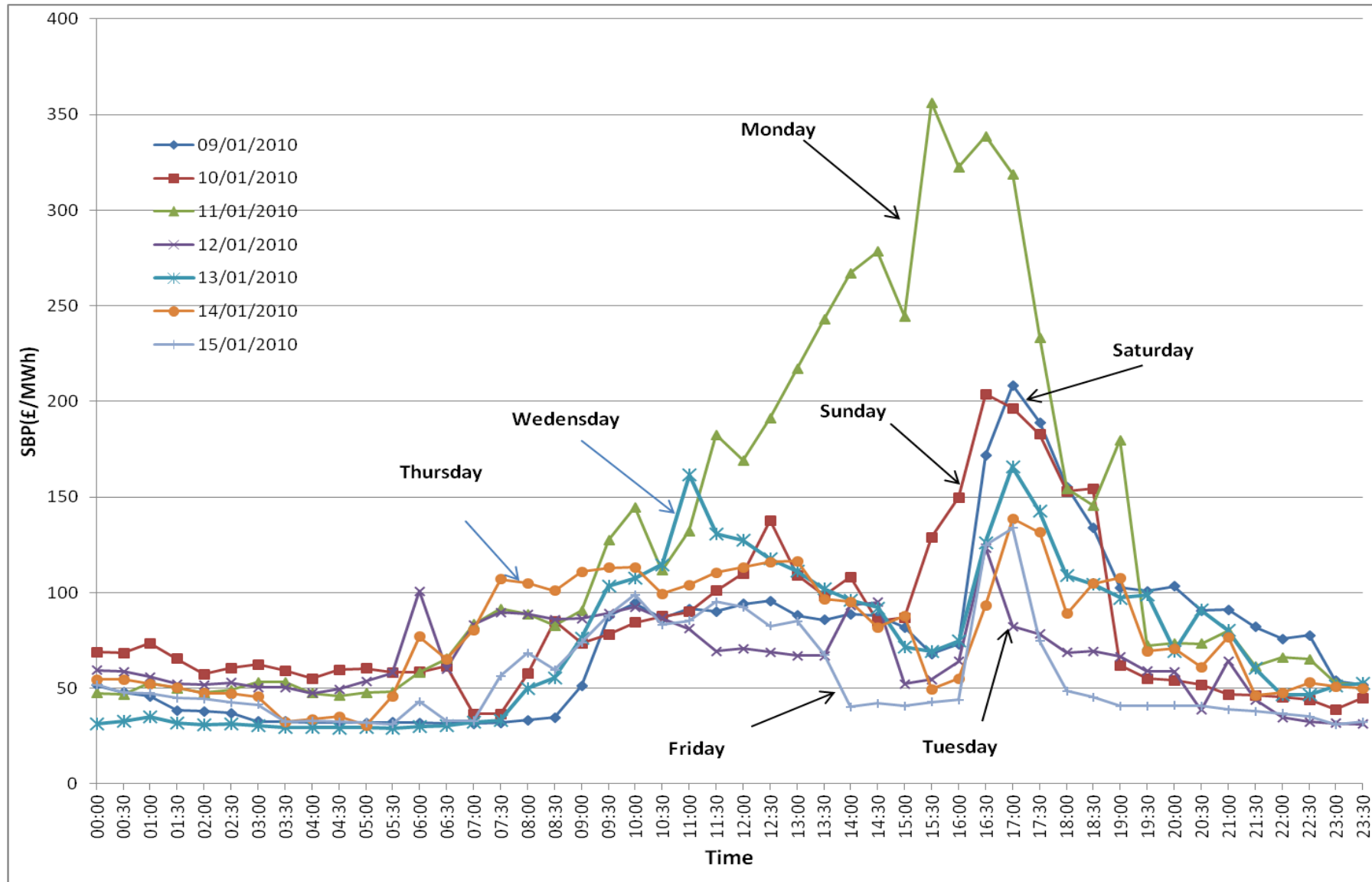
Wholesale Market

- Generation
- Contracts between companies
- Spot difference market

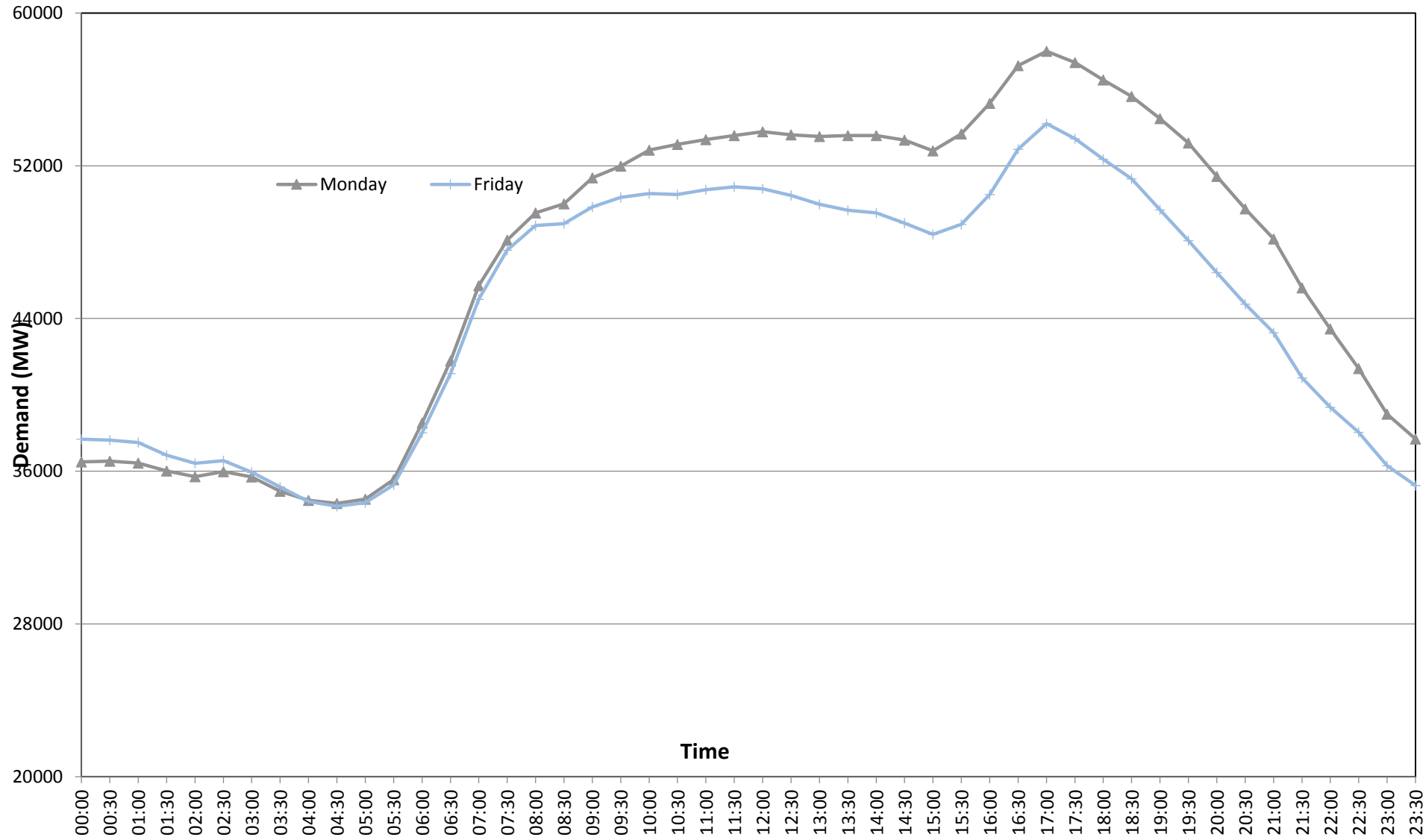
Retail Market

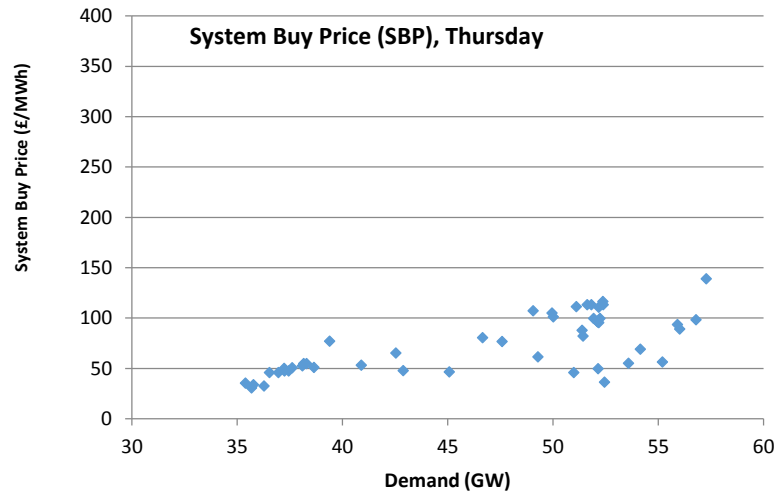
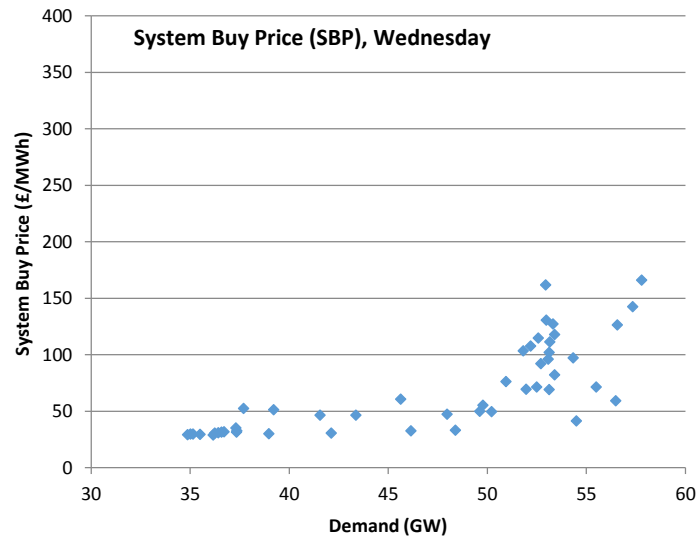
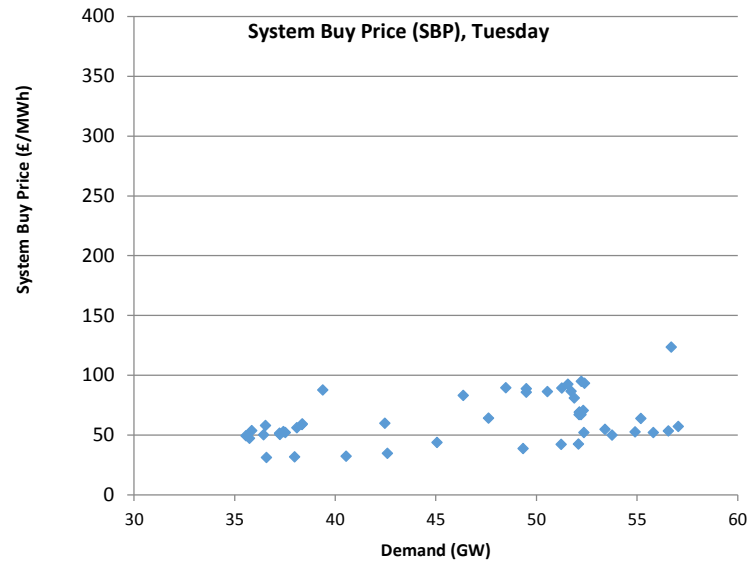
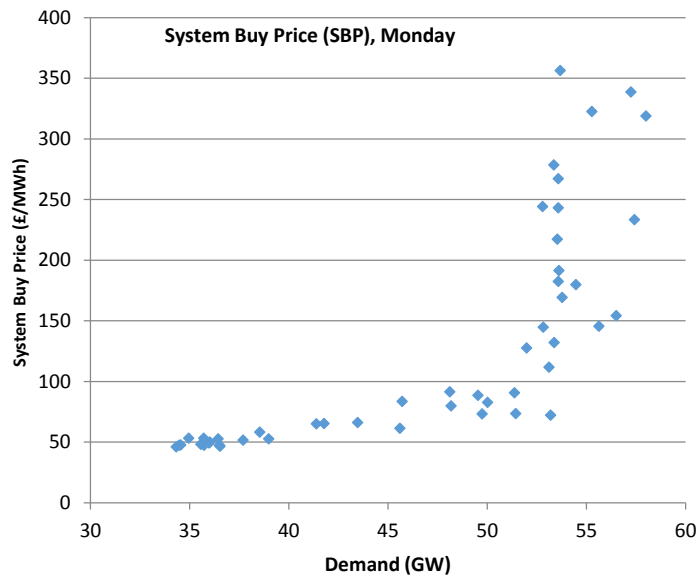
- Domestic customer bills
- Commercial customer bills

UK System buy prices for one week



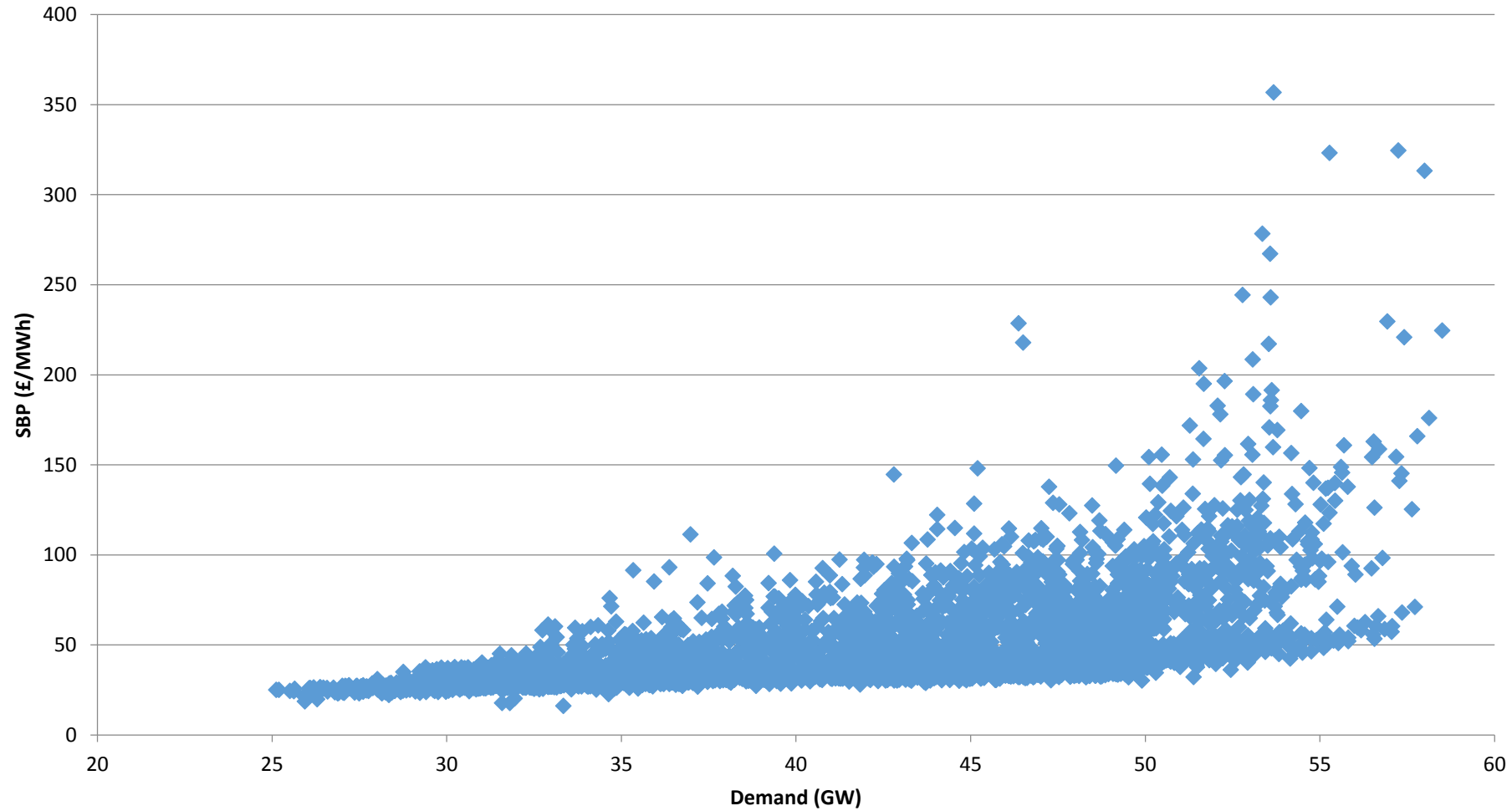
UK System demand over 24 hrs – two days



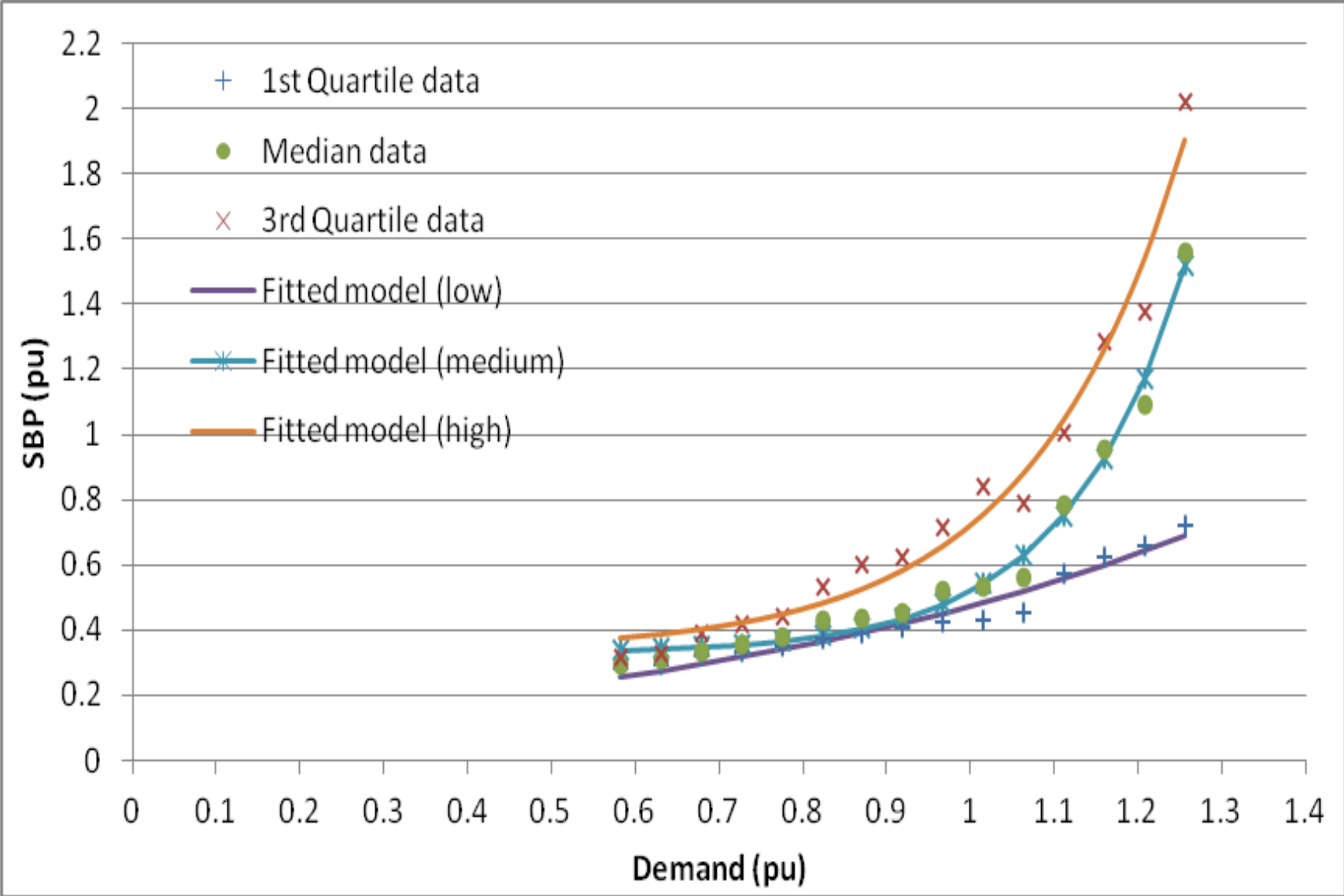


System Buy Price
vs. demand
On different days

System buy price vs demand combined



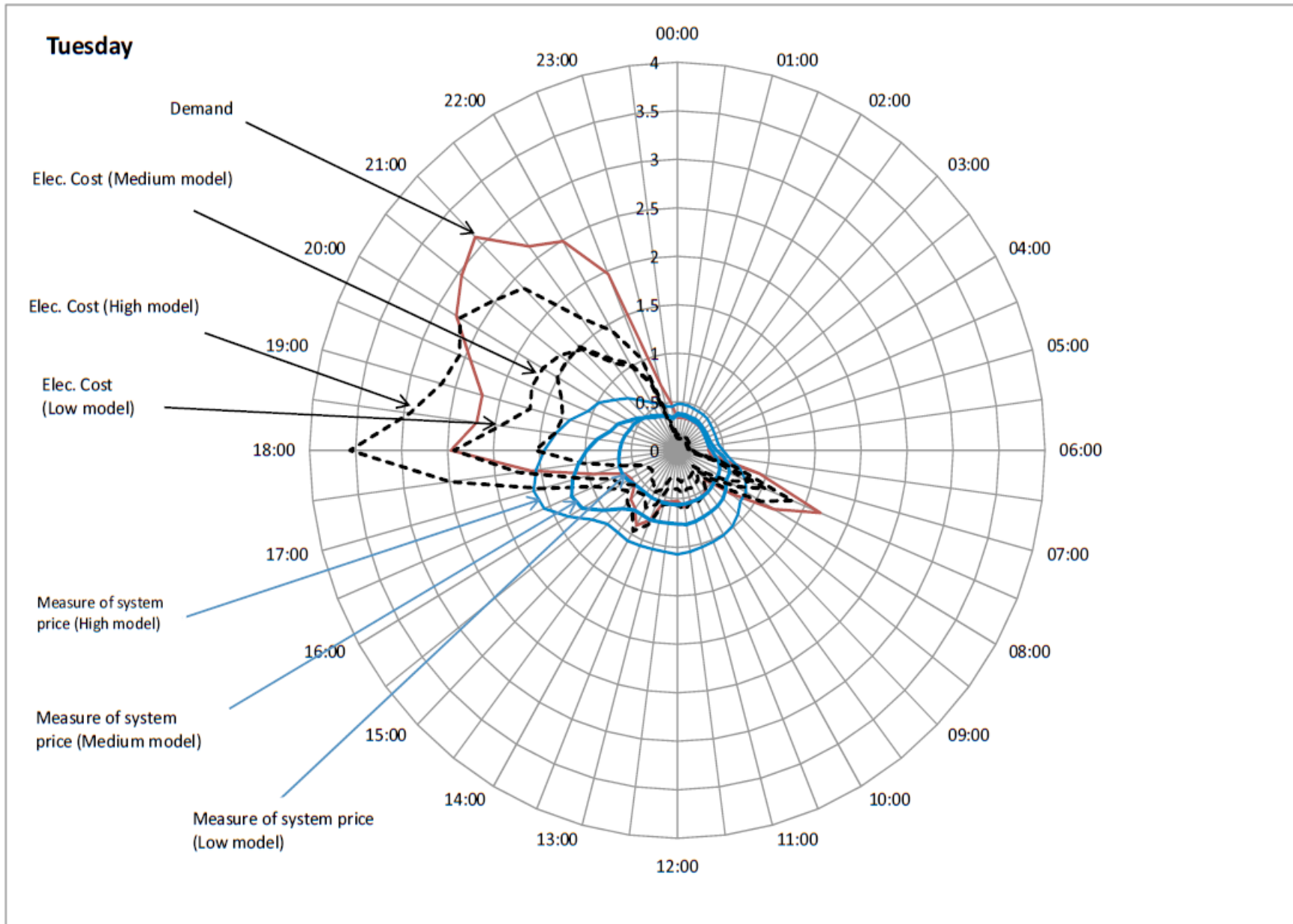
Simple model of system buy price vs demand PU



Pricing aspects

- Range of prices indicates that peak price costs the **supplier** almost 2 p.u.
- Generally the most efficient generators are switched on first, then the more inefficient ones.
- Also indicative of the capital costs for meeting peak demand.

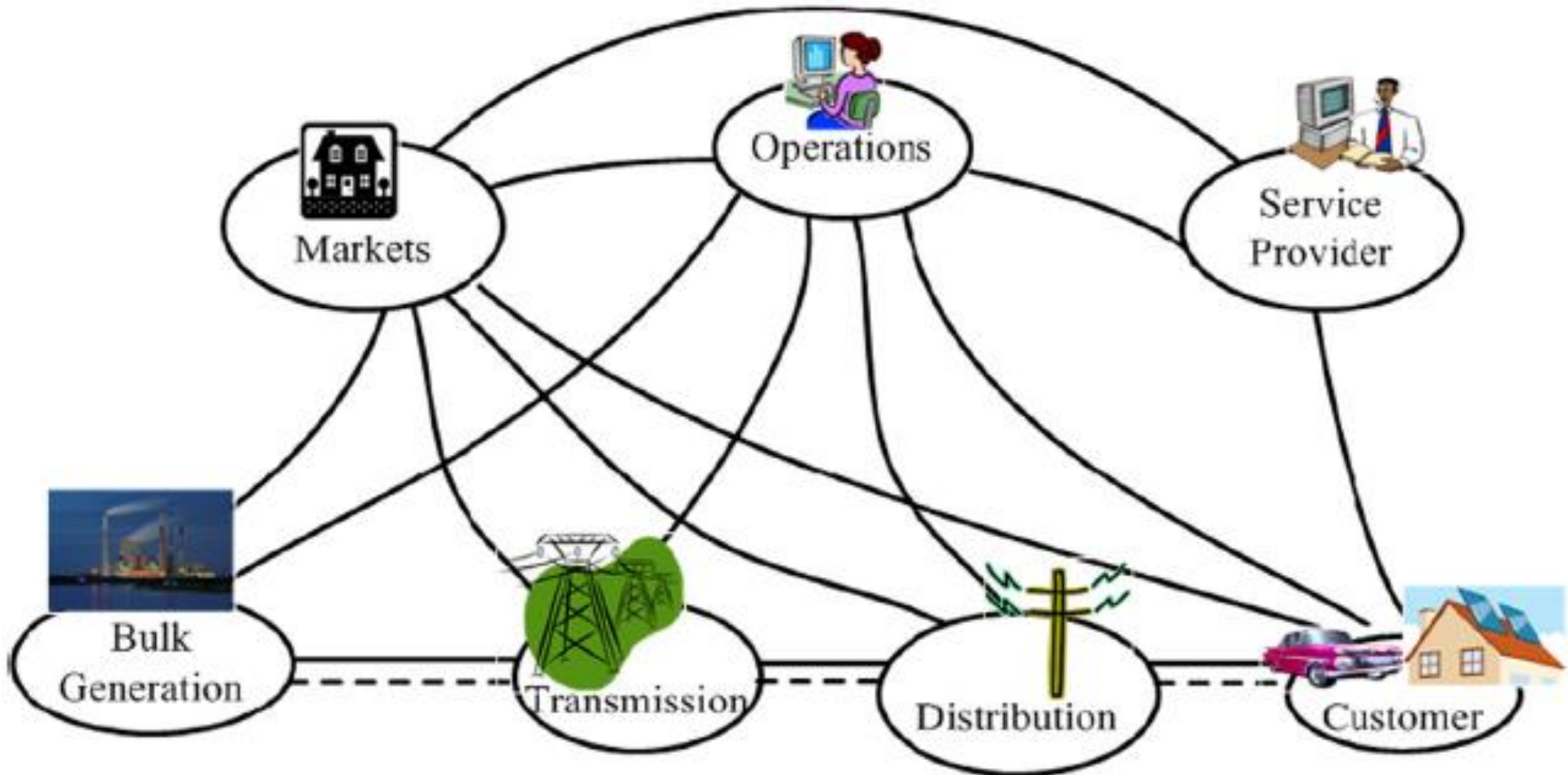
Community Electricity Cost under the three pricing ranges

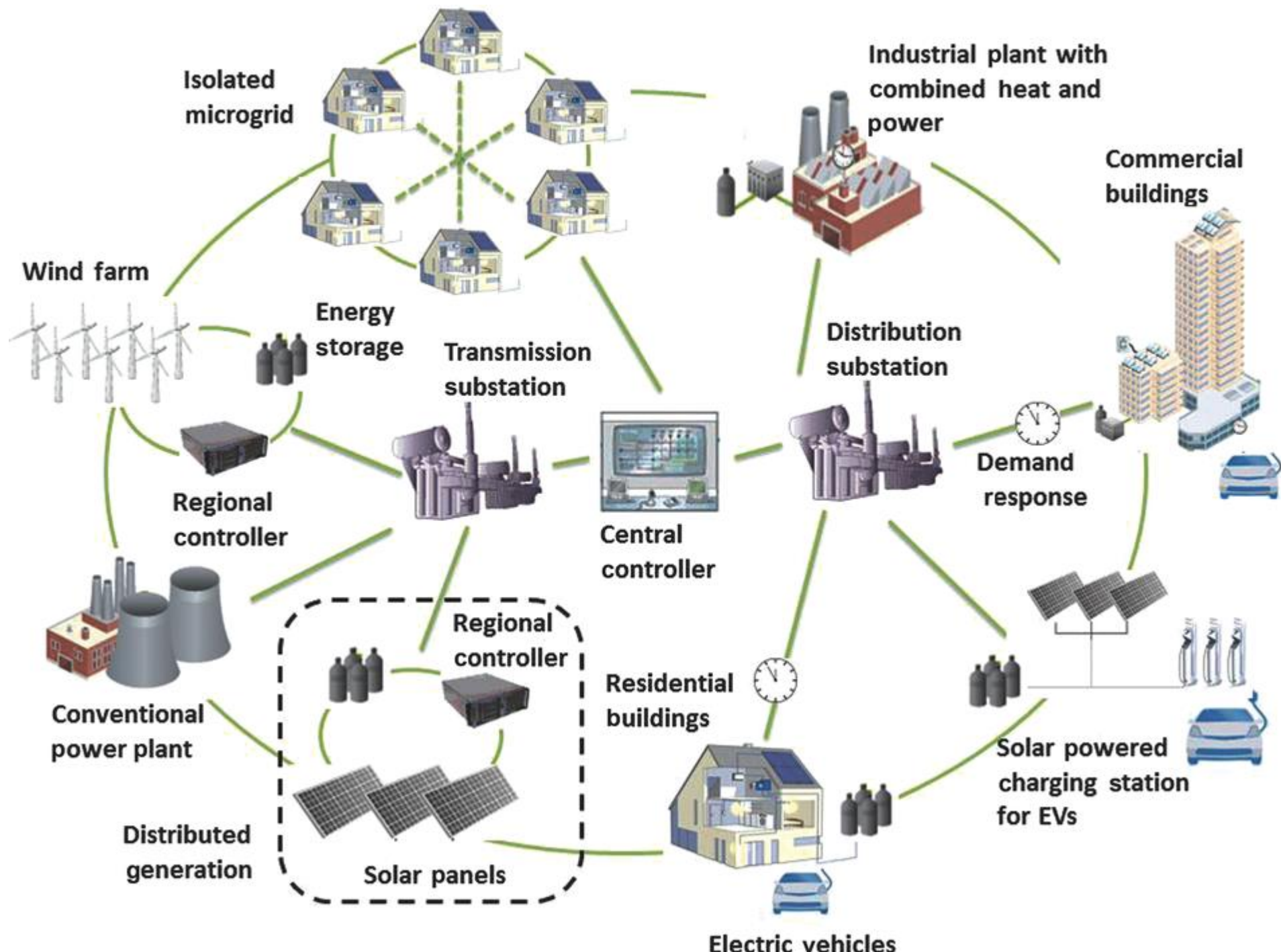


Key points

- Actual maximum cost does not occur at maximum load
- Only gives indication of cost of electricity supply
- Provides a basis for evaluating an intervention – behaviour and also cost.

How does this fit in with Smart Grid?





New requirements

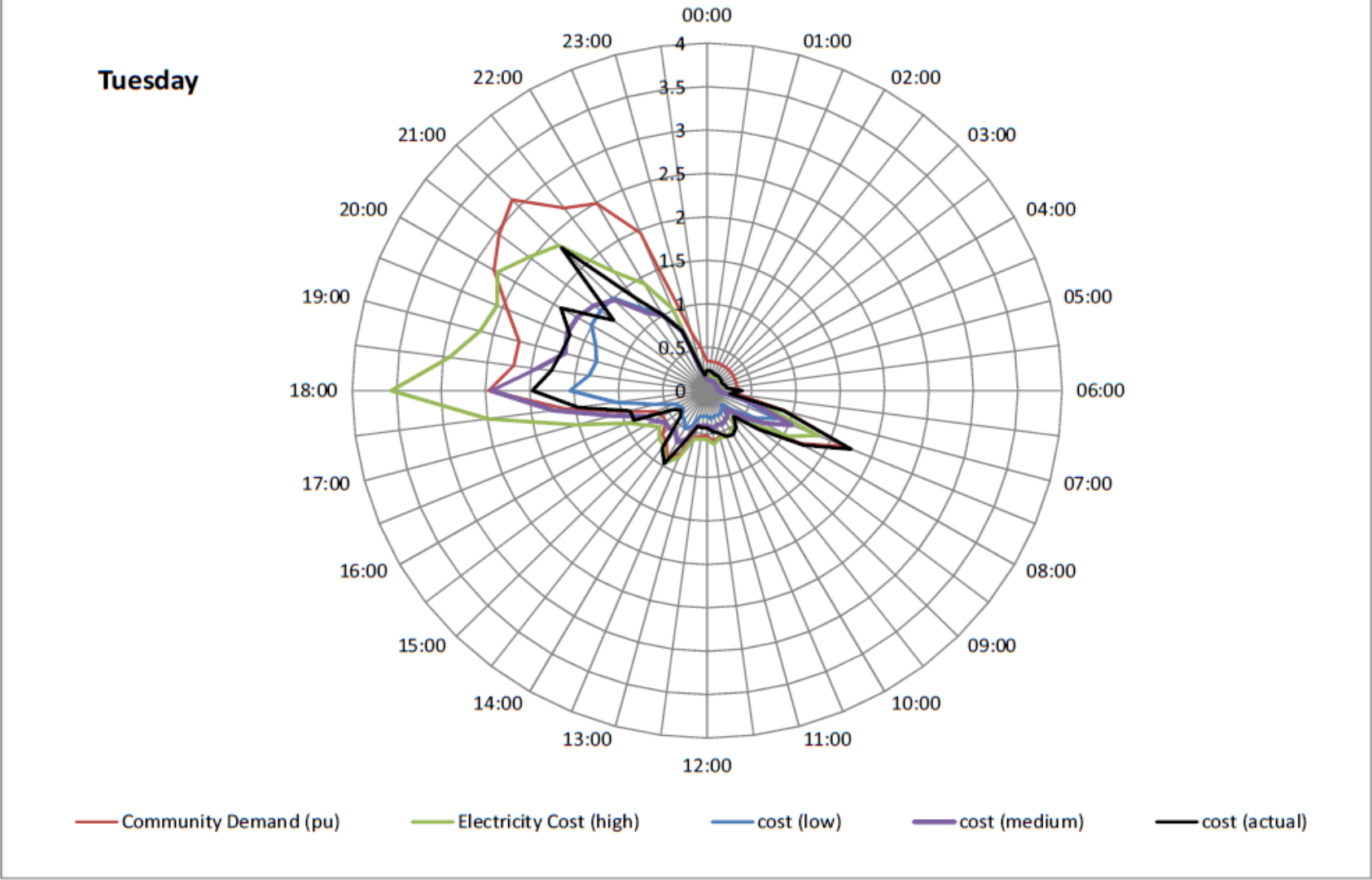
- Need to have some way of establishing the relative cost of demand and supply over a day, over weeks, and over months.
- Need for service provider to identify consumer behaviour, and opportunities in order to develop market instruments.
- Need to manage loads remotely, and also to monitor them.
- Consumer needs to be able to participate ultimately in a financial manner.

Some relevant areas

- What are the electrically energy intense chemical engineering processes that can participate in Smart Grid in such a way as to give mutual benefit?
- What kind of intelligent elements are needed to enable such processes to be integrated into the Smart Grid or into local micro-grids?
- Smart buildings for smart grid integration
- Development of reward mechanisms etc.
- Driverless cars virtually linked to get home quickly!

Thank you

Electricity Cost under three price model options and actual data

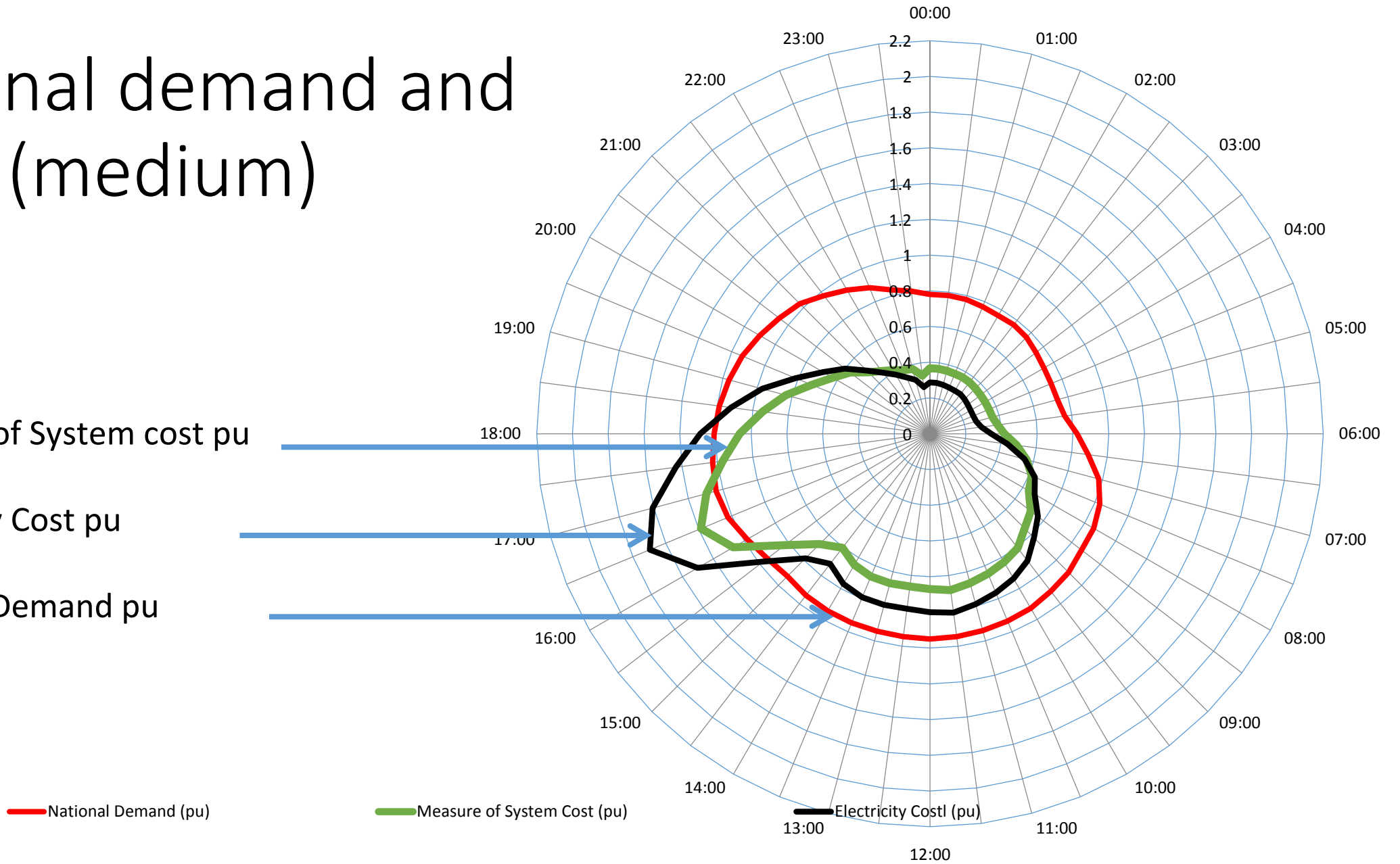


National demand and price (medium)

Measure of System cost pu

Electricity Cost pu

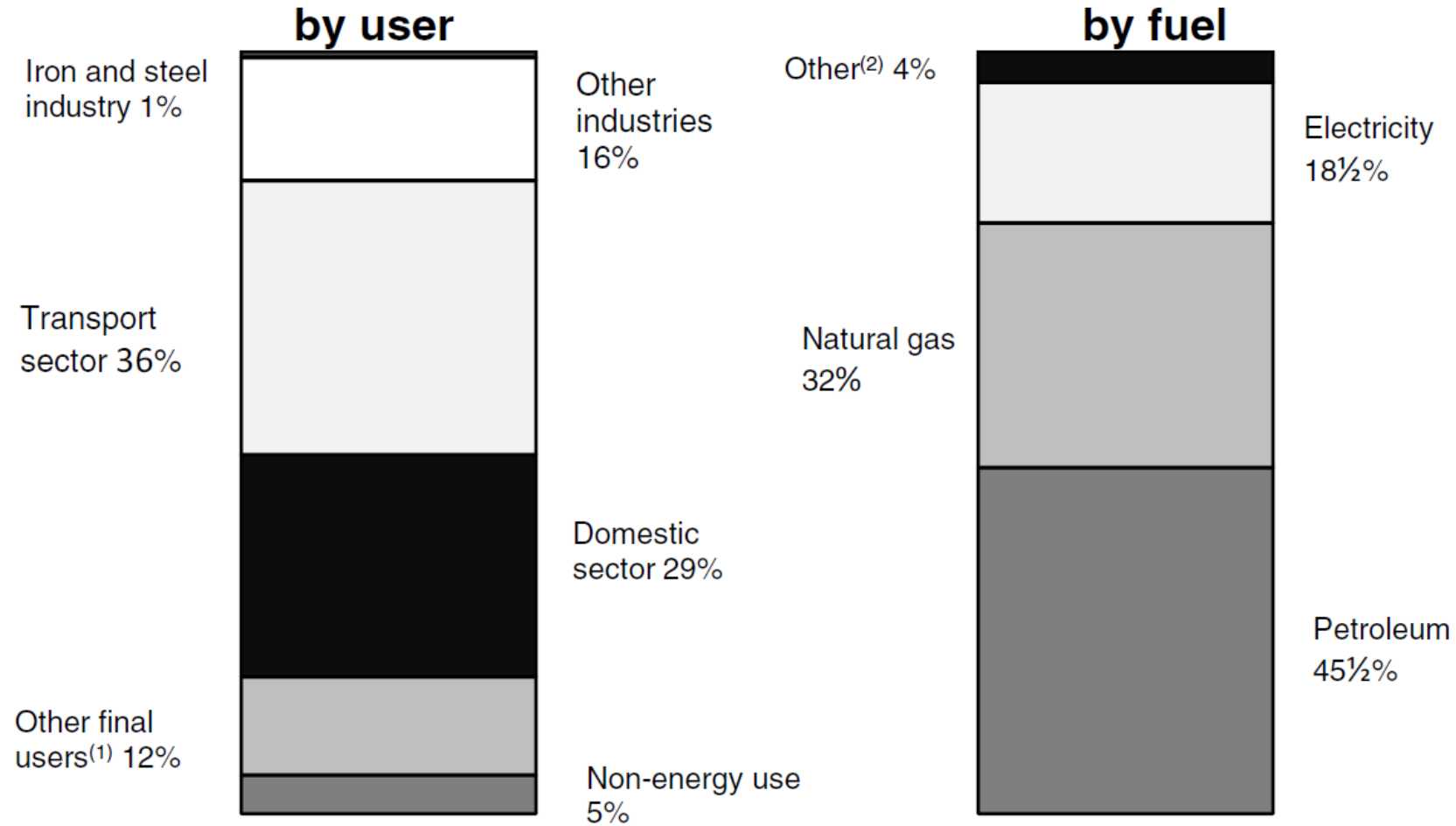
National Demand pu



Average energy consumption of electrical appliances in the UK

Appliance	Average annual consumption per household (kWh/day)	Average annual consumption per capita (kWh/day)
Electric hob	1.33	0.39
Electric oven	0.74	0.22
Microwave Oven	0.23	0.07
Refrigerator	0.82	0.33
Freezer	1.9	0.55
Television	0.91	0.27
Video recorder	0.3	0.09
Dishwasher	1.72	0.48
Washing Machine	0.8	0.2
Tumble Driers	0.78	0.28
Electric Kettle	0.78	0.28
Iron	0.3	0.09
Vacuum Cleaner	0.15	0.04
Miscellaneous	1.1	0.33
Computers	0.5	0.3

UK Energy end use (2012 DECC)



Total: 148.2 million tonnes of oil equivalent

