Integrated Resource Planning Training for Decision Makers

Day 2, Session 3 Presentation - Load forecasting: bottom up and top down

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Load forecasting: bottom up and top down

Load forecasting basics

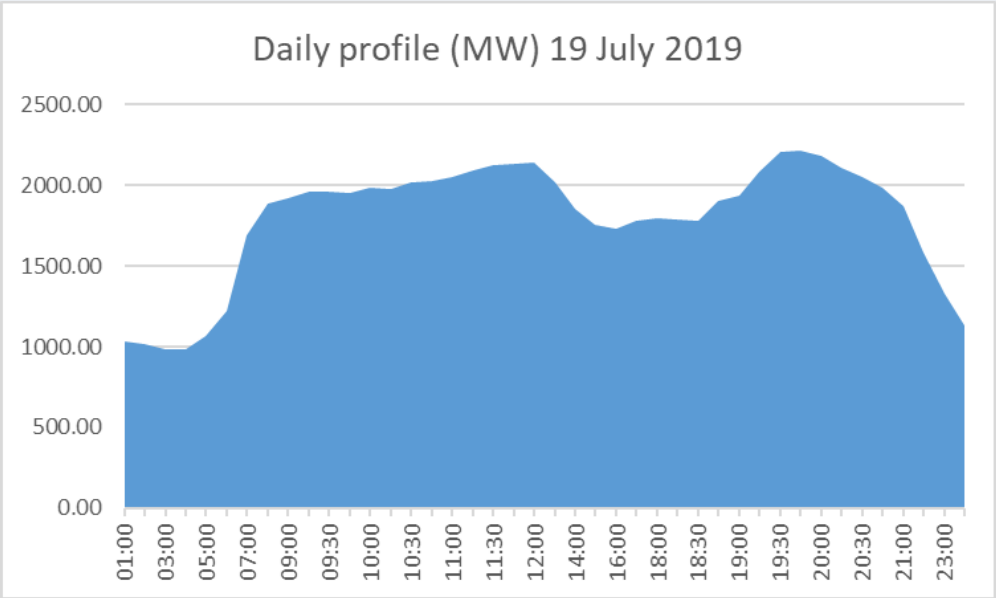
Demand forecasting methods
Dealing with suppressed demand and uncertainty

Why are electricity demand forecasts needed?

Typical uses of electricity demand forecasts	Typical horizon	Typical spread	Energy demand	Peak demand	Time of Use pattern
Generation planning	Long term (+20 years)	National level	√	√	√
Contracting and purchasing of wholesale/bulk electricity	Long term (+15 years)	Mix	√	√	-
Transmission planning	Medium term (10-20 years)	By location	-	√	-
Distribution planning	Medium term (5-10 years)	By location	-	√	-
Tariff setting	Short to medium term	By tariff category	√	√	√
System operation and scheduling of generation and transmission	Short-term (day ahead)	No	√	√	√

Main elements of electricity demand for load forecasting

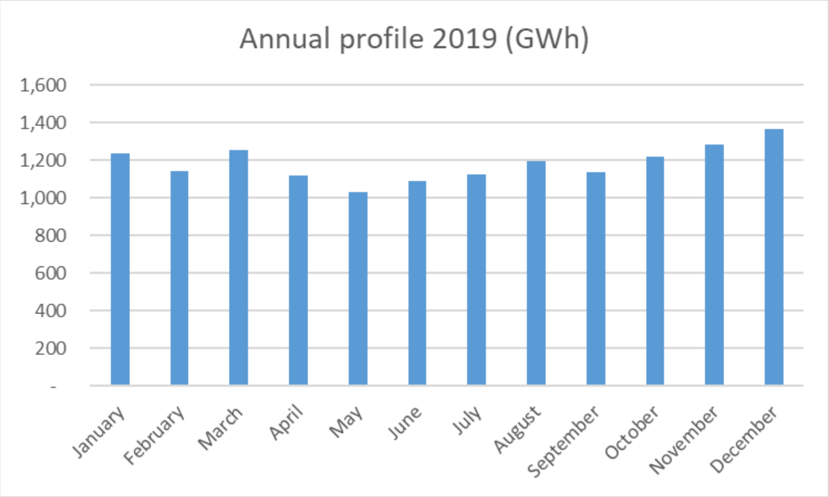
- ***Energy (GWh) demand forecast –*** sets the total amount of energy that needs to be supplied
- ***Peak (MW) demand forecast –*** sets the total amount of capacity that needs to be developed for generation, transmission and distribution
- ***Load shape –*** sets the amount of capacity/energy that has to be satisfied at any given hour. It will determine how much a power plant will operate within a day/year
  - Annual or daily hourly load profiles?
  - The former increases accuracy but significantly increases modelling execution times and is much harder to obtain
  - The latter is simpler and easier to obtain giving relatively accurate results. Disadvantage is that it may fail to capture peculiarities in specific hours

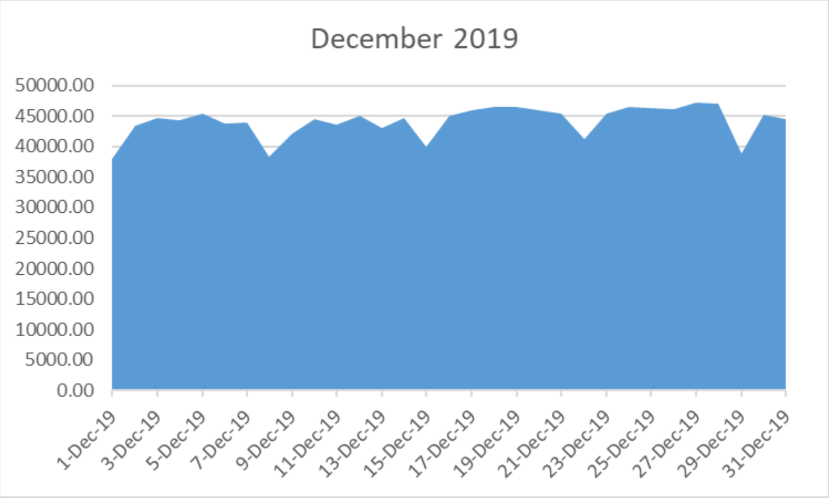


- While generators do not constantly operate to full capacity, capacity must be sufficient to meet peak demand
- The network has to be designed to be able to cover the peak demand

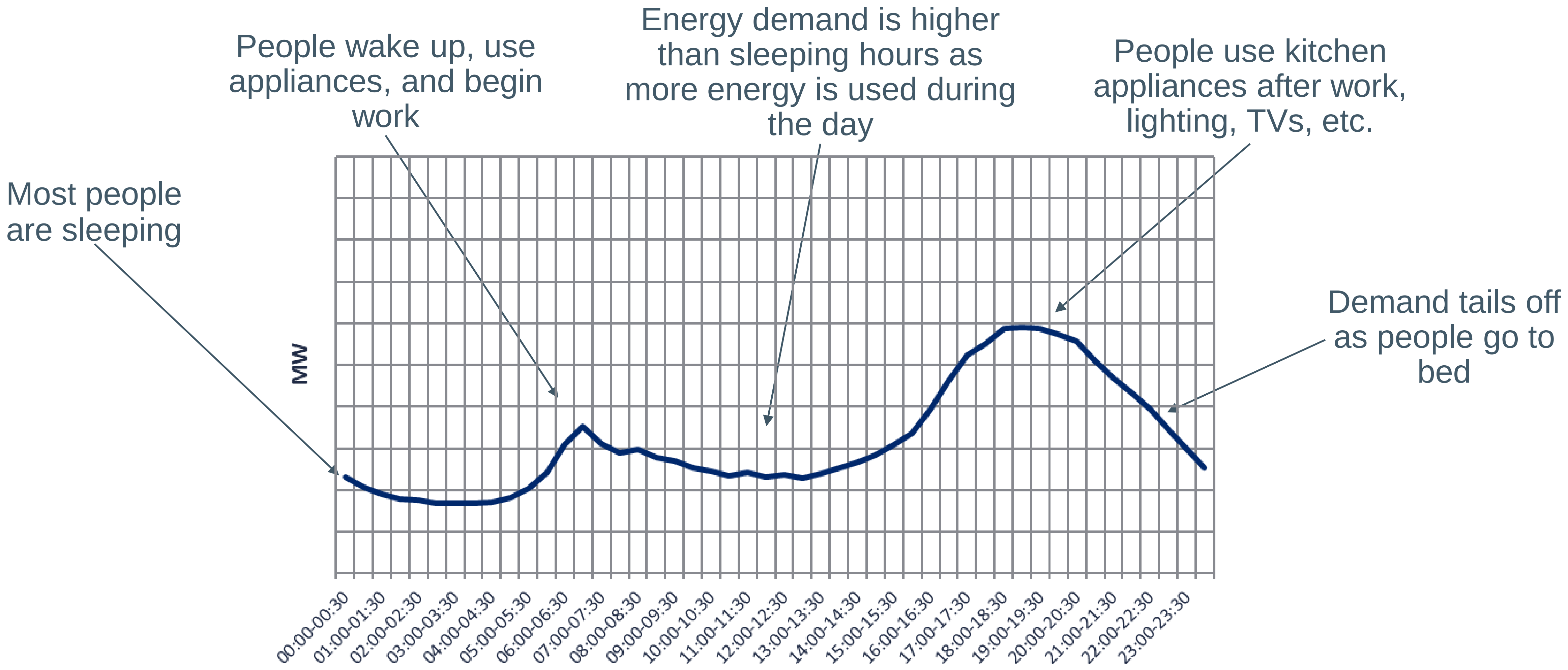
Electricity demand varies by hour/season/year

- Energy consumption varies by season:
  - In some countries, consumption increases during hot months because air-conditioning facilities are used
  - In some, consumption increases during cold months when heating facilities are used
- Energy consumption differs across days of the week:
  - Weekends have different consumption patterns from workdays
  - Weekends and holidays differ across countries
- Energy consumption differs across the day:
  - There are usually spikes in demand before and after work
  - There is a drop in demand when most people are asleep

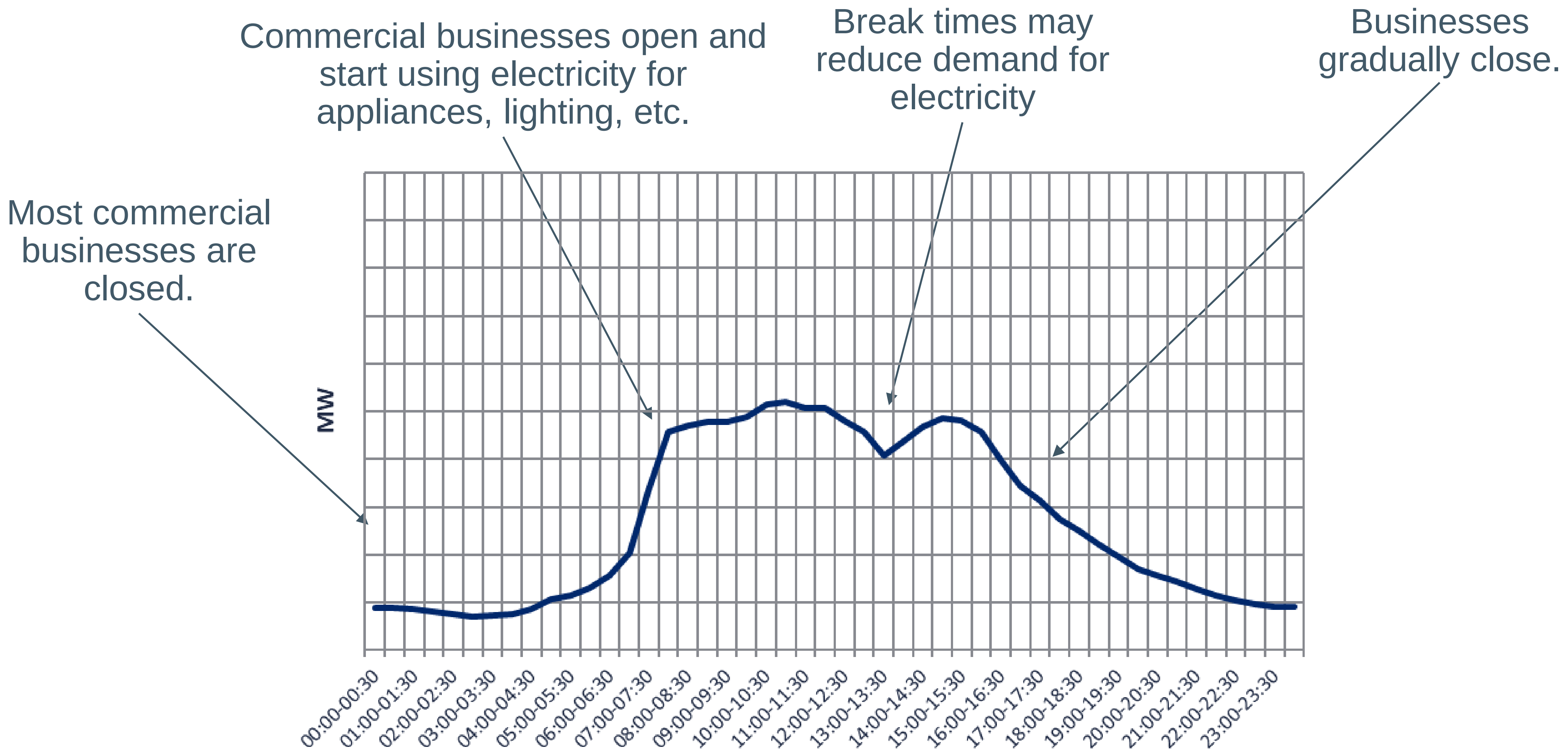




Typical consumption pattern of residential customers

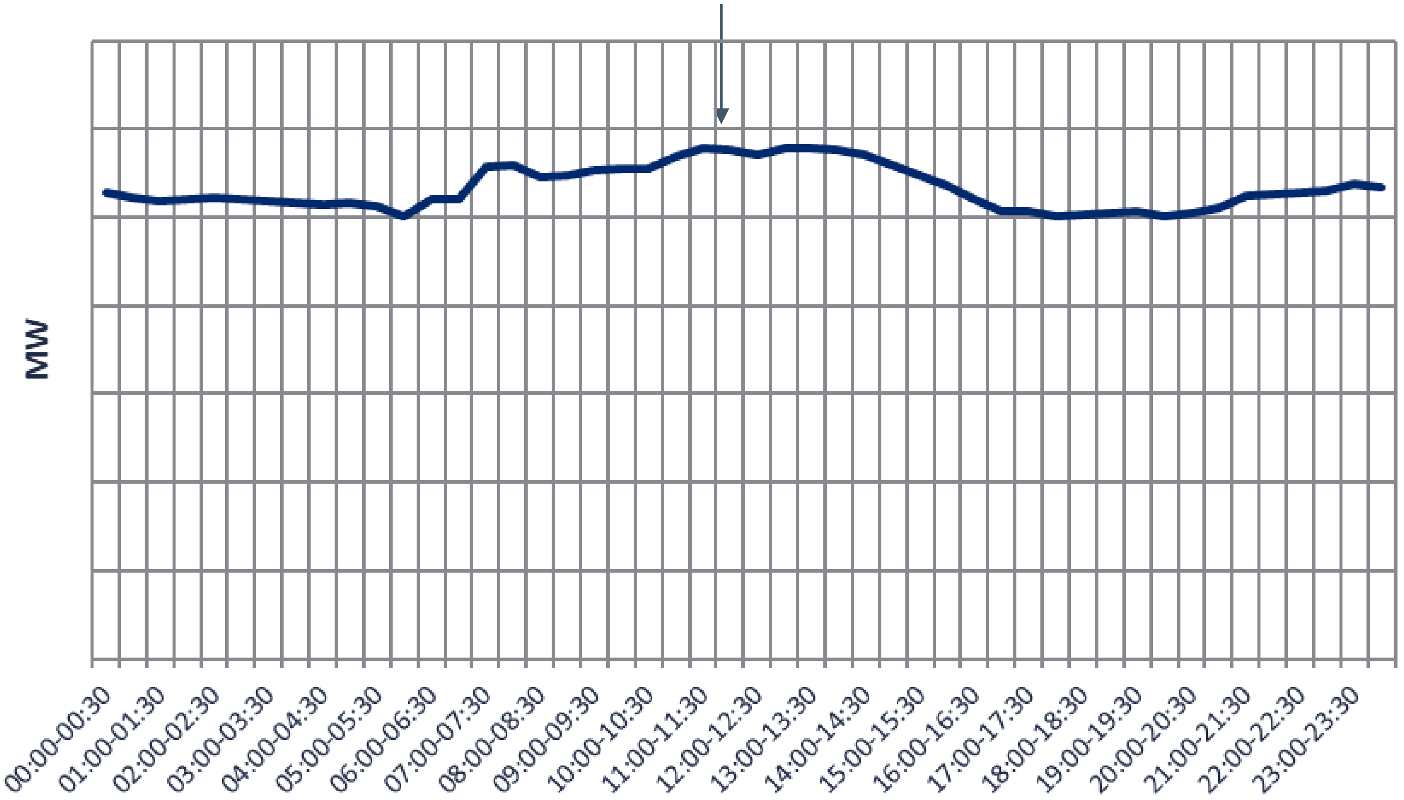


Typical consumption pattern of commercial customers



Typical consumption pattern of industrial customers

Big industrial customers usually consume electricity throughout the day with higher consumption observed during working hours



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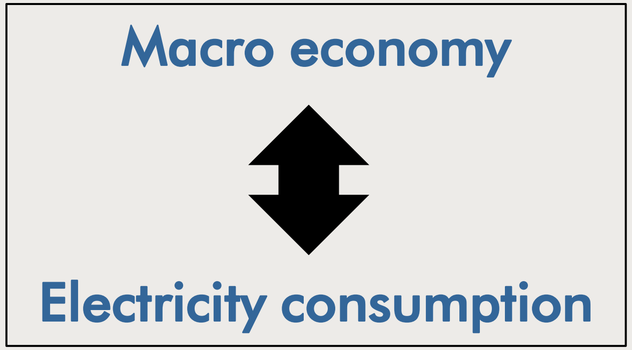
Which are the most common models for demand forecasting in power system planning?

Most modern-day economic activities involve the use of electricity



The development of an economy is a useful real-time proxy for electricity consumption

- **The most common load forecasting models for power system planning are:**
  - Trend
  - Bottom-up
  - Econometric models
  - Hybrid approaches
- **Most forecasts use a combination of the above techniques. It is rare to find a forecast using only one method**
  - The development of each sector in the economy is different
  - The consumption characteristics of each customer differ

Trend approach

Trend analysis involves an extrapolation of past growth trends into the future.

It involves fitting a line through past electricity demand and assuming that future growth will follow a similar trajectory.

- Simple and easy to use
- Relatively good performance in the short-term
- Does not attempt to explain or understand the reasons for growth in load
- Assumes that the historical trend continues into the coming years
- If the underlying factors change in the future, the future demand will not follow a similar trajectory and the forecast will be wrong

Year	Actual sales	Growth rate	Forecast
	GWh	%	GWh
2008	2,572	-	-
2009	2,661	3%	-
2010	2,623	-1%	-
2011	2,751	5%	-
2012	2,959	8%	-
2013	3,110	5%	-
2014	3,113	0%	3,113
2015	3,291	6%	3,235
2016	3,447	5%	3,362
2017	3,578	4%	3,493
2018	3,708	4%	3,630
2019	3,658	-1%	3,772
Average growth (2008-2019)	-	3%	-
Average growth (2008-2013)	-	4%	-

Exercise 1: Forecast the peak load of a primary substation up to 2025 using the trend approach

- Calculate the growth rate in the historical years
- Use the average growth rate of the past 5 years to estimate the demand in the next 5 years

Year	Peak load (MW)
2013	55.4
2014	59.7
2015	64.6
2016	69.3
2017	73.3
2018	75.8
2019	78.6
2020	81.6

Bottom-up approach

Bottom-up analysis involves a detailed assessment of the usage of electricity by different types of consumers and how those consumers will change their consumption habits in the future and how the consumer mix changes over time.

- Can be relatively accurate if the input assumptions and equations are accurate (also uses some econometric analyses and equations)
- Require large amounts of detailed engineering and demographic data. It would normally tend to ask about the ownership of lightbulbs, TVs, radios, fans, etc.
- Time consuming to prepare
- Accuracy depends on the level of effort used in collecting and analysing data.

		Actual 2019	*Forecast* 2020	*Forecast* 2021	*Forecast* 2022	*Forecast* 2023	*Forecast* 2024	*Forecast* 2025
Number of households								
Total	*Number*	266,934	275,850	285,051	294,546	304,345	314,458	324,893
Urban	*Number*	188,674	196,470	204,536	212,879	221,510	230,438	239,671
Rural	*Number*	78,260	79,380	80,515	81,667	82,835	84,020	85,222
Electrification rate (% of households)								
Total	*% of households*	63%	66%	70%	73%	76%	80%	83%
Urban	*% of households*	82%	85%	88%	91%	94%	97%	100%
Rural	*% of households*	17%	20%	23%	26%	29%	33%	36%
Average consumption per household (kWh / month)								
Total	*kWh / month*	98	87	91	96	97	98	100
Urban	*kWh / month*	101	90	95	100	101	103	105
Rural	*kWh / month*	60	50	53	57	58	59	60
Energy sales (GWh)								
Domestic sales	*GWh*	197	190	217	247	271	296	324

$$Domestic\ demand = electrification\ rate * consumption\ per\ household * number\ of\ total\ housholds$$

Exercise 2: Forecast the demand of electric vehicles up to 2025 using the bottom-up approach

- Use the given assumptions to estimate the electricity demand per EV per year
- Use the average demand per EV per year and the estimated fleet of EV per year to forecast the demand for electricity from EVs up to 2025

Average efficiency	0.178	kWh/km
Annual km per EV	10,000	km

Year	EV Stock
2019	165
2020	176
2021	191
2022	223
2023	285
2024	422
2025	797

Econometric approach

An econometric model uses mathematical equations to describe the relationship between the primary driver (e.g., GDP or GDP per capita) and electricity consumption

The mathematical equations in combination with projections of the external drivers (population, GDP, etc.) are then used to forecast future electricity load

- is grounded in a theory of causation e.g., that increased income leads to increased spending power that leads to increased appliance ownership and/or increased use of owned appliances and therefore to increased electricity load
- uses econometric analysis to test whether the theory of causation is confirmed by the historical data and to provide parameter estimates
- the major disadvantage is that it requires long historical datasets to run effectively the statistical analysis to estimate the coefficients

The general form of an econometric equation is:

$$lnDemand_{y_{i_j}} = \beta_{0_{jg}} + \beta_{1_{jg}} * \ln X_1 + \beta_{2_{jg}} * lnX_2 + \cdots + \beta_{n_{jg}} * lnX_n$$

- $\beta_{0_{jg}}$ is the constant term and
- $\beta_{1_{jg}}, \beta_{1_{jg}}, \ldots, \beta_{1_{jg}}$ are the estimated coefficients. Each coefficient corresponds to the logged value of each macroeconomic parameter (i.e. $lnX_1, lnX_2, \ldots, lnX_n$)
- $lnX_1, lnX_2, \ldots, lnX_n$ are the logged values of the macroeconomic parameters (i.e. the population, GDP per capita, GDP, etc.)
- Typically the values are growth rates

Then demand is calculated as:

$$Demand_{y_{i_j}} = e^{lnDemand_{y_{i_j}}}$$

Exercise 3: Forecast the demand of domestic customers up to 2025 using the following econometric equation

Use the following equation to forecast the demand of domestic consumers up to 2025:

$$ln(Demand) = -4.9 - 0.2 * ln(number\ of\ connections) + 1.5 * ln\left(\frac{GDP}{capita}\right) + 0.3 * ln(demand_{t-1})$$

	Coefficients
Intercept	-4.9
ln(Number of Domestic Customers (Connections))	-0.2
ln(GDP/Capita)	1.5
ln(Domestic sales (GWh))	0.3

Year	Number of Domestic Customers (Connections)	GPD/Capita	Domestic sales (GWh)
2019	7,039,806	10,724	4,209
2020	7,814,184	11,404	
2021	8,595,603	12,151	
2022	9,455,163	12,947	
2023	10,400,679	13,795	
2024	11,440,747	14,699	
2025	12,584,822	15,661	

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How to deal with suppressed demand

- Suppressed demand is not recorded in actual historical sales data
- Any model that builds on historical data to develop the forecast cannot capture suppressed demand directly
- For example, a trend approach will not capture the suppressed demand going forward as the suppressed demand is not included in the growth rate nor the demand of the base year
- The suppressed demand has to be added on top of the forecasted demand
- Typically, bottom-up approaches are used to estimate the forecast demand including the suppressed demand

How to deal with uncertainty in demand forecasting

- Scenarios – scenarios can be used to forecast the demand under different conditions in the economy
- Sensitivities – sensitivities can be used to model the impact of different parameters on the demand forecast
- Probabilistic assessment – probabilities can be used to model the uncertainty of different loads in the future

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