# ECON 4930 Spring 2011
# Electricity Economics
## Lecture 1

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# Hydro capacity

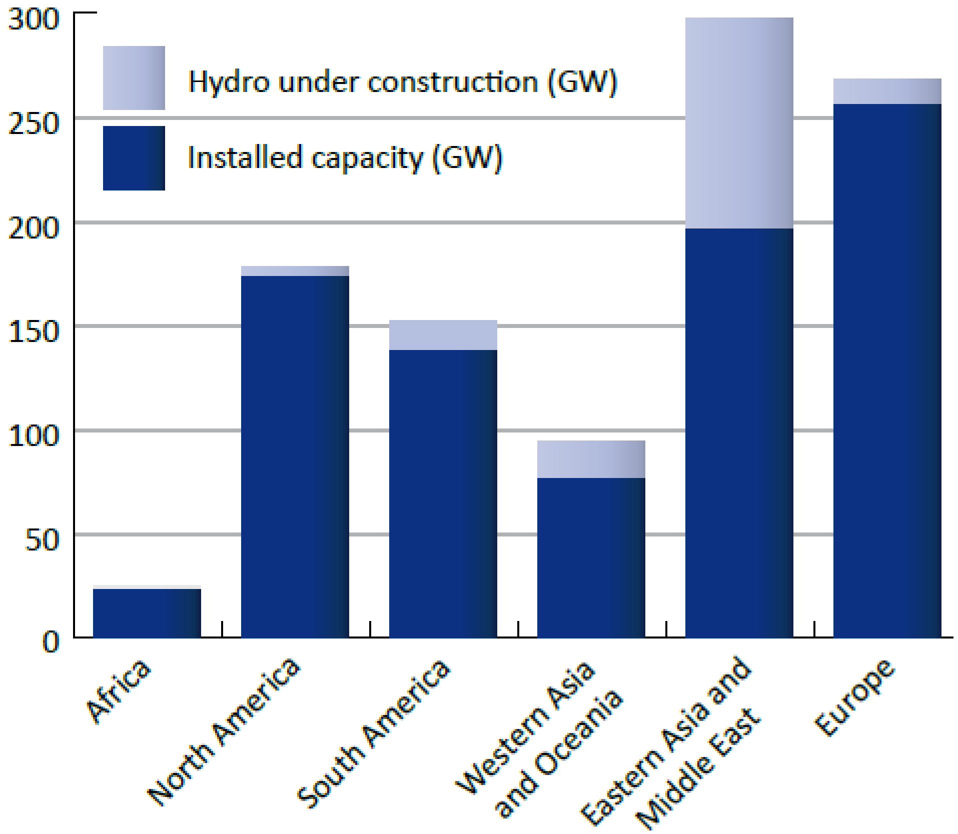



Figure 2: Hydro under construction, by region, with existing capacity included for reference

# Overview of the course

- Basic learning objectives
  - Know key qualitative results as to optimal social planning in electricity economics when hydropower is involved
  - Have a satisfactory understanding of how to formulate dynamic management models using standard non-linear programming
  - Understand how constraints on the generating system and uncertainty of inflows of water to hydro reservoirs affect the optimal path of social prices
  - Be able to discuss actual market organisations in view of theoretical results obtained from the social planning analyses

# Introduction

- Why dynamics
  - Hydropower plants can store energy in the form of water if there is a dam or reservoir
  - Water used today can alternatively be used tomorrow; there is an opportunity cost attached to current water use
  - A dynamic analysis is then necessary in order to determine the time profile of the use of water in reservoirs

# Introduction, cont.

- Why standard non-linear programming
  - Can use more specialised methods (dynamics programming, Bellman)
  - But will use a more basic tool
- Baumol
  - the Kuhn – Tucker conditions may perhaps constitute the most powerful single weapon provided to economics theory by mathematical programming

# Overview of the course

- Main themes
  - Introduction to electricity and hydropower
  - The formulation of a dynamic social planning problem
  - Understanding price changes over time
  - Multiple hydro plants and aggregation
  - Introducing thermal generating capacity
  - Introducing renewables (wind)
  - Trade between countries
  - Transmission network
  - Market power
  - Uncertainty
  - Market design

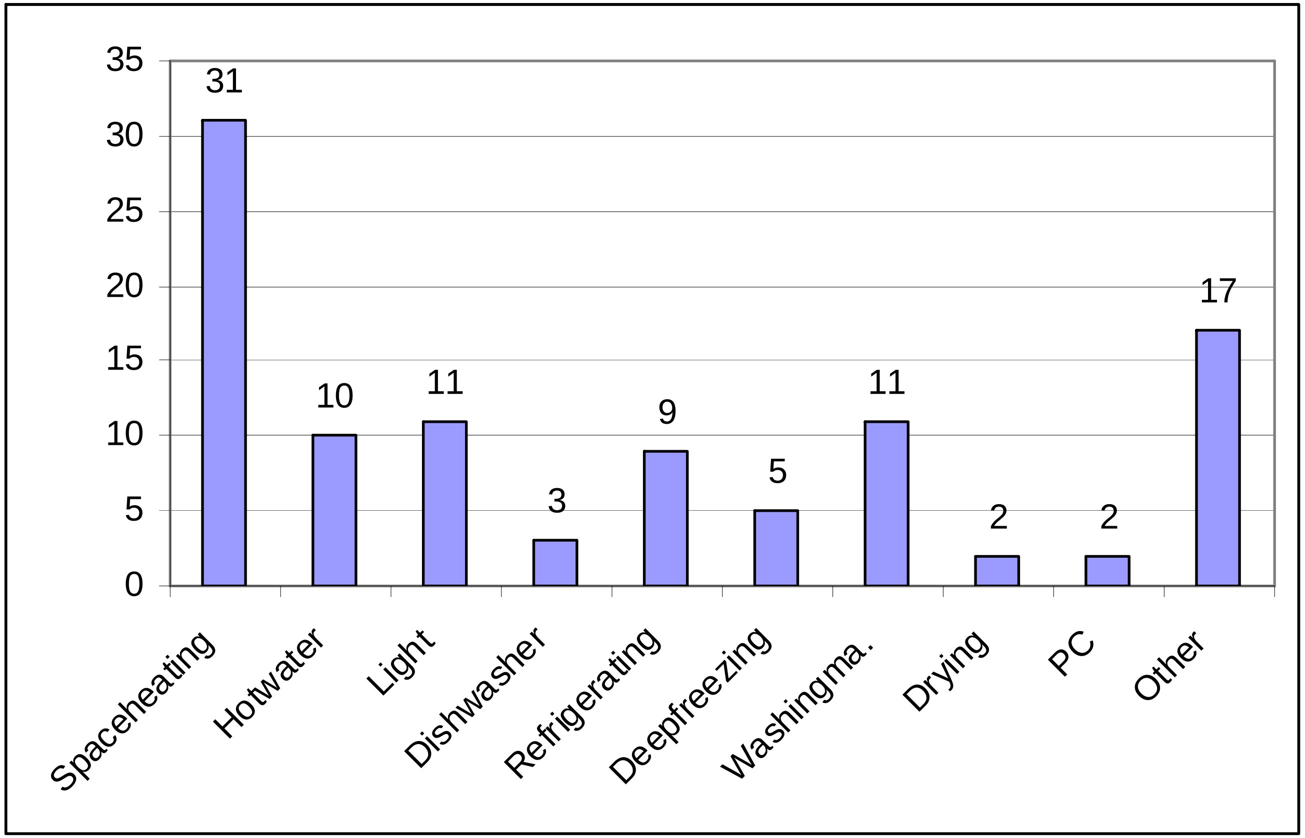
# Lecture plan Econ4930 Spring 2011

- 17 January Lecture 1. Introduction to electricity and hydropower
- 24 January Lecture 2.The formulation of a dynamic social planning problem
- 31 January Lecture 3. Understanding price changes over time
- 1 February Seminar 1
- 7 February Lecture 4. Multiple hydro plants and aggregation
- 14 February Lecture 5. Introducing thermal generating capacity
- 15 February Seminar 2
- 28 February Lecture 6. Introducing renewables (wind)
- 7 March Lecture 7. Trade between countries
- 8 March Seminar 3
- 14 March Lecture 8.Transmission network
- 21 March Lecture 9. Market power
- 22 March Seminar 4
- 28 March Lecture 10. Uncertainty
- 4 April Lecture 11. Market design
- 5 April Seminar 5
- 11 April Lecture 12
- 2 May Lecture 13
- 3 May Seminar 6

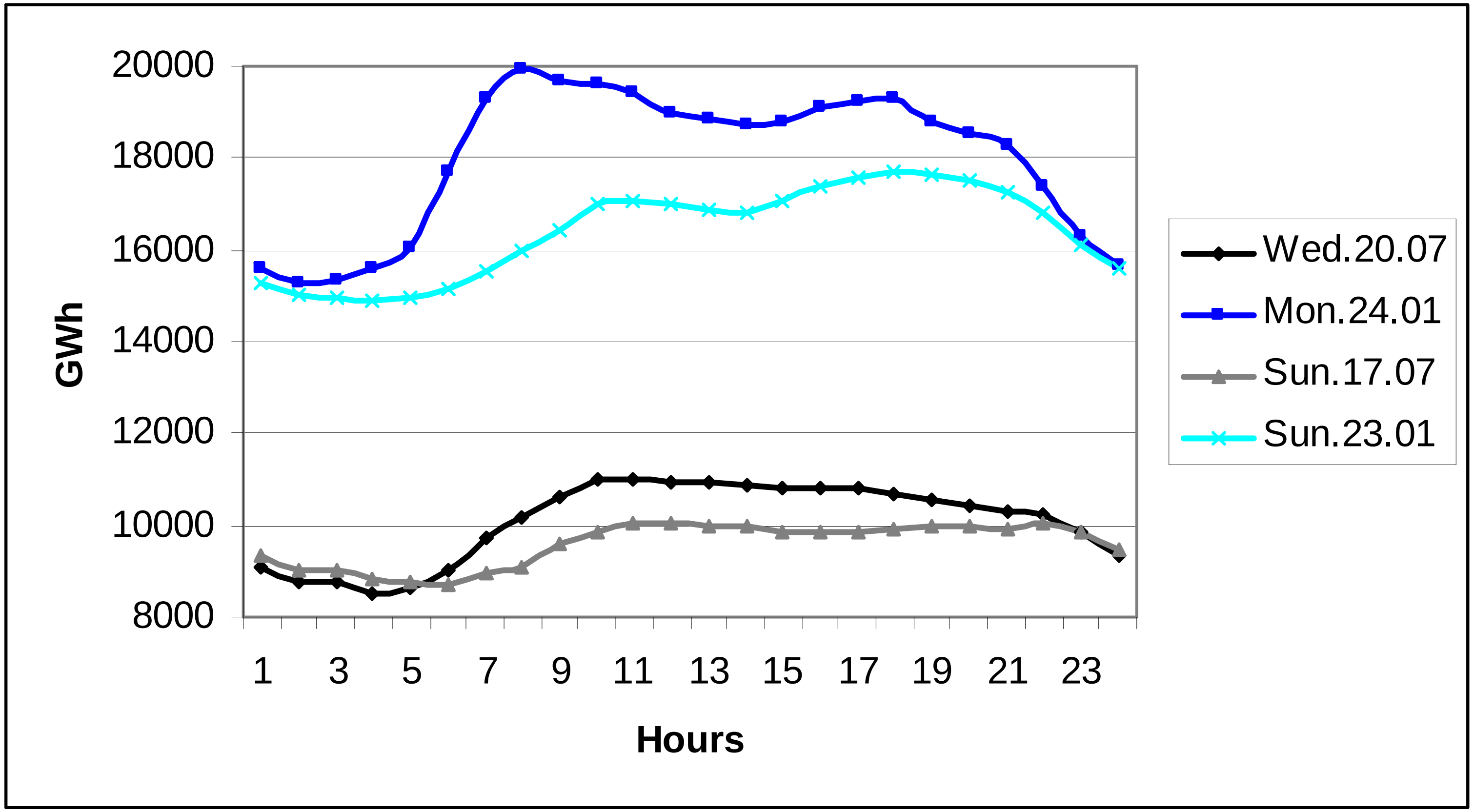
# Electricity

- One of the key goods in a modern economy
- Supply and demand must be in continuous physical equilibrium
- Transmission network links together supply and demand nodes
- Key variables
  - Power (kW)
  - Energy (kWh)
  - Voltage (kV)

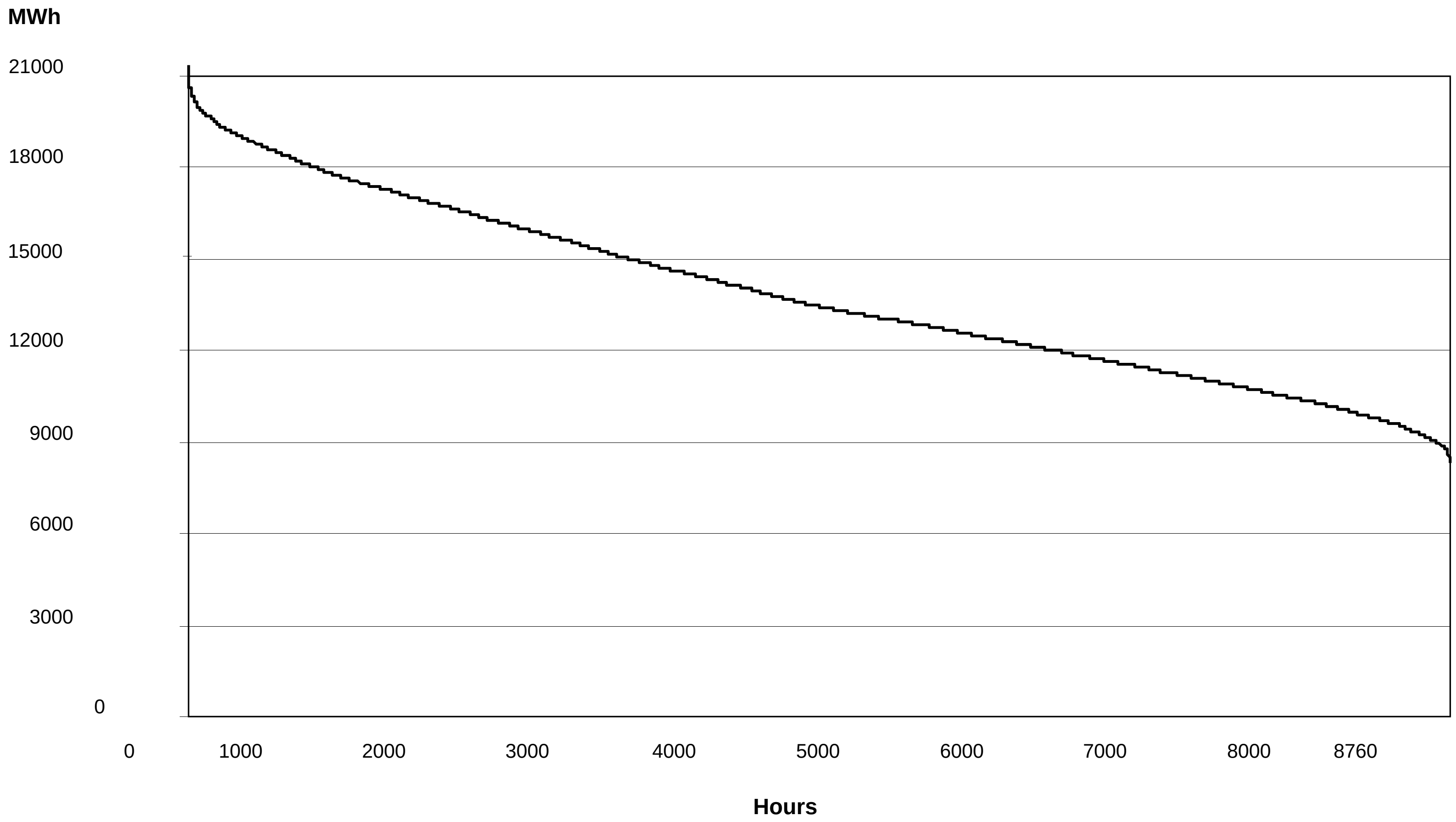
# The use of electricity in Norwegian households



# Load curves for consumption



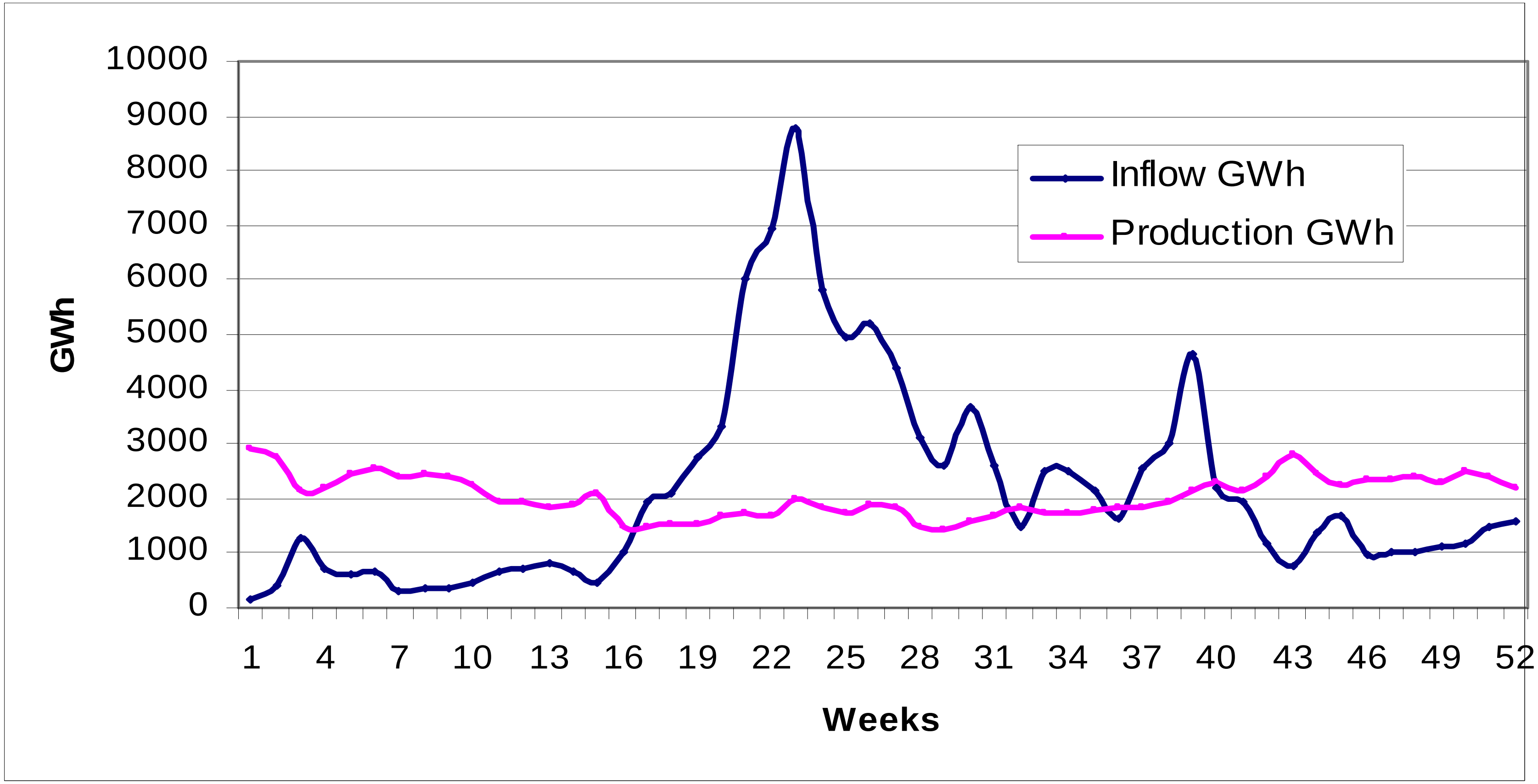
# Load-duration curve



# Hydropower

- The dynamics of water accumulation:
  $R_t \leqq R_{t-1} + w_t - r_t$ , $t$ =1,..,$T$
  - Reservoir, stock of water *R*
  - Inflows *w*
  - Releases *r*
- Inequality implies overflow
- Converting water from the dam to electricity
  $e^H{}_t \leqq (1/a)r_t$
- Fabrication coefficient *a* assumed to be constant

# Storage and production of hydropower in Norway 2003



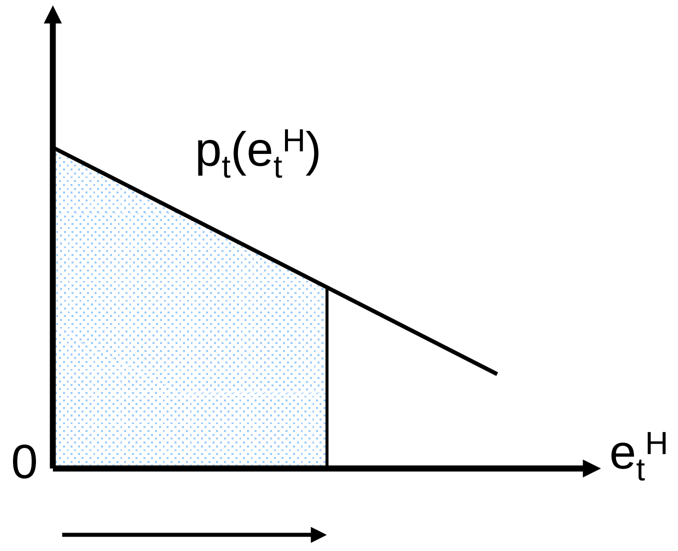
# A social planning problem

- The objective function: Maximising consumer plus producer surplus

$$\sum_{t=1}^{T} \int_{z=0}^{e_t^H} p_t(z)\,dz$$

- $e_t^H$ : consumption of hydropower in period t
- $p_t(e_t^H)$: demand function on price form, period t
- Discrete time, period from hour, week, month, season, year
- Variable production costs zero

- Illustration of the objective function




- Area under the demand curve

# A social planning problem, cont.

- Reservoir dynamics in energy variables

$$R_t \leq R_{t-1} + w_t - r_t = R_{t-1} + w_t - ae_t^H \Rightarrow$$

$$\frac{R_t}{a} \leq \frac{R_{t-1}}{a} + \frac{w_t}{a} - e_t^H$$

  – Assuming equality in the production function
- All variables expressed in energy units by deflating with the fabrication coefficient

# A social planning problem, cont.

$$\max \sum_{t=1}^{T} \int_{z=0}^{e_t^H} p_t(z)\,dz$$

subject to

$$R_t \leq R_{t-1} + w_t - e_t^H$$

$$R_t \leq \overline{R}$$

$$R_t, e_t^H \geq 0\ ,\ \ t = 1,..,T$$

$$T, w_t, R_o, \overline{R} \text{ given, } R_T \text{ free}$$