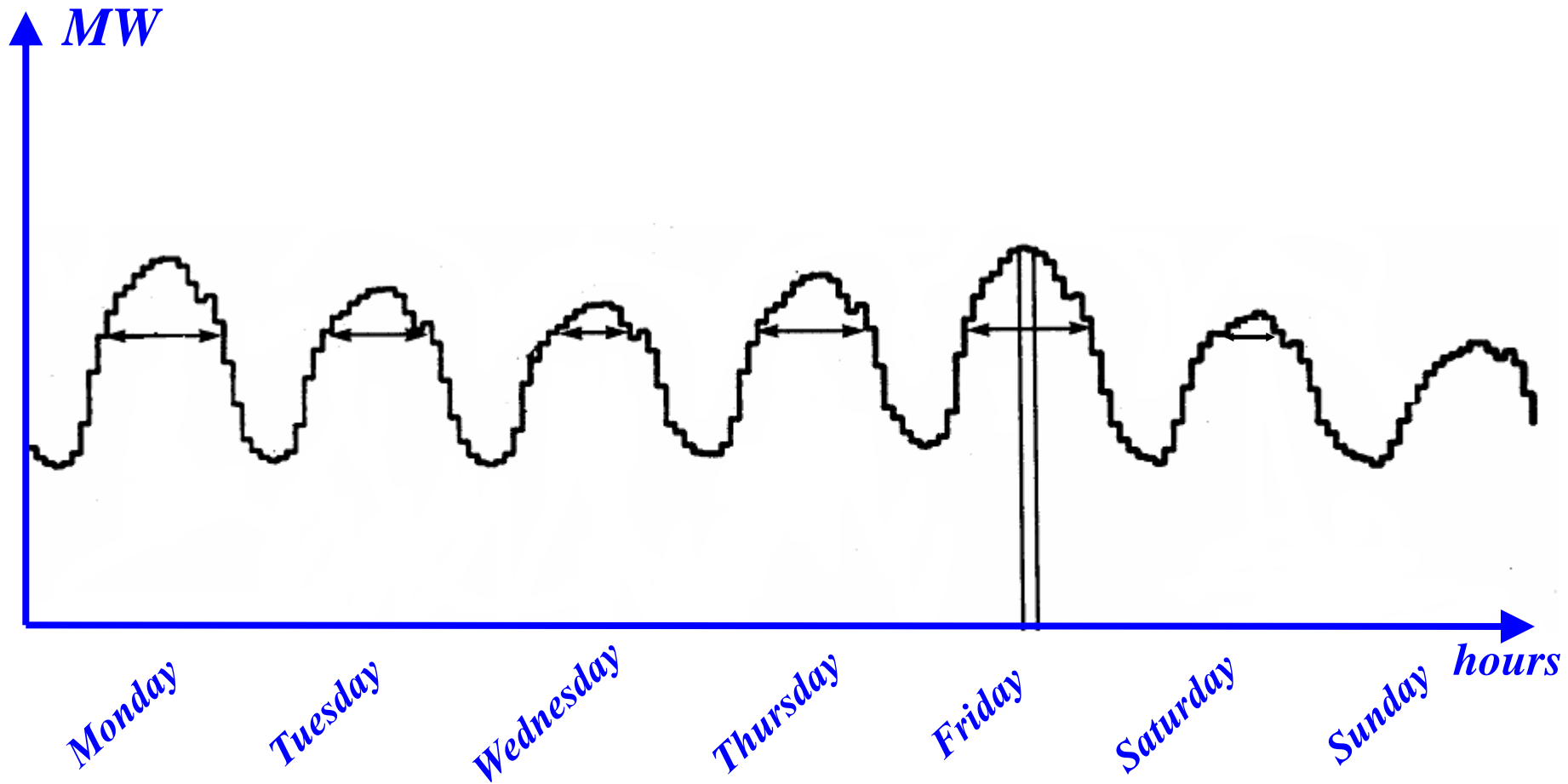

ECE 333 – Green Electric Energy

10. Basic Concepts in Power System Economics

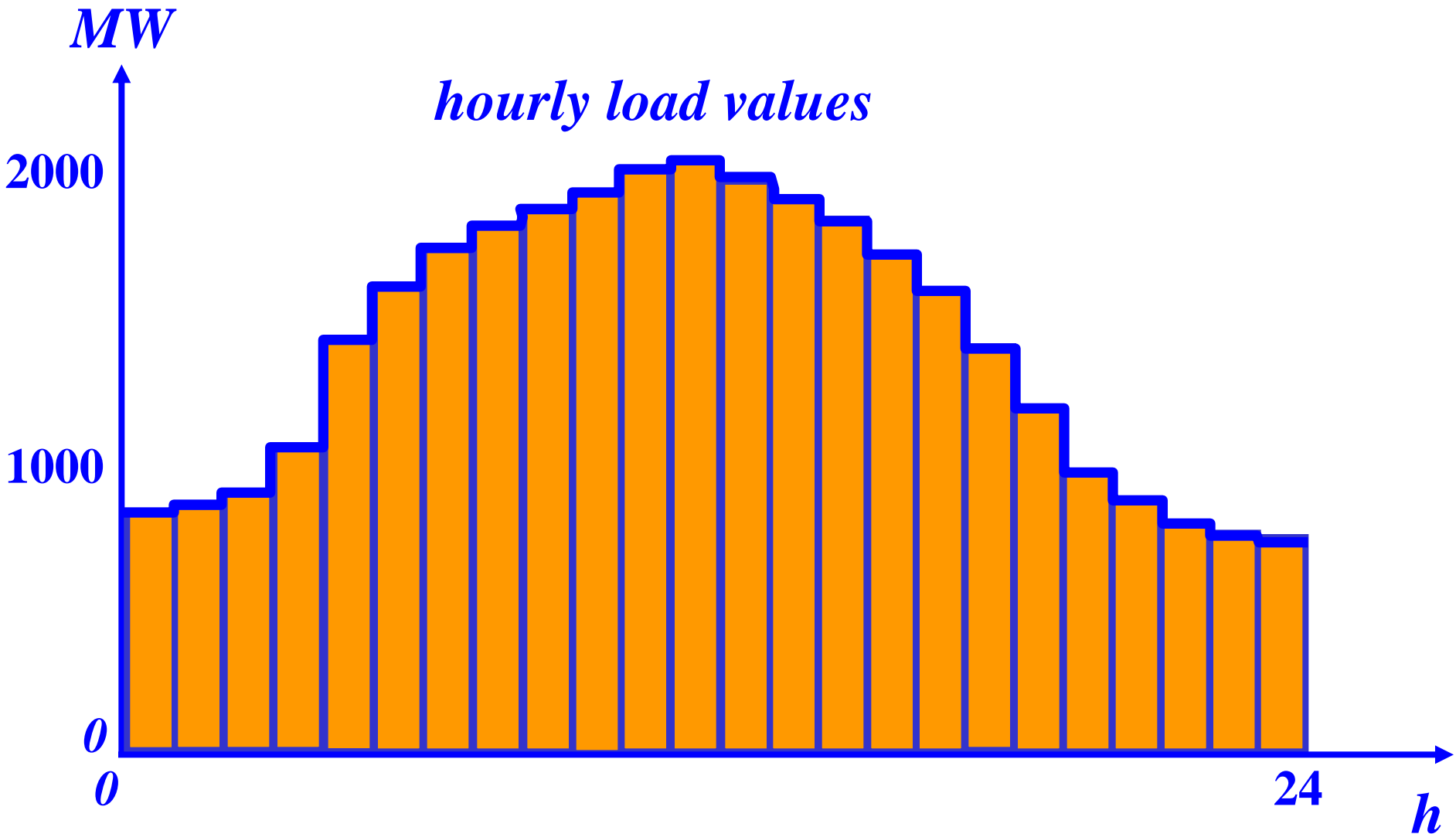
George Gross

**Department of Electrical and Computer Engineering
University of Illinois at Urbana-Champaign**

CHRONOLOGICAL LOAD FOR A SUMMER WEEK



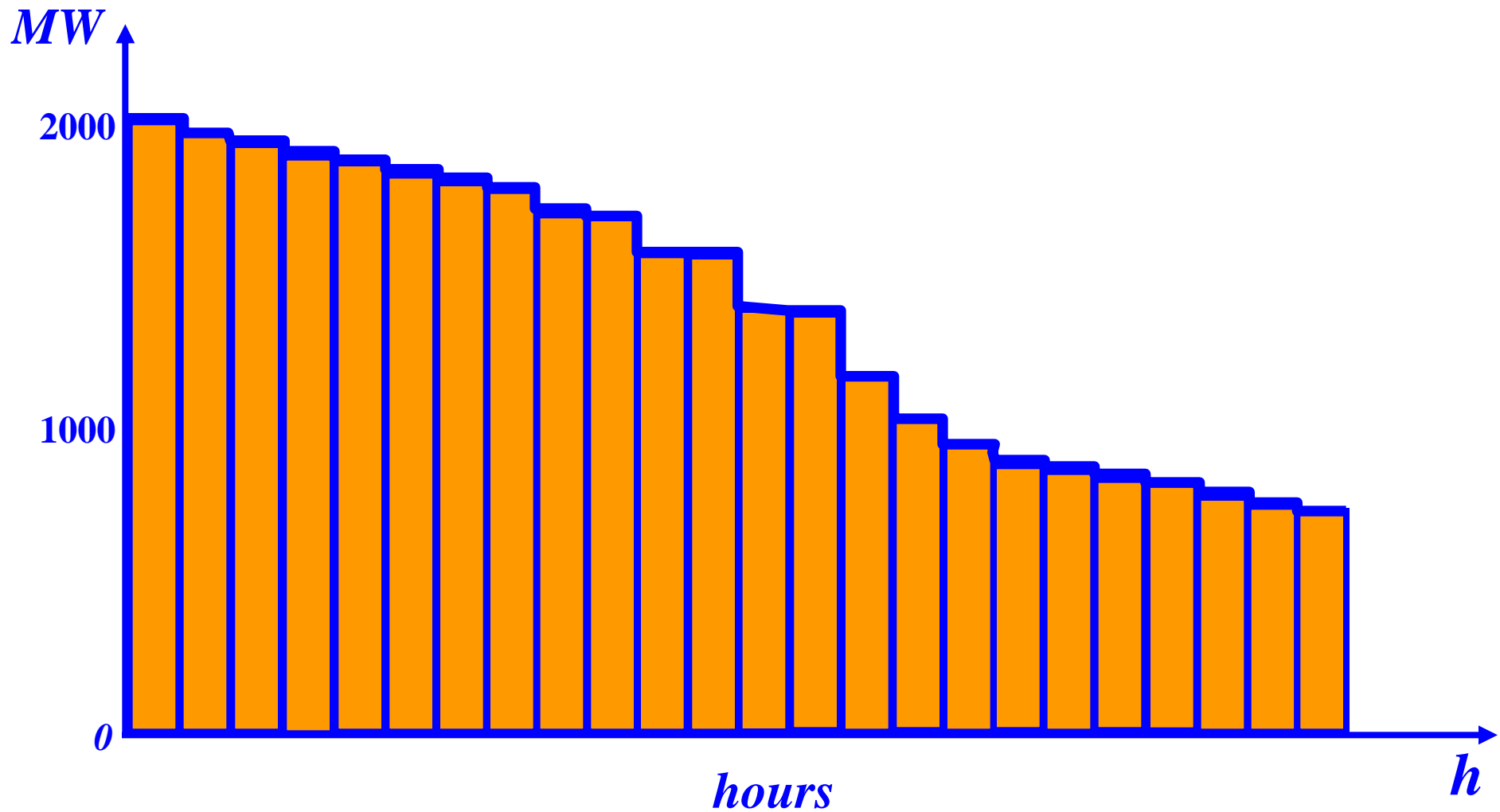
A WEEKDAY CHRONOLOGICAL LOAD CURVE



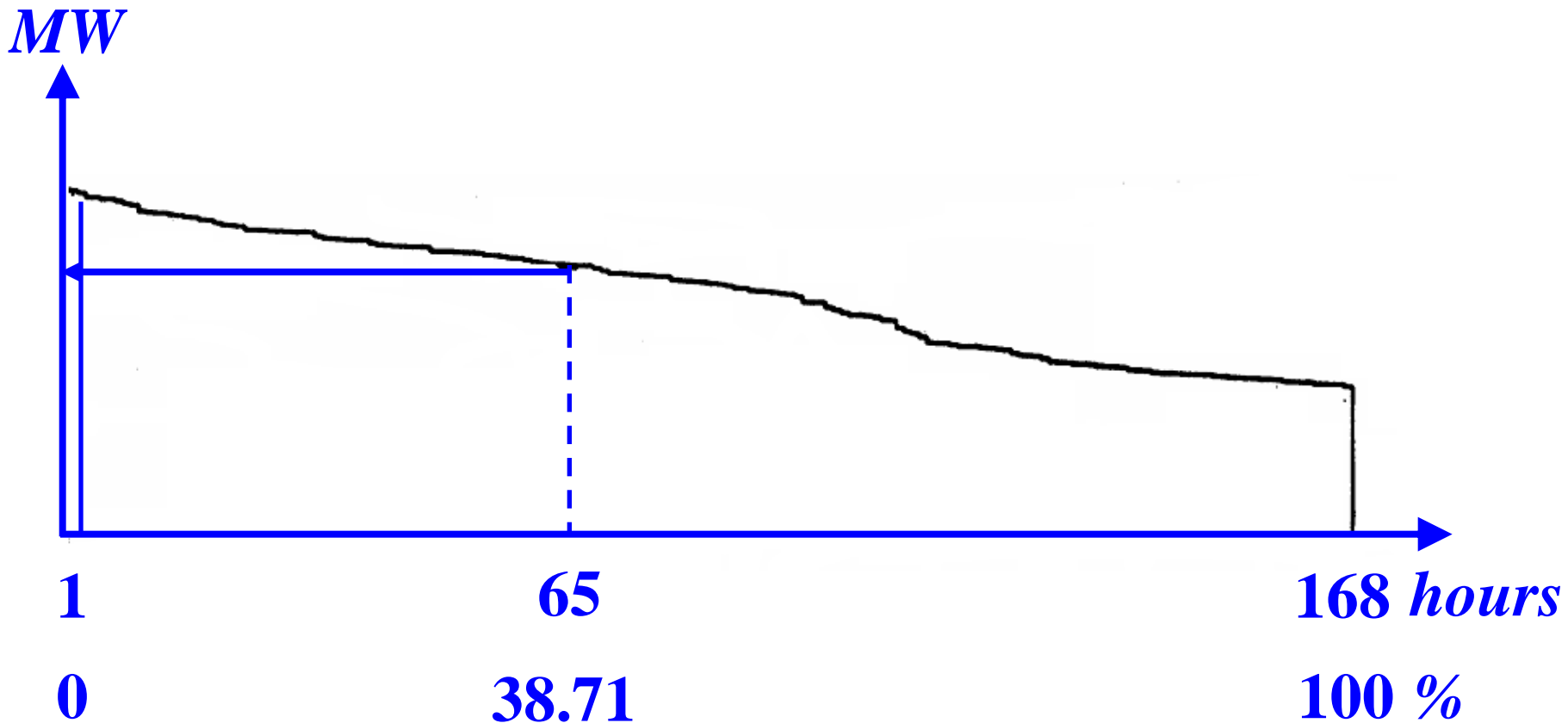
FRIDAY HOURLY LOAD VALUES

<i>h</i>	<i>load (MW)</i>	<i>h</i>	<i>load (MW)</i>
0100	820	1300	1900
0200	840	1400	1850
0300	885	1500	1780
0400	1010	1600	1680
0500	1375	1700	1550
0600	1560	1800	1370
0700	1690	1900	1130
0800	1775	2000	975
0900	1810	2100	875
1000	1875	2200	780
1100	1975	2300	775
1200	2000	2400	750

FRIDAY LOAD DURATION CURVE



LOAD DURATION CURVE FOR A SUMMER WEEK



LOAD DURATION CURVE CHARACTERISTICS

□ Inability to

- specify the load at any specific hour
- distinguish between weekday and weekend loads

□ Ability to

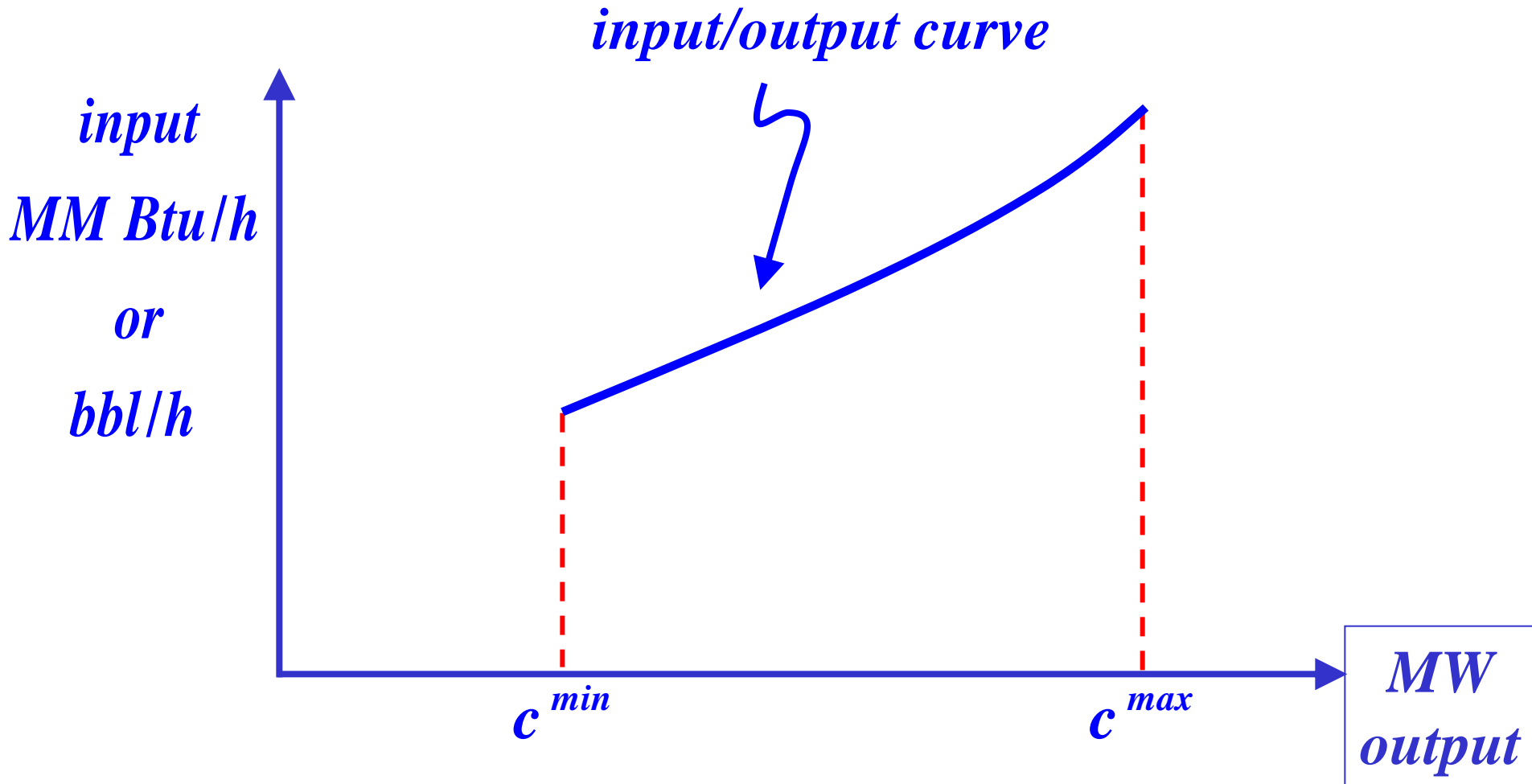
- specify the number of hours at which the load exceeds any given value
- Quantify of the total energy requirement for the specified period in terms of the area under the

LDC

GENERATION UNIT ECONOMICS

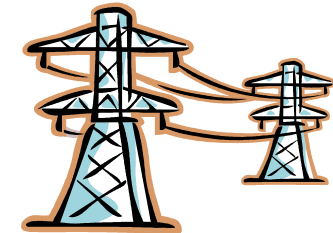
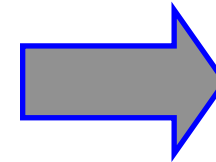
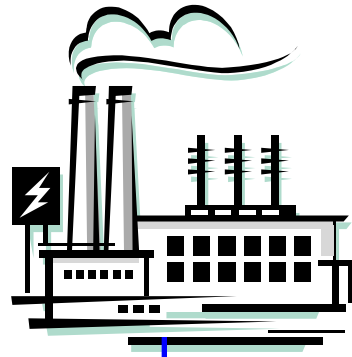
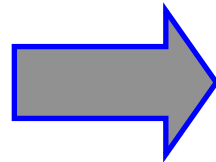
- The costs of generation for a unit are described by an *input-output function* which quantifies the level of input required to obtain a specific level of output
- Typically, such functions are obtained from actual measurements and have a monotonically non-decreasing form

GENERATION UNIT ECONOMICS



INPUT – OUTPUT MEASUREMENTS

heat input
(MMBtu/h)



output
(MWh/h)

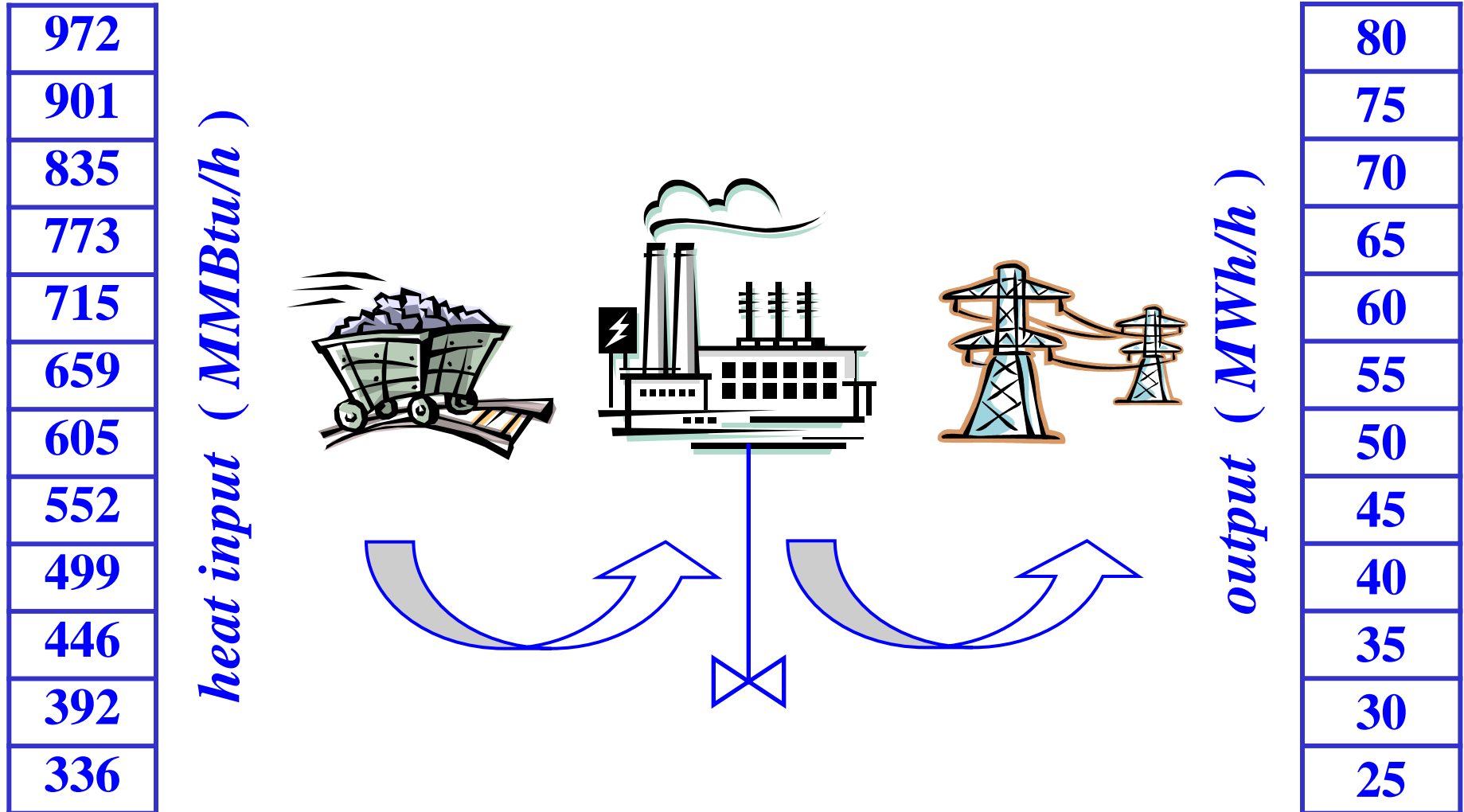
measurement
heat content &
flow-rate of fuel

measurement
energy
output

set control valve
points

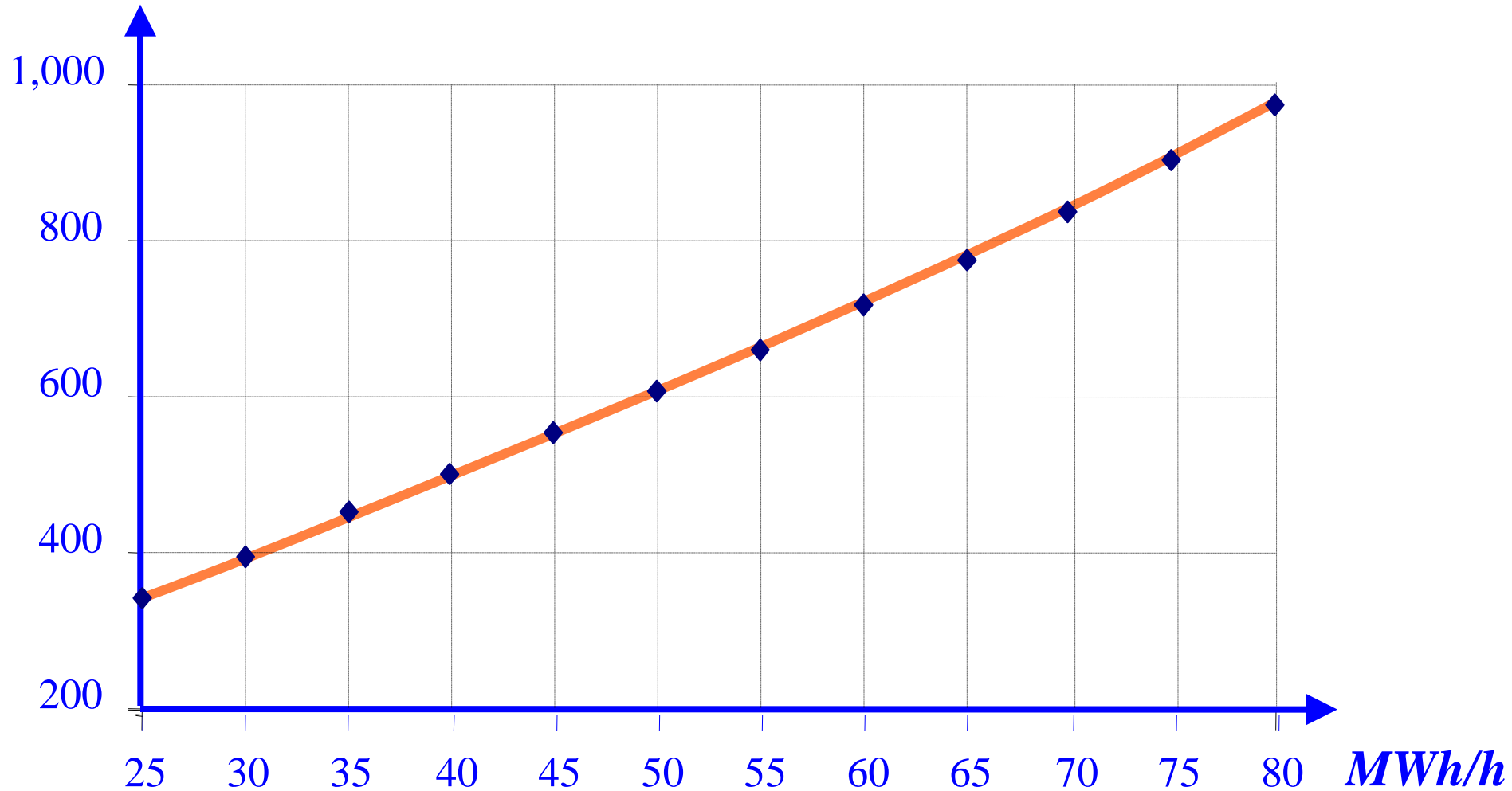
EXAMPLE :

CWLP DALLMAN UNITS 1 AND 2



CWLP DALLMAN UNITS 1 AND 2 INPUT – OUTPUT CURVE FITTING

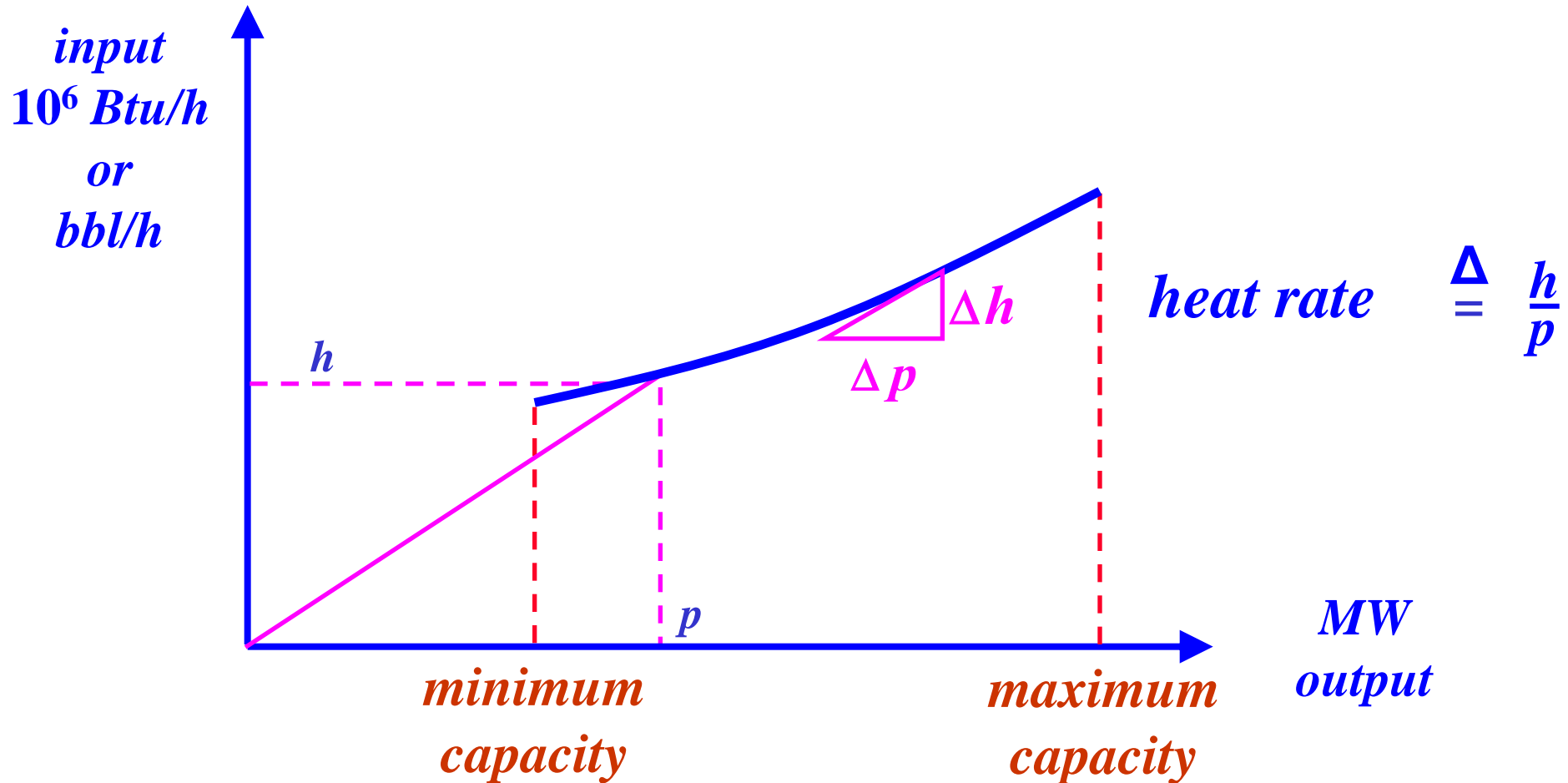
MMBtu/h



GENERATION UNIT ECONOMICS

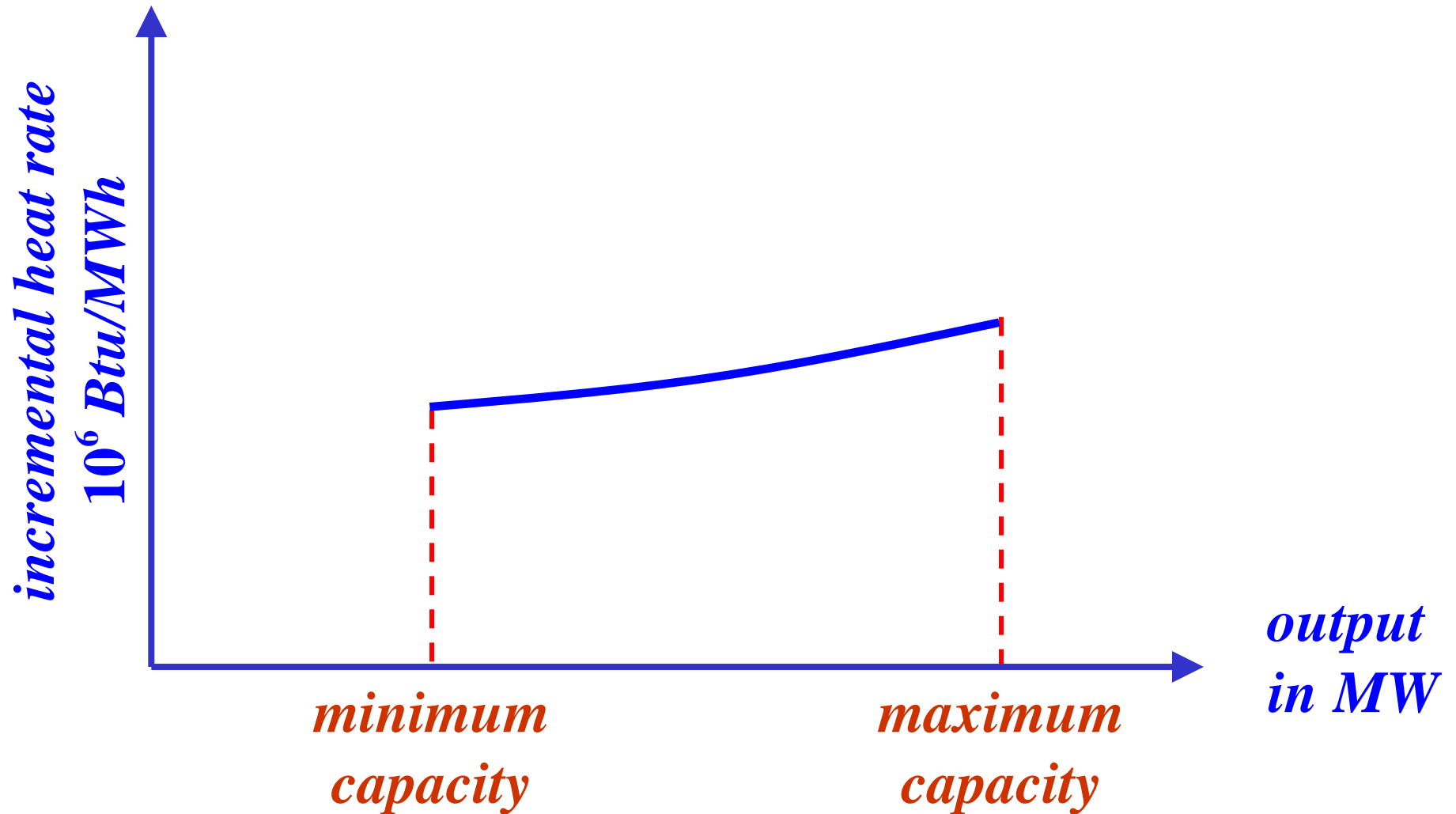
- The output is in MW and the input is in bbl/h or Btu/h (volume or thermal heat contents of the input fuel)
- We may also think of the abscissa in units $\$/h$ since the costs of the input are obtained by linearly scaling the fuel input with the unit price of the fuel
- We use the input-output curve to obtain the *incremental input-output curve* which provides the costs to generate an additional MWh at a given level of output

GENERATION UNIT ECONOMICS

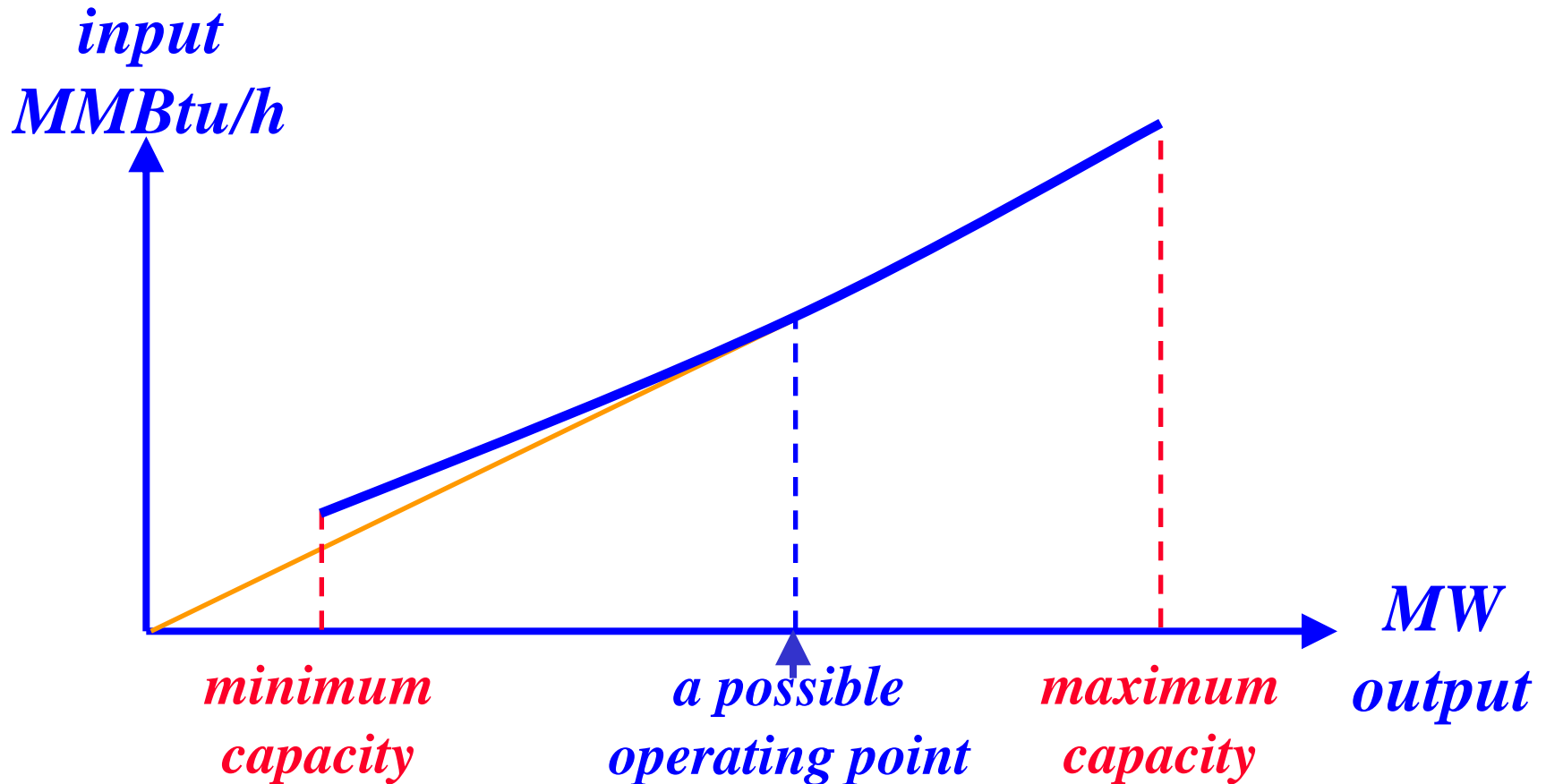


$$\text{incremental heat rate} = \frac{\Delta h}{\Delta p} = \text{incremental input output}$$

INCREMENTAL CHARACTERISTICS



HEAT RATE



$$\text{heat rate} = \frac{\text{input}}{\text{output}} \quad \text{incremental heat rate} = \frac{\text{incremental input}}{\text{incremental output}}$$

HEAT RATE

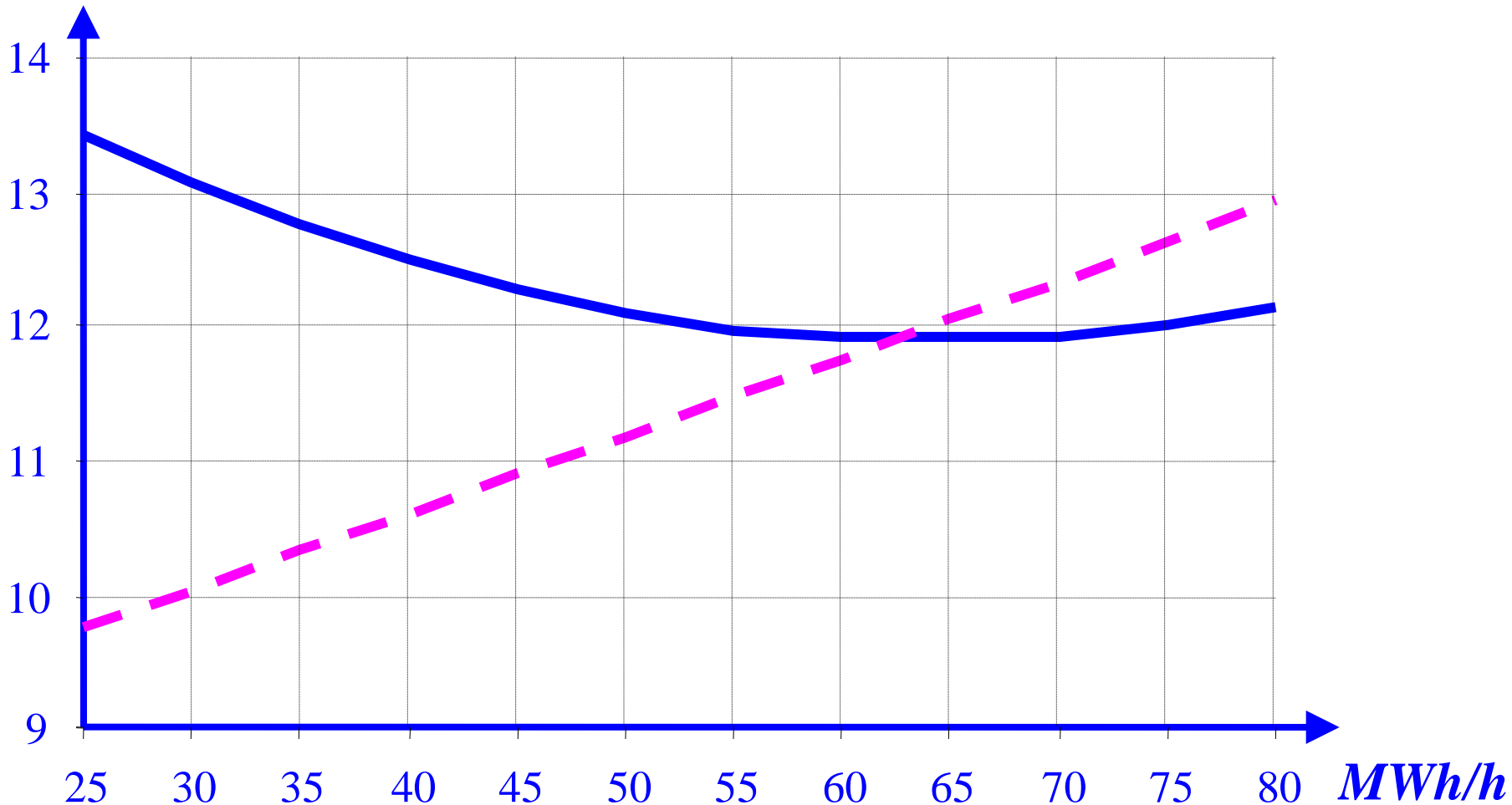
- ❑ The *heat rate* is a figure of merit widely used in the industry
- ❑ The *heat rate* gives the inverse of the efficiency measure of a generation unit since

$$H.R. = \frac{\textit{input}}{\textit{output}}$$

- ❑ The lower the *H.R.*, the higher is the efficiency of the resource

CWLP DALLMAN UNITS 1 AND 2 H. R. AND H. R. CURVES

MMBtu/MWh



— *heat rate (H.R.)* - - - *incremental heat rate (I.H.R.)*

GENERATOR CAPACITY FACTOR

- The amount of generation a generating unit produces is a function of
 - the generator capacity
 - the generator availability
 - the loading of the generator to meet load
- A 100 % available base-loaded unit with capacity c runs around the clock and so in a T -hour period generates total MWh given by

$$\mathcal{E} = cT$$

GENERATOR CAPACITY FACTOR

- The maximum it can generate is

$$\mathcal{E}_{max} = cT$$

- The capacity factor \mathcal{K} of a base-loaded unit is

$$\mathcal{K} = \frac{\mathcal{E}}{\mathcal{E}_{max}} = 1$$

- A cycling unit exhibits on – off behavior since its loading depends on the system demand; its

$\mathcal{E}_{max} = cT$ exceeds the actual generation since the unit generates only during certain periods

GENERATOR CAPACITY FACTOR

- Therefore, a cycling unit has a *c.f.*

$$K = \frac{\mathcal{E}}{\mathcal{E}_{max}} < 1$$

- For example, a cycling unit of 150 MW that operates typically 1,800 hours per year with no outages and at full capacity has

$$K = \frac{150 \cdot 1,800}{150 \cdot 8,760} = \frac{180}{876} = 0.21$$

- A peaking unit operates only for a few hours each year and consequently has a relatively small *c.f.*

GENERATOR CAPACITY FACTOR

- An expensive peaker may have, say, a capacity factor

$$\kappa = 5\%$$

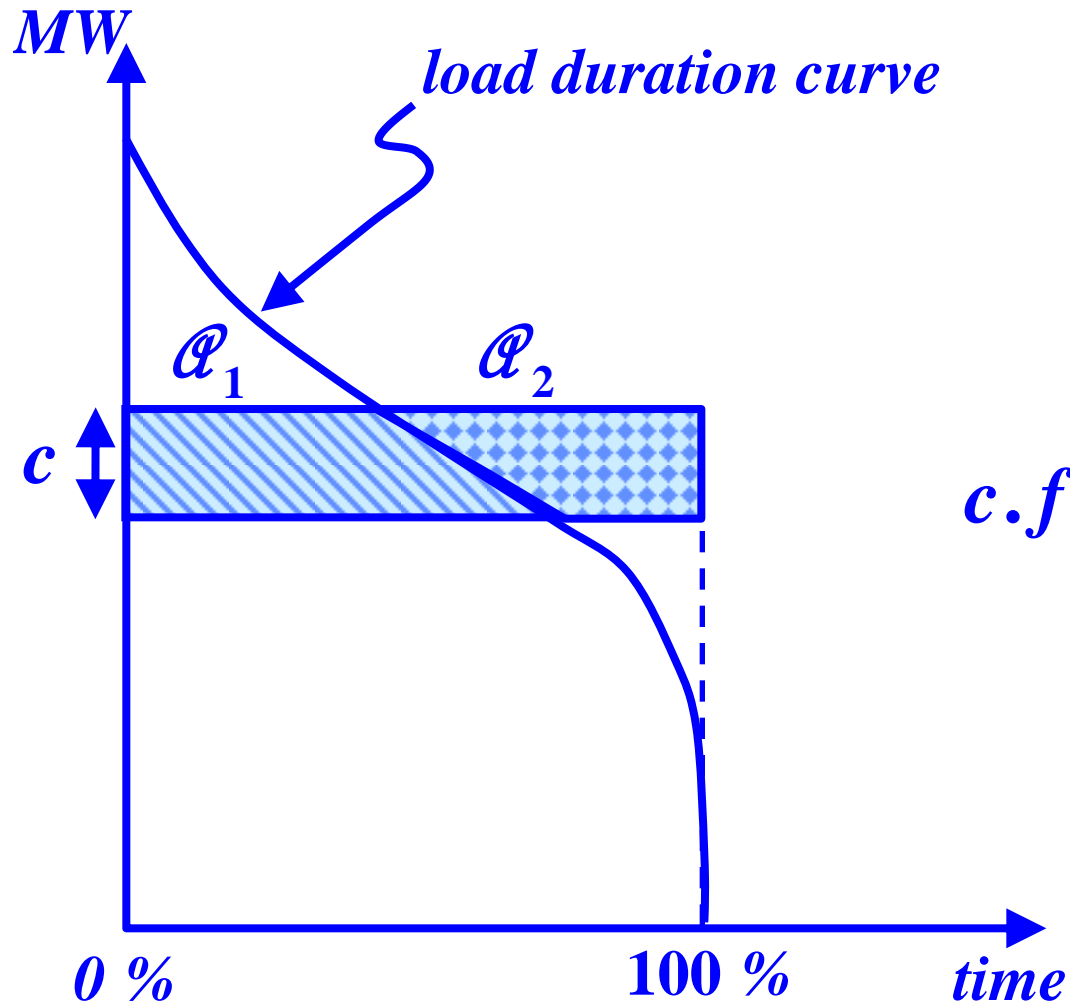
indicating that under perfect availability it operates 438 hours a year

- In general, κ is given a definition on a yearly basis

$$\kappa = \frac{\textit{annual energy generated}}{\textit{maximum energy generated}}$$

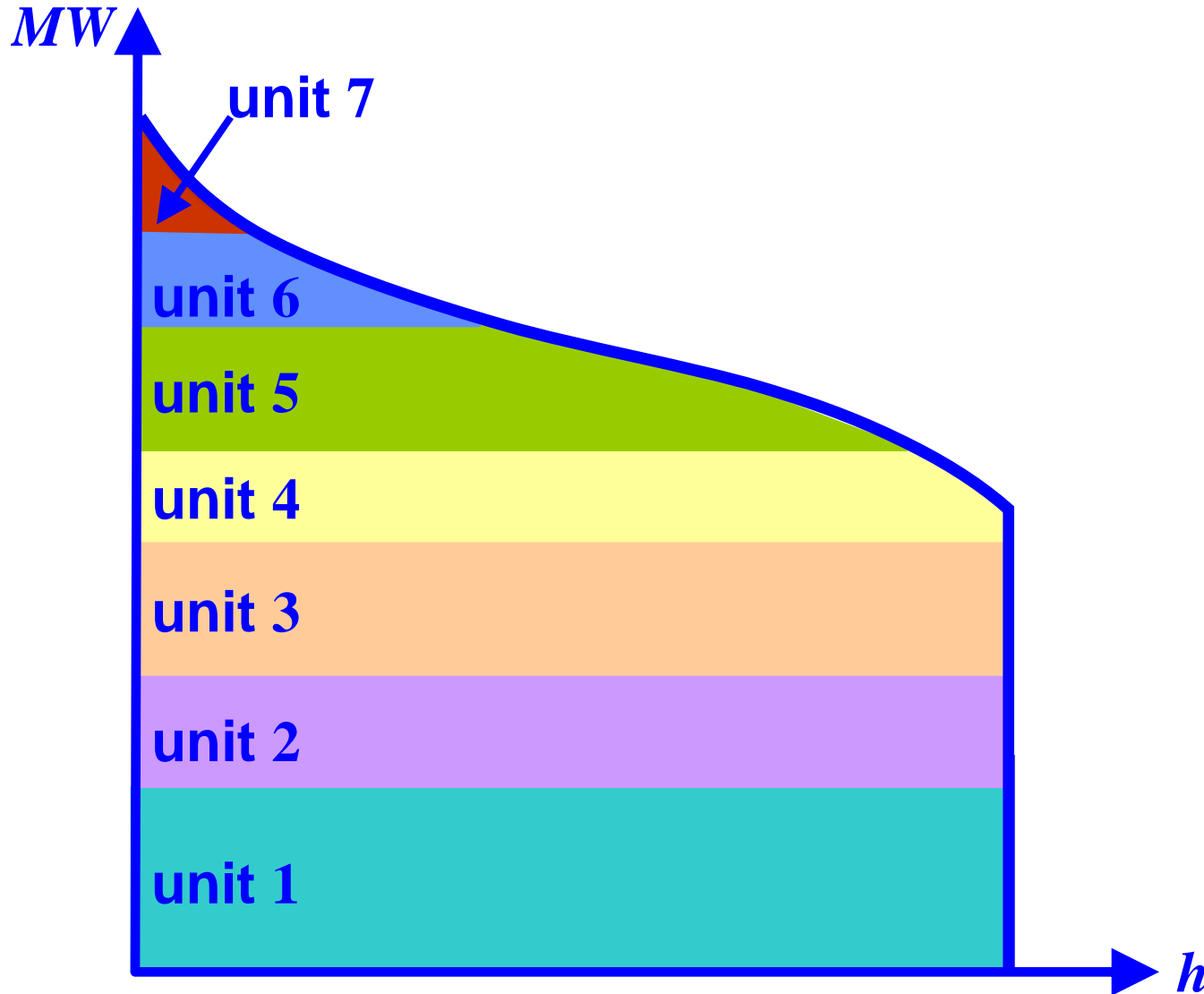
where, the denominator may account for annual maintenance and forced outages and so would imply less than 8,760 hours of operation

CAPACITY FACTOR

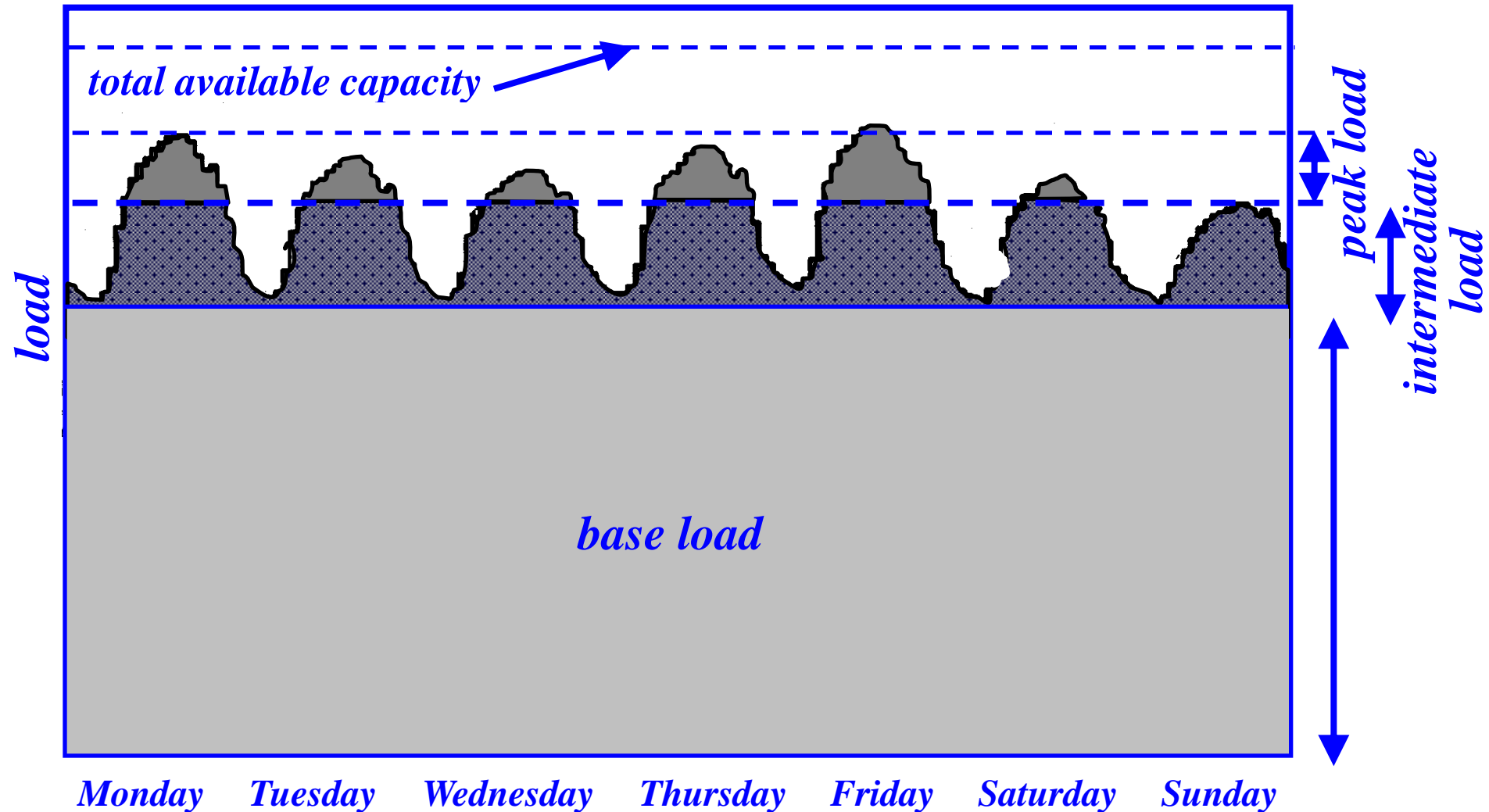


$$c.f. = \frac{Q_1}{(Q_1 + Q_2)}$$

LOADING OF RESOURCES



LOADING OF RESOURCES



RESOURCE FIXED AND VARIABLE COSTS

- ❑ Fixed costs are those costs incurred that are independent of the operation of a resource and are incurred even if the resource is not operating
- ❑ Typical components of fixed costs are:
 - investment or capital costs
 - insurance
 - fixed *O&M*
 - taxes

RESOURCE FIXED AND VARIABLE COSTS

- Variable costs are associated with the actual operation of a resource

- Key components of variable costs are
 - fuel costs

 - variable *O&M*

 - emission costs

ANNUALIZED INVESTMENT OR CAPITAL COSTS

□ The *fixed charge rate* annualizes the capital costs to produce a yearly uniform cash–flow set over the life of a resource

□ The annual fixed costs are

$$\textit{yearly costs} = (\textit{fixed costs}) \cdot (\textit{fixed charged rate})$$

□ Typically, the yearly charge is given on a per unit

– *kW* or *MW* – basis

ANNUALIZED INVESTMENT OR CAPITAL COSTS

- ❑ The fixed charge rate takes into account the interest on loans, acceptable returns for investors and other fixed cost components: however, each component is independent of the generated *MWh*
- ❑ The rate strongly depends on the costs of capital

ANNUALIZED VARIABLE COSTS

- The variable costs are a function of the number of hours of operation of the unit or equivalently of the capacity factor κ
- The annualized variable costs may vary from year to year

$$\text{variable costs} = \left[\left(\begin{matrix} \text{fuel} \\ \text{costs} \end{matrix} \right) \left(\begin{matrix} \text{heat} \\ \text{rate} \end{matrix} \right) + \left(\begin{matrix} \text{variable} \\ \text{O \& M costs} \end{matrix} \right) \right] \left(\begin{matrix} \text{number of} \\ \text{hours} \end{matrix} \right)$$

ANNUALIZED VARIABLE COSTS

- ❑ The yearly variable costs explicitly account for
fuel cost escalation
- ❑ Often, the yearly costs are given on a *per unit – kW*
or *MW – basis*
- ❑ We illustrate these concepts with a pulverized –
coal steam plant

EXAMPLE: COAL-FIRED STEAM PLANT

<i>characteristic</i>	<i>value</i>	<i>units</i>
<i>capital costs</i>	1,400	<i>\$/kW</i>
<i>heat rate</i>	9,700	<i>Btu/ kWh</i>
<i>fuel costs</i>	1.5	<i>\$/MBtu</i>
<i>variable O&M costs</i>	0.0043	<i>\$/kWh</i>
<i>annual fixed charge rate</i>	0.16	
<i>full output period</i>	8,000	<i>h</i>

EXAMPLE: COAL-FIRED STEAM PLANT

- The annualized fixed costs per kW are

$$(1,400 \text{ \$ / kW})(0.16) = 224 \text{ \$ / kW}$$

- The initial year annual variable costs per kW are

$$\left[\begin{array}{l} (1.5 \times 10^{-6} \text{ \$ / Btu})(9,700 \text{ Btu / kWh}) + \\ 0.0043 \text{ \$ / kWh} \end{array} \right] (8,000 \text{ h})$$

$$= 150.8 \text{ \$ / kW}$$

EXAMPLE: COAL-FIRED STEAM PLANT

- Total annual costs for 8,000 h are

$$\frac{(224 + 150.8) \$ / kW}{8000 h} = 0.0469 \$ / kWh$$

- Note, we do the example under the assumption of full output for 8,000 h and 0 output for the remaining 760 h of the year
- We also neglect any possible outages of the unit and so ignore any uncertainty in the unit performance