Nazarbayev University Kazakhstan
Energy Transitions:
Exploring the nexus of Sustainability, Economy and Climate

Electricity economics

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Understanding basics of the economics vocabulary and underlying theoretical ideas.

Overview:

- Discourse and elusive truths
- Basic concepts about markets
- Marginal cost pricing
- Marginal costs in a planned power system (Lambda values)
- Electricity pricing in practice
- Fringe prices
- Future electricity generation needs new electricity economics

Discourse and delusive-truth

Ideas, myths, narratives, discourse, symbols, … are highly influential in human societies since all times.

Religions are built around scriptures of prophets, masters, leaders, … Some include moral norms (Zarathustra), some reflect human acts (Greek-Roman mythology)

Secular societies create ideologies, like capitalism, socialism, liberalism.

Since the 1970s, the neoliberalism discourse reigns, with *free markets* as façade

Delusive-truth **(far more effective deceit than *fake news*)**

Construct counterfeit on a truth, e.g., mathematical theorem, law of physics, fact.

Archimedes *Give me a firm place to stand and a lever and I can move the Earth*.
Truth is the lever multiplying force. Man moving the earth is illusion, deceit.

Free market

Neoclassical economic theory is an assemblage of mathematical theorems, truth façade of neoliberalism, while big money and corporations destroy free markets.

In 2022, European electricity corporations used *marginal cost pricing* as the truth for deluding politicians, media and academics while capturing super-profits.

Basic concepts about markets

The economist market theory

A market consists of a *demand* for goods or services and a *supply* thereof

A market is *free* when participation as buyer or seller is a *free choice* of the participant; the opposite of mischievous power abuse by the strongest companies

A market is *competitive* when sufficient quantities of buyers and suppliers preclude participants to manipulate the market process

The economist market equilibrium

Market demand is the *aggregate of the marginal benefit curves* of numerous buyers

Market supply is the *aggregate of the marginal cost curves* of numerous sellers

Where demand and supply cross, the *equilibrium quantity and price* are established

This *bliss point maximizes welfare*, being the sum of consumer and producer surplus

Important to remind

A market realizes the astonishing results only when *all conditions are fulfilled*

Imperfect markets fail basicly on one or more condition

Markets are human-made institutions, installed, manipulated, regulated by humans

Marginal cost pricing

Utilitarian optimation

Buyers of goods & services are considered to maximize their economic *utility*

Sellers are considered to maximize their economic *profits*.

Profit maximation

Profits = Revenues – Costs = Price x Quantity – Costs = P.q – C(q)

The first order condition of maximum profit is: P –MC(q) = 0 or:

$$P^* = MC(q)$$

This golden rule is simple on paper, however rarely observed in real business practices

Marginal Cost (MC) pricing in electricity generation

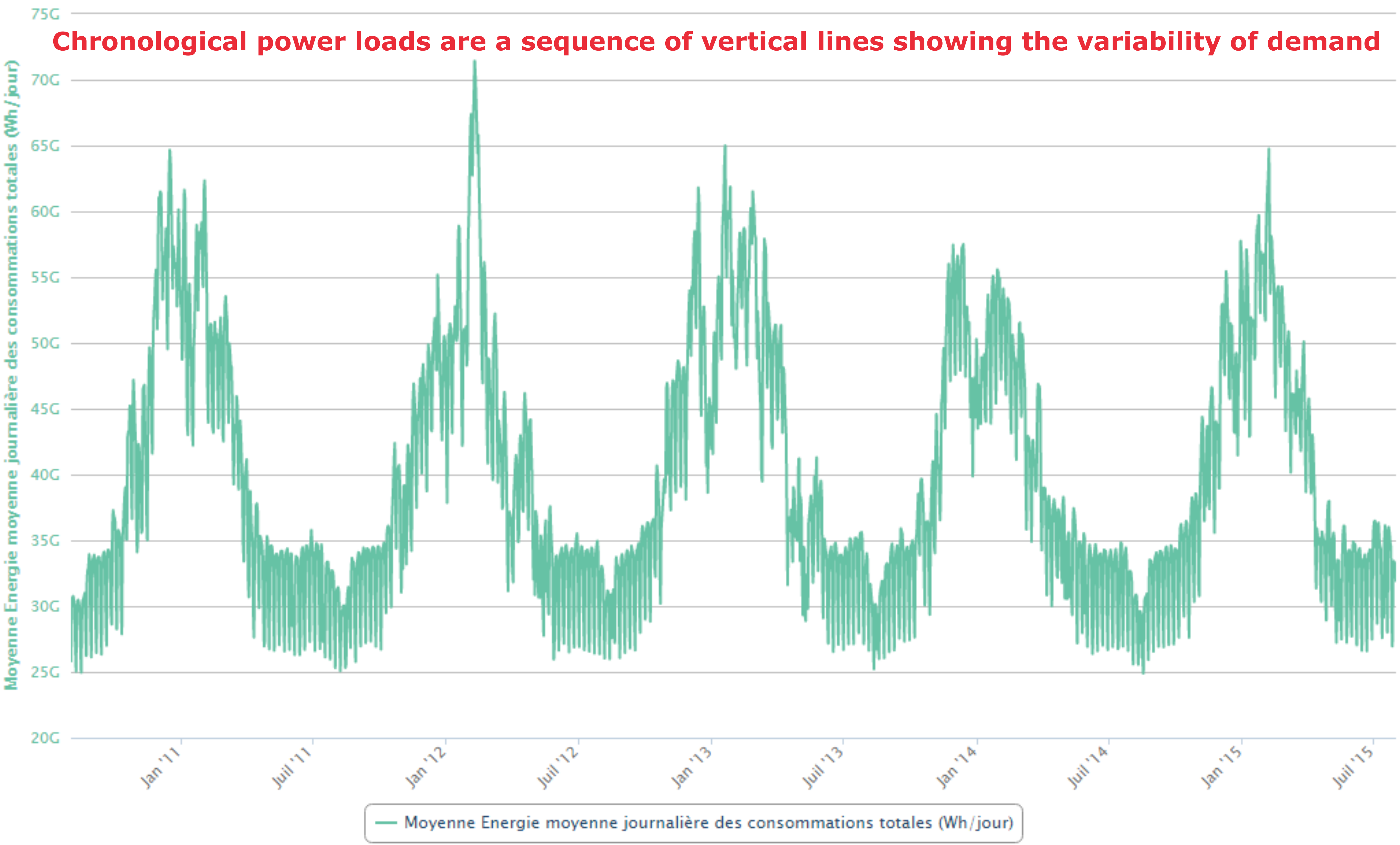
Electricity generation is one of the few economic activities where MC-pricing is tried

(M. Boiteux, CEO Electricité de France, was a pioneer in theory and application)

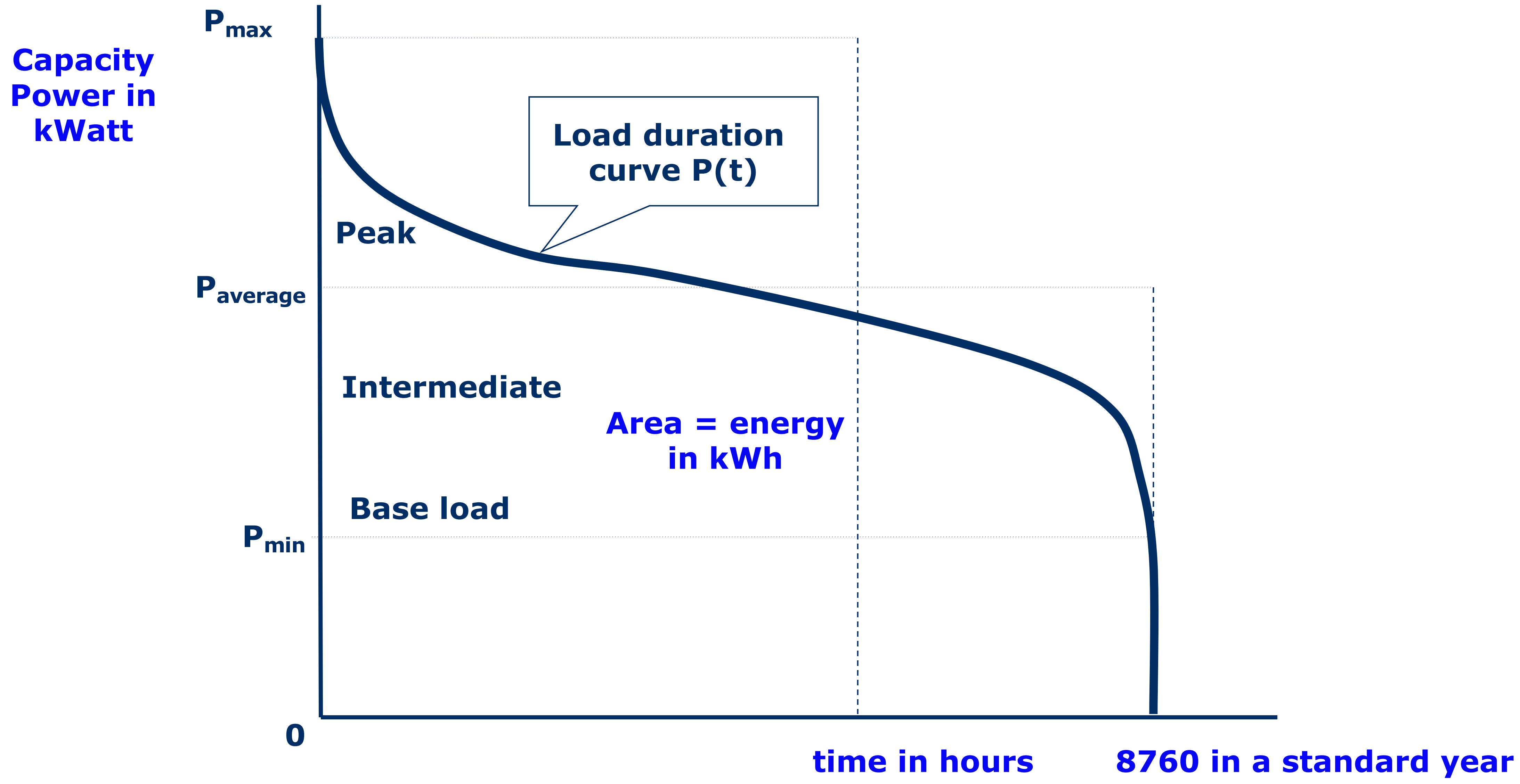
The context of the trials was a public vertical integrated monopoly supplier, with control over practically all power generation plants, being thermal or dam hydro.

It is instructive to review the basic theory

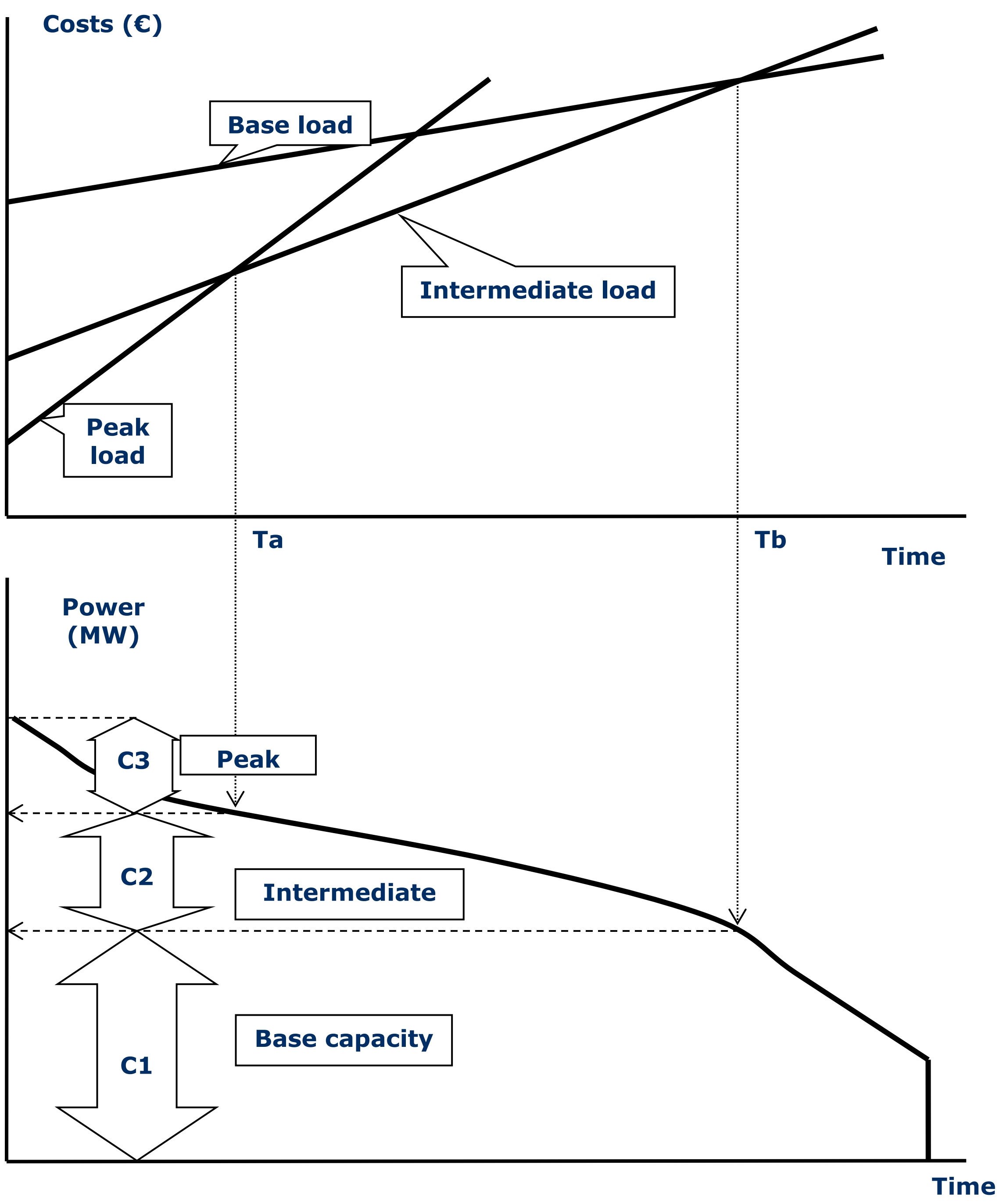
Chronological power loads are a sequence of vertical lines showing the variability of demand



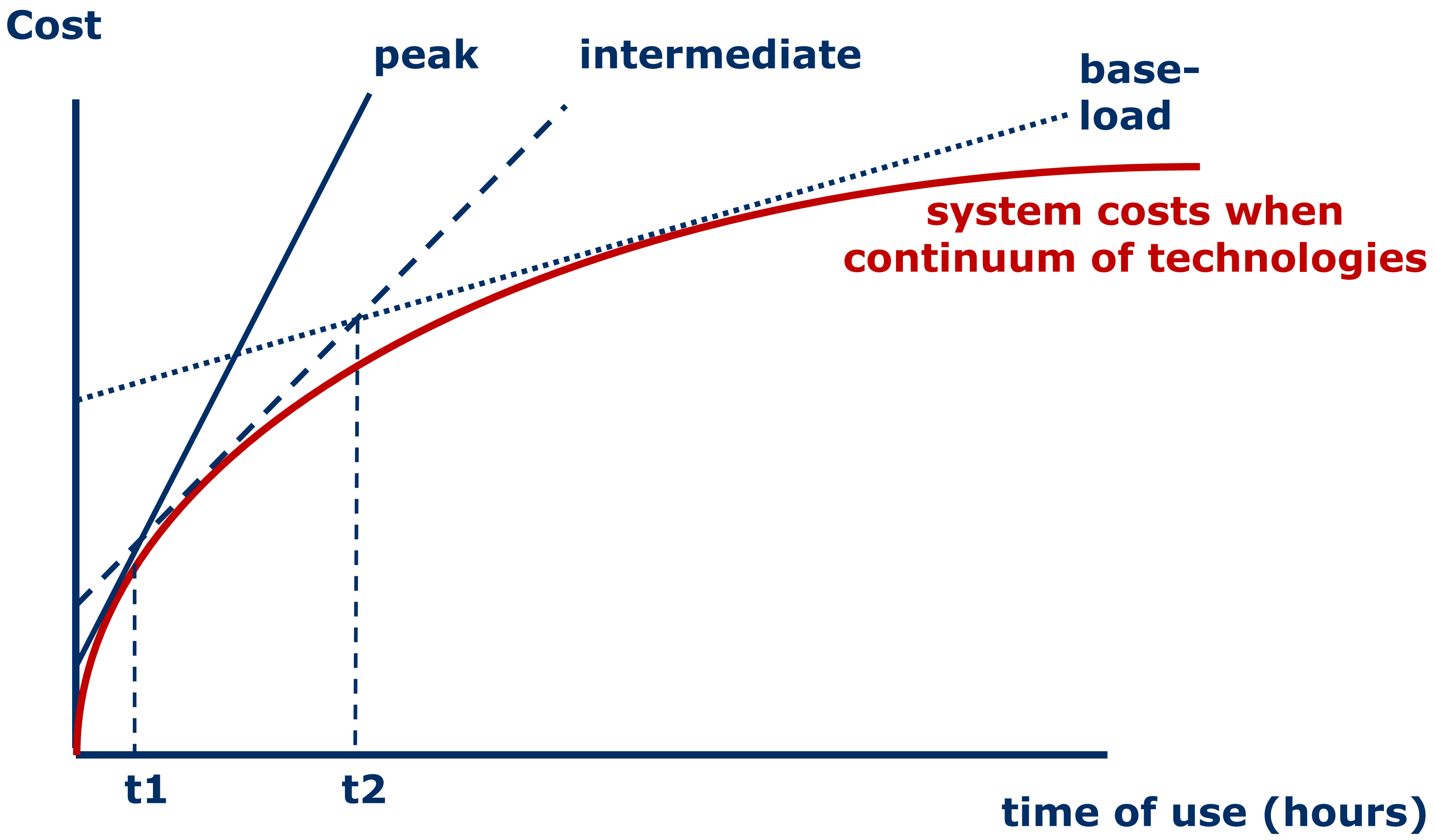
For comprehending electric loads, chronological data are reordered to Load duration curves



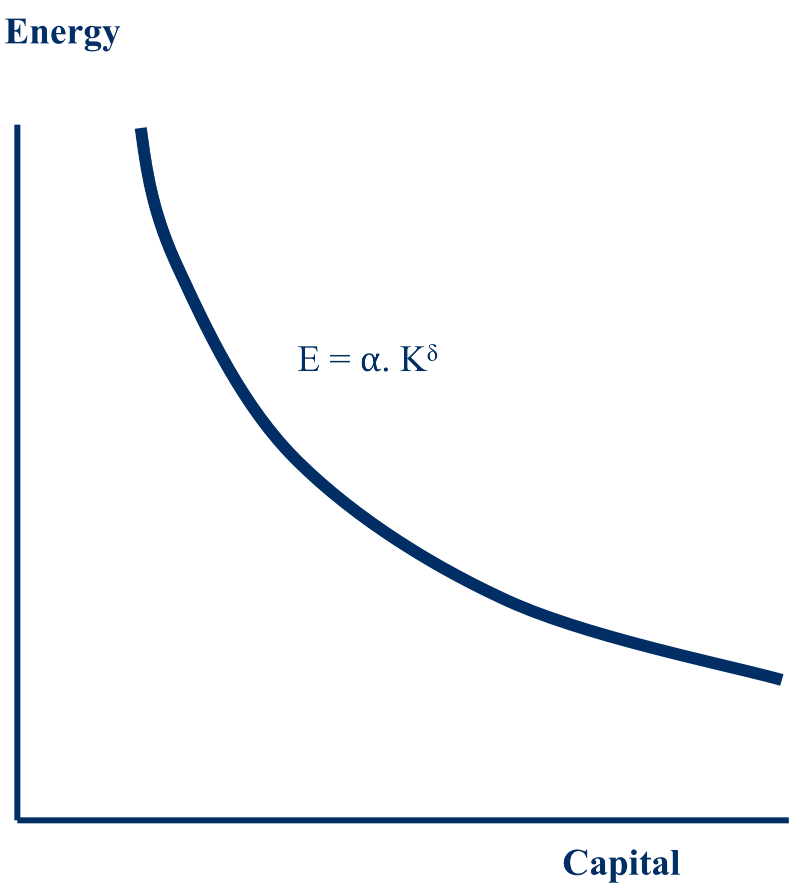
Optimal composition of integrated power generation system



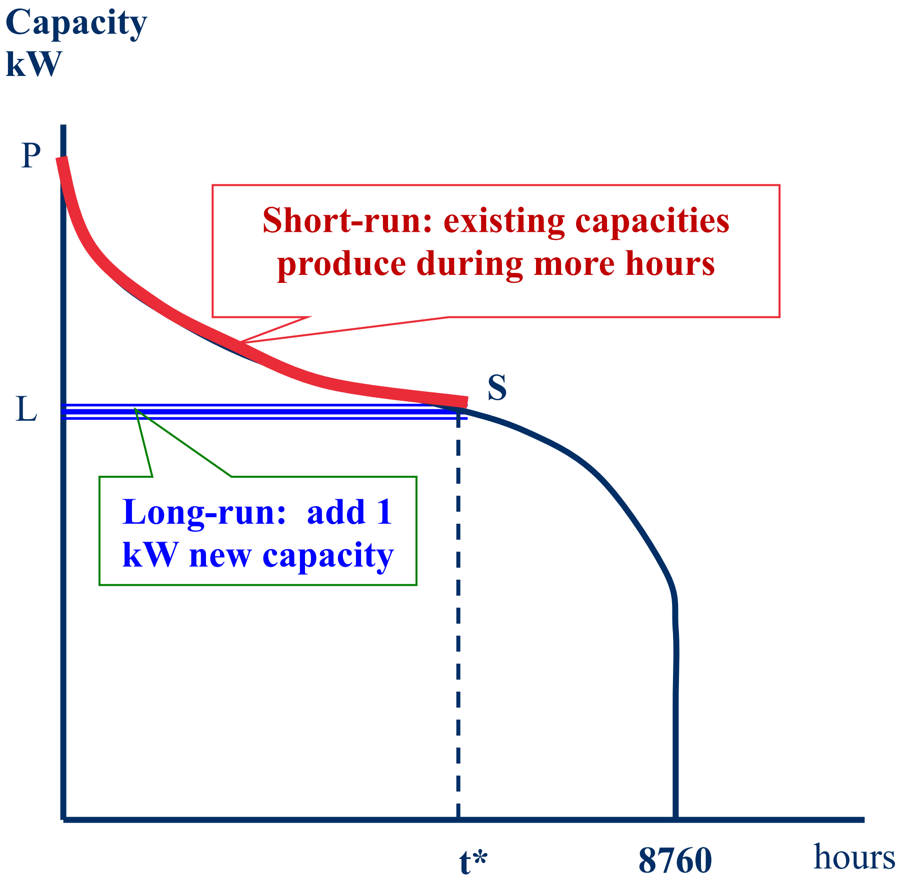
Electricity Supply: Long-run Marginal Costs



A continuum of Technologies = Combinations of production factors Capital and Energy: Optimal, least-cost composition means equality of Long-run and Short-run costs



Production ISOQUANT, continuum of Energy-Capital combinations for generating electricity



Load Duration curve. Meeting 1kW load extra during t* hours: by new capacity (blue) or by longer running of existing capacities (brown)

Lagrange Optimal operation of an optimal composed power system through minimizing the Operational Costs OC of the generating plants

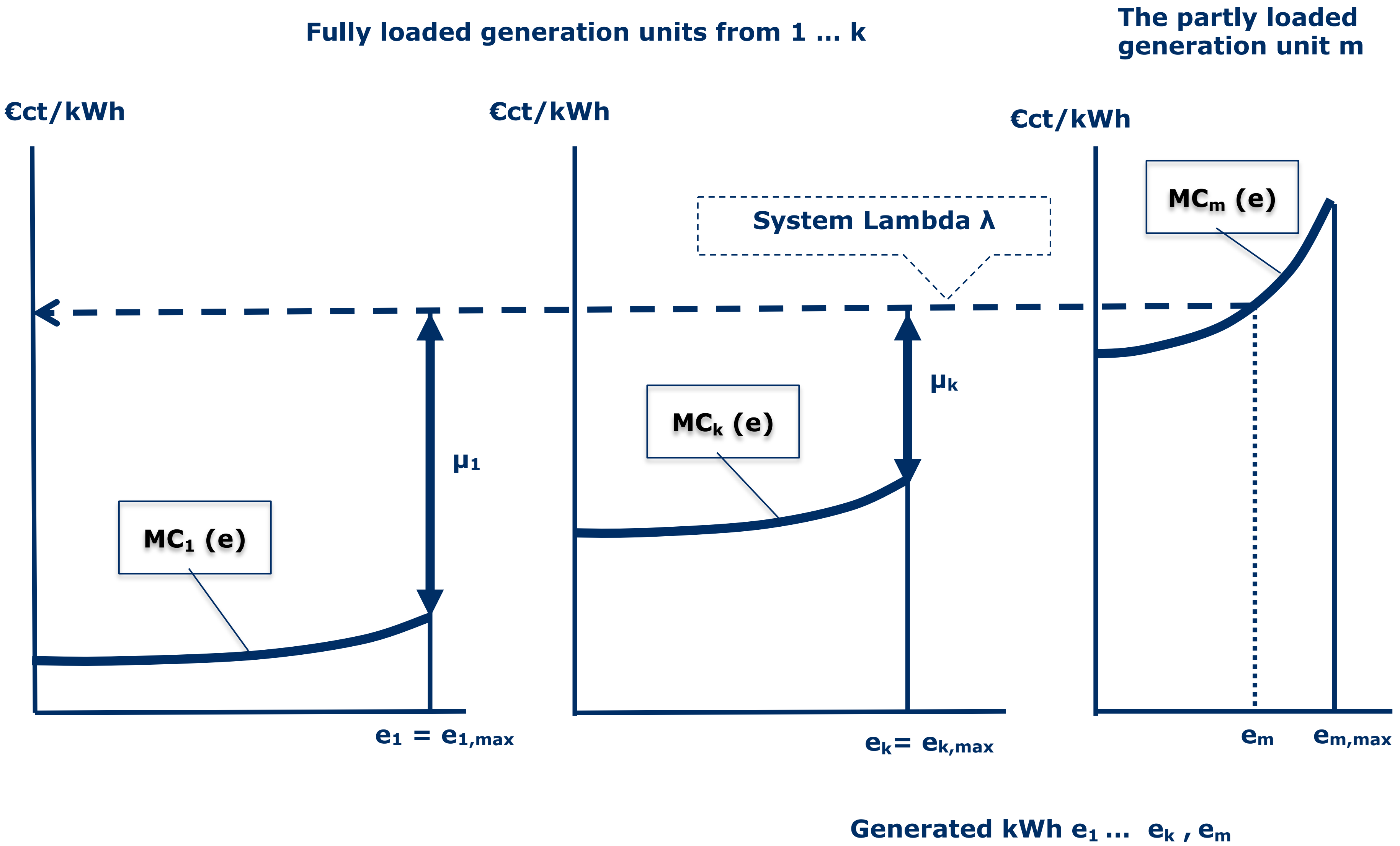
Min! $\Sigma_i OC_i(q_i)$ subject to $\Sigma_i q_i = Q$ and $q_i \leq q_{i,max}$

Min! $L = \Sigma_i OC_i(q_i) - \lambda[\Sigma_i q_i - Q] - \Sigma_i \mu_i [q_{i,max} - q_i]$

when for every i: $MOC_i = \lambda - \mu_i$
and : $\Sigma_i q_i = Q$
and: $\mu_i [q_{i,max} - q_i] = 0$

with: $\lambda = \partial OC^*/\partial Q$ = MC of total load Q
for every i: $\mu_i = \partial OC^*/\partial q_{i,max}$ = value of capacity of generation unit i

Marginal Cost (MC) curves of generation units ranked in merit order (1 … m … Ω)
The partly loaded plant m determines momentarily the system Lambda λ



MC pricing of electricity in practice

feasible when used electric currents are measured in '*real time*'

Smart meters

- Used electricity is measured in the same time intervals as the system's λ
- Smart meters can manage loads of the end-user (household, SME, etc.)

Electricity markets **substitute for** ***central planned*** **power systems**

- Both opposite approaches will, in principle, obtain the same outcomes
- Condition is: they should function in *optimal mode*
- *Reality:* several factors preclude or squander optimality
- *Hence* the terms imperfect markets, second-best solutions, regulatory oversight

Problematic issues in electricity pricing

Monopoly/oligopoly power of big companies

- Such companies set prices for maximizing their profits
- Monopoly prices reduce total welfare
- End-use prices differ across customers (price discrimination)
- Monopolies capture a share of the surplus consumers would obtain under competition

EU's Emissions Trading System allowed big electric companies

- 2005-2008 to charge swindle profits on permits they received for free
- 2012-2020 to levy 'climate surcharge' for permits they gradually have to buy
- Such charges means taxing non-ETS electricity users

Fringe price ≠ Marginal cost price

Daily emission permit prices on the Leipzig exchange

- **Result of speculative transactions of financial companies and energy companies (like SHELL)**
- **Except electricity generators, other ETS companies receive free permits**
- ***Speculation prices* are Fringe prices**

Fringe prices

- **Are related to the *borderline* of an economic activity**
- **However, they are *detached from the full* economic activity**
- **While marginal cost prices are the paramount of an economic activity (see the system Lambda λ of an electric power system)**

Fringe pricing

- **Common practice, given the conditions of MC prices are seldom fulfilled.**
- **In 2022, European power companies charged *excessive high electricity prices.***
- **They argued: gas price hikes in Europe increased the *marginal cost price*, and**
- **MC-pricing is best economic practice**
- **While the gas price hikes disrupted optimal system composition, needed for true MC-pricing**
- **Actually, they applied fringe prices and captured significant super profits**

A new reality is developing

Old theory

- Electricity plants deliver capacity or stop delivering on command
- Electricity plants have CAPEX, and OPEX mainly fuel consumption
- Planning or market competition provide the proper capacities for least costs
- In OPEX, the external costs (pollution, risks, climate chnage) are not or little included

New reality

- Electricity supply from harvested renewable currents like sunlight, wind, running water, active geothermal, depend on *natural phenomena* not on human command
- Bypassing the natural currents is easy and immediate
- The harvesting plants have CAPEX, but the OPEX is zero or faint
- Planning least cost in the old way is no longer feasible
- The *marginal cost price* concept in power generation is void

Challenges and opportunities

Challenges

- Future electricity systems consist of 100% RE supplies with zero or faint marginal costs
- A small share of capacity may function on command, such as dam hydro or other stored energy
- Grid congestion by growing redundancy in power capacities, mainly PV
- Grid congestion could lead to '*over-voltage*', far more dangerous than '*under-voltage*' known as brown-out or black-out

Opportunities

- Redundancy supports security and high reliability
- Smart meters for end-users and prosumers become default standard
- ICT, big data processing, realtime optimizations, … are available
- Technological innovation in power electronics, PV, batteries, data handling, … is continuing
- Community projects may succeed in full islanding with smart grids, load management, storage
- They may buy insurance for complementary and back-up power from the interconnected grid

Regulatory questions and suggested answers

Questions to regulators

- With redundancy, which plant is allowed to sell to the grid?
- Given the marginal cost of renewable electricity is zero, how are deliveries to the grid rewarded?
- How is electricity, consumed by end-users, priced?
- Which terms for interaction between smart local grids and the interconnected grid?

Suggested answers

- Given the future of small-scale generators, 'proximity' substitutes for disintegrated 'merit order'
- 'Proximity' rule refers to the shortest distance between generator and user locations
- Rewarding delivered power on the basis of standardized LCOE values of the generation plant
- Given generic use of smart meters, reliability pricing in real-time is recommended
- Interaction between community systems and the interconnected grid asks for proper technical and financial terms, with distinction between complementary and back-up power

Proper relationship between central top-down generation & decentral bottom-up, based on the principle *central complements decentral* instead of today's *central obstructs decentral*.