The intelligent energy system of the future

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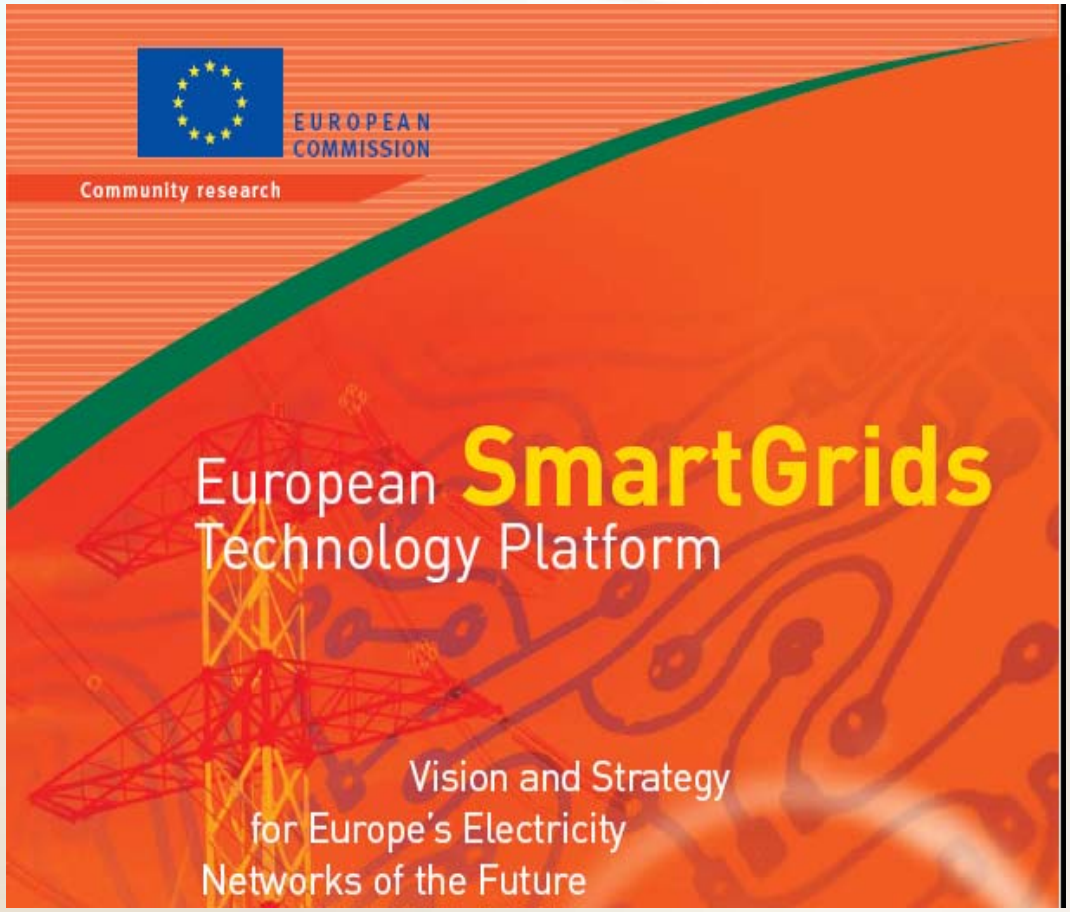
Visions for the electricity system

- DOE (2003): Grid 2030
- EPRI (2003): Electricity sector framework for the future
- EU (2006): SmartGrids



Key features

- Much more communication:
  - Every node can interact with every other node
    - A node can be a large power plant, a micro power plant, a transformer, an end-user, an equipment
  - Real-time markets
  - Quality of supply adapted to individual needs
  - Demand and production are optimised to real-time prices

System-wide intelligence

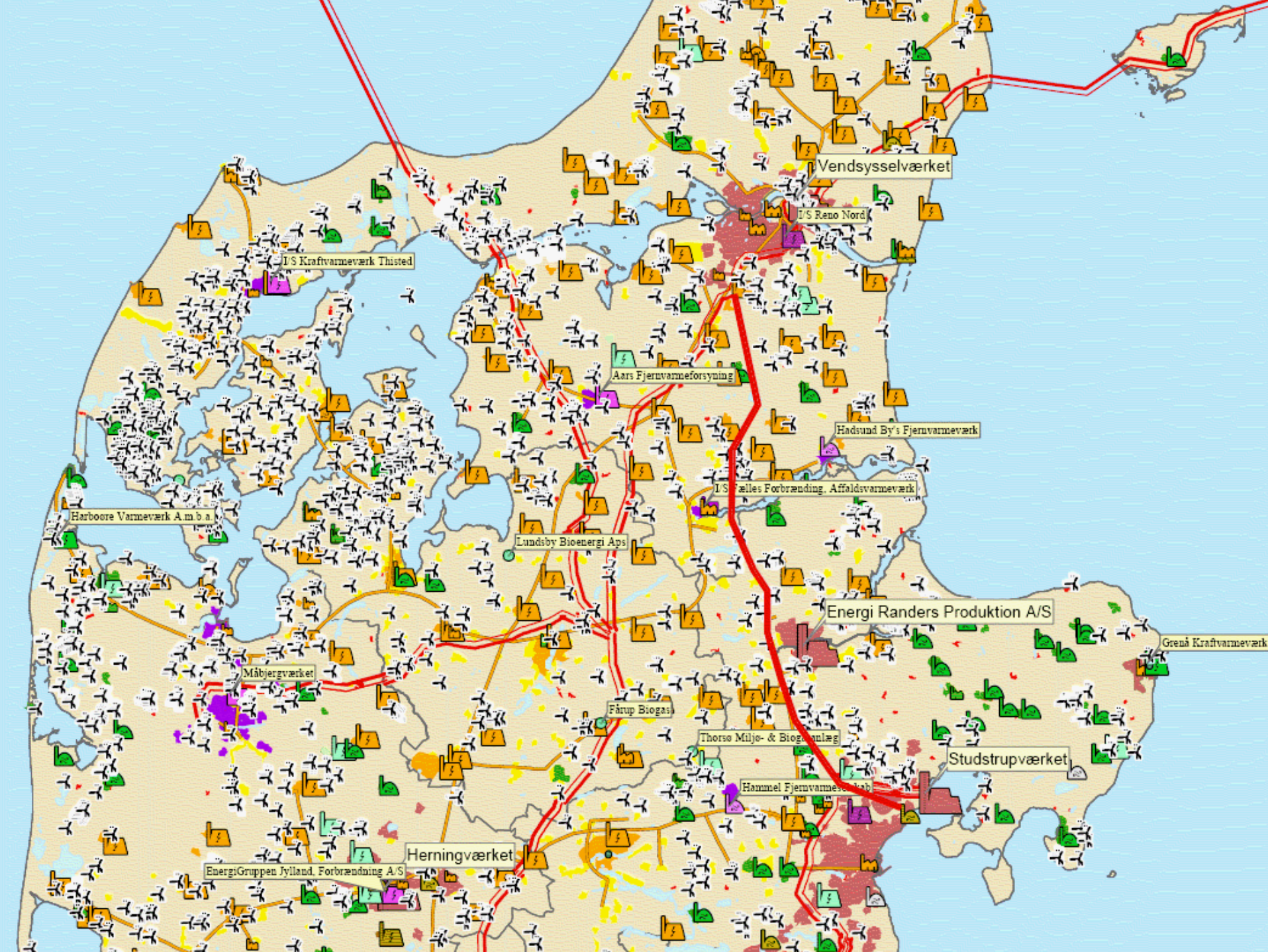
- Wide area monitoring and protection systems (WAMS/WAPS) are used to improve security of supply
- Prediction of failures
- Self-heeling

New technology

- Micro generation
- FACTS (Flexible AC Transmission System) can control the flow in the network
- Superconducting cables
- Energy storage
- Fuel cells
- Hydrogen, electric or hybrid automobiles

2006: Substantial parts of the electricity system is liberalised

- Financial market, day-ahead and hour-ahead power market and, e.g. Nord Pool
  - Strong competition hour by hour
  - Large volume traded
- Nordic system for regulating power (NOIS)
  - Dispatching lowest cost regulating power across control areas


Vendsysselværket
I/S Reno Nord
I/S Kraftvarmeværk Thisted
Aars Fjernvarmeforsyning
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2006: Command and control

- Monopoly part of electricity system (40% of total costs) dominated by command and control
- Monopoly part:
  - Transport of electricity
    - Network
    - Losses
  - Ancillary services
    - Regulating power
    - Reserves
- Large potential savings:
  - Adapting demand to real-time prices
    - Including individual level of security of supply
  - Activating new generation technologies

Monopoly tariffs

- Does not reflect real-time dynamics of costs
- Two different views:
  - Collecting costs (today)
  - Activating best technology (future)

Examples of command and control

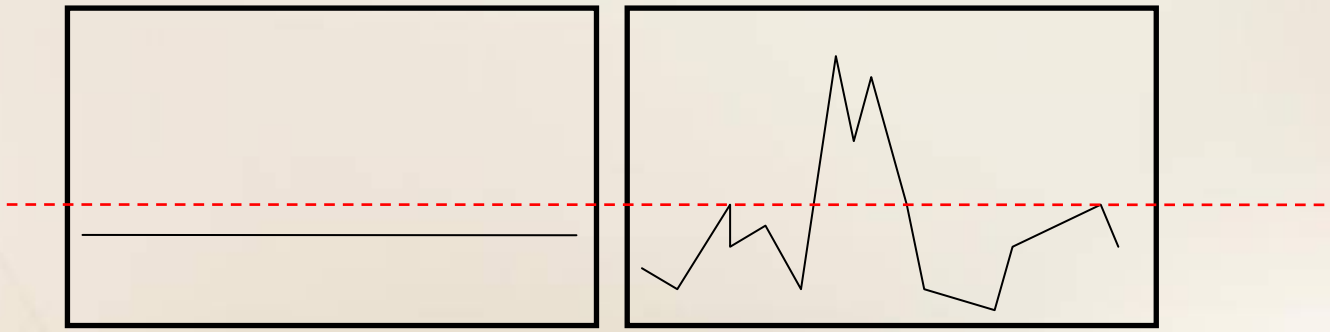
- Administrative barriers:
  - Minimum size (e.g. 10 MW)
  - Requirements of constant availability (years, not hours)
  - Requirements of individual, real-time measurements

Dynamic nodal pricing

- Prices vary
  - By time
  - By location
- May benefit small-scale generation and demand
  - Can react quickly
  - Many plants spread over the whole country
- Will create different prices for different users
  - Can to some extent be levelled out by adjusting the yearly subscription tariff

All markets with prices in real-time

- Dependent on cost structure:
  - Average price = No production
  - Dynamic prices = Production in most expensive periods
- Reduced demand:
  - Average price = No adaptation
  - Dynamic prices = Highest demand in cheapest periods



Consequences of dynamic prices

- Optimal timing
  - Demand
  - Heat pumps (with heat storage)
  - Micro generation (with heat storage)
  - Combined heat and power
- Reduced production in rare cases
  - Wind power
  - Photovoltaic

Conclusions

- Vision for the electricity system = More communication
  - Dynamic prices (also for monopoly costs)
- Demand:
  - Adapting demand => Reduced costs
- Production:
  - Decentralised production may benefit from nodal pricing
    - Can counteract high losses in the distribution system
    - Can be an alternative to costly network expansion