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# Smart Grids

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# Contents

- Basic concepts
- Energy storage systems
- Smart Metering (AMM)
- Virtual power plant
- Pilot project Vrhlabi

# Introduction

- The beginning of a common strategy for the development of European electricity system was the document "Vision and Strategy for the European electricity grid of the future" published in 2006
  - The market should ensure a highly reliable, flexible and affordable supply of electricity
- Electricity, nowadays, a strategic commodity and its importance will grow in future
- Therefore, the European Union gives more emphasis on stability, safety and security of energy supply
- European Commissioner for Science and Research said that the EU will spend more on research and development of new technologies related to future electricity system

# Introduction

- The joint operation of large centralized energy sources with decentralized
- Decentralized small power sources are distributed throughout Europe
- It based on the efforts and commitment of the European Union to increase the share of energy production from renewable energy sources (RES) to 20% in 2020
- The change will also apply to the traditional chain of production, transmission, distribution and consumption of electrical energy
- It will cause a new energy flows in transmission and distribution grids

# Concept of Smart Grid

- The high rate of automation in distribution and transmission systems
- Increased reliability and safety
- The higher efficiency of electricity usage
- Higher convenience for customers
- Reduction of losses in the power systems, it would entail an increase in ecological, economic and operational efficiency
- Support for distributed generation, along with research and development of new management methods

# Smart grid

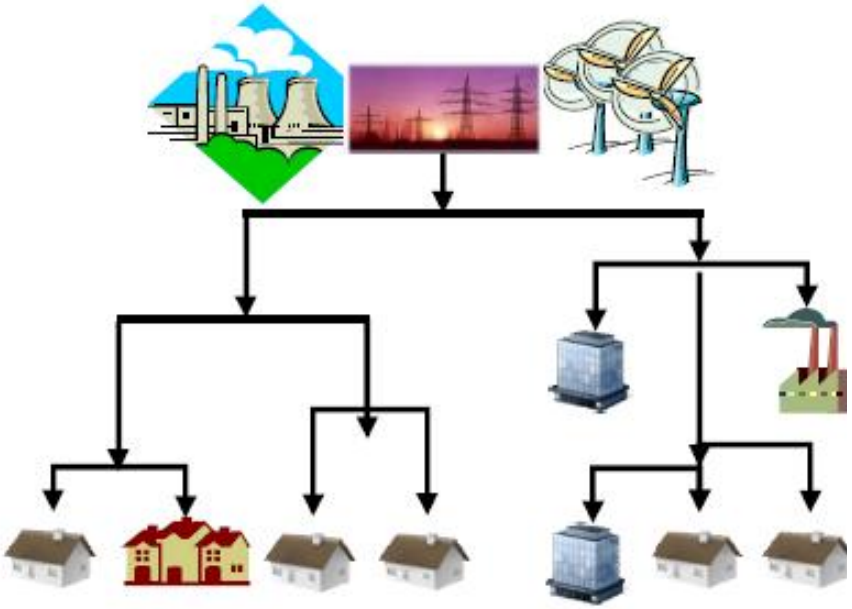
- Smart grid could be defined as intelligent, self-regulating power supply grid. It capable to transmit energy from any source to the customer responding to possible unpredictable changes in the grid parameters

- It includes control system that constantly monitors the operation of a distribution network, the data are then evaluated and, if necessary, further operation of the network is adapted to the new conditions

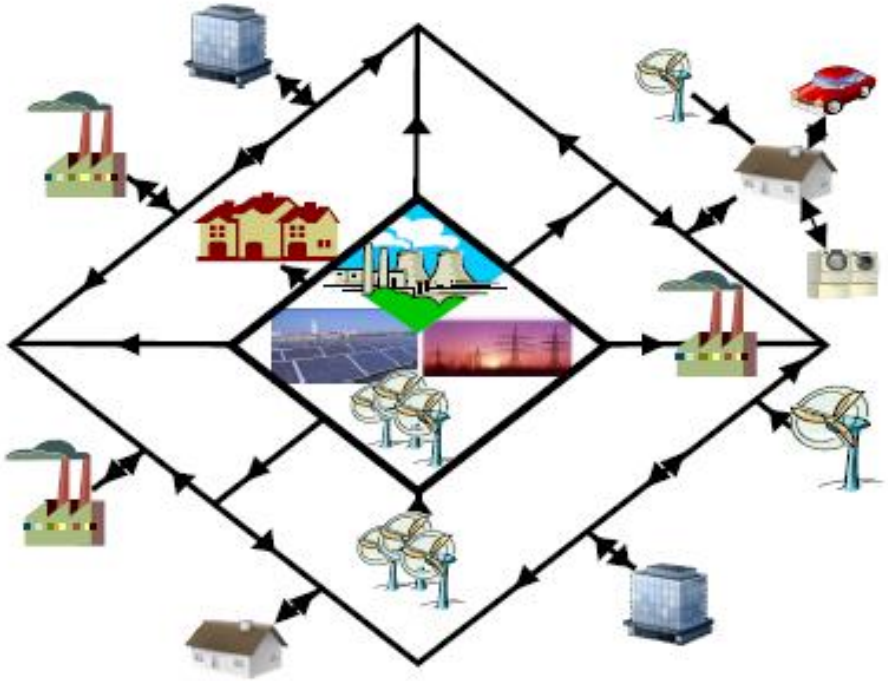
- Another concept is the process of "self healing" when the power grid using smart features implemented can reach the balance itself without human intervention

- The benefit of automatic control is monitoring of the distribution network, in case of failure the affected area can be isolated. It results in increased stability and savings during distribution network operation

# Smart grid



Nowadays distribution grid



Smart grid

# Smart grid

**The basic functionality of smart grid allows to:**

- **Reach better balance electricity supply with demand, which leads to operational savings and better use of infrastructure - through smart appliances**
- **Transformer monitoring**
- **Substations automation - an increase of supply while reducing operating costs**
- **Fast fault detection**
- **Advanced parameters measurement in the network**
- **Communication - the use of distribution for broadband services**

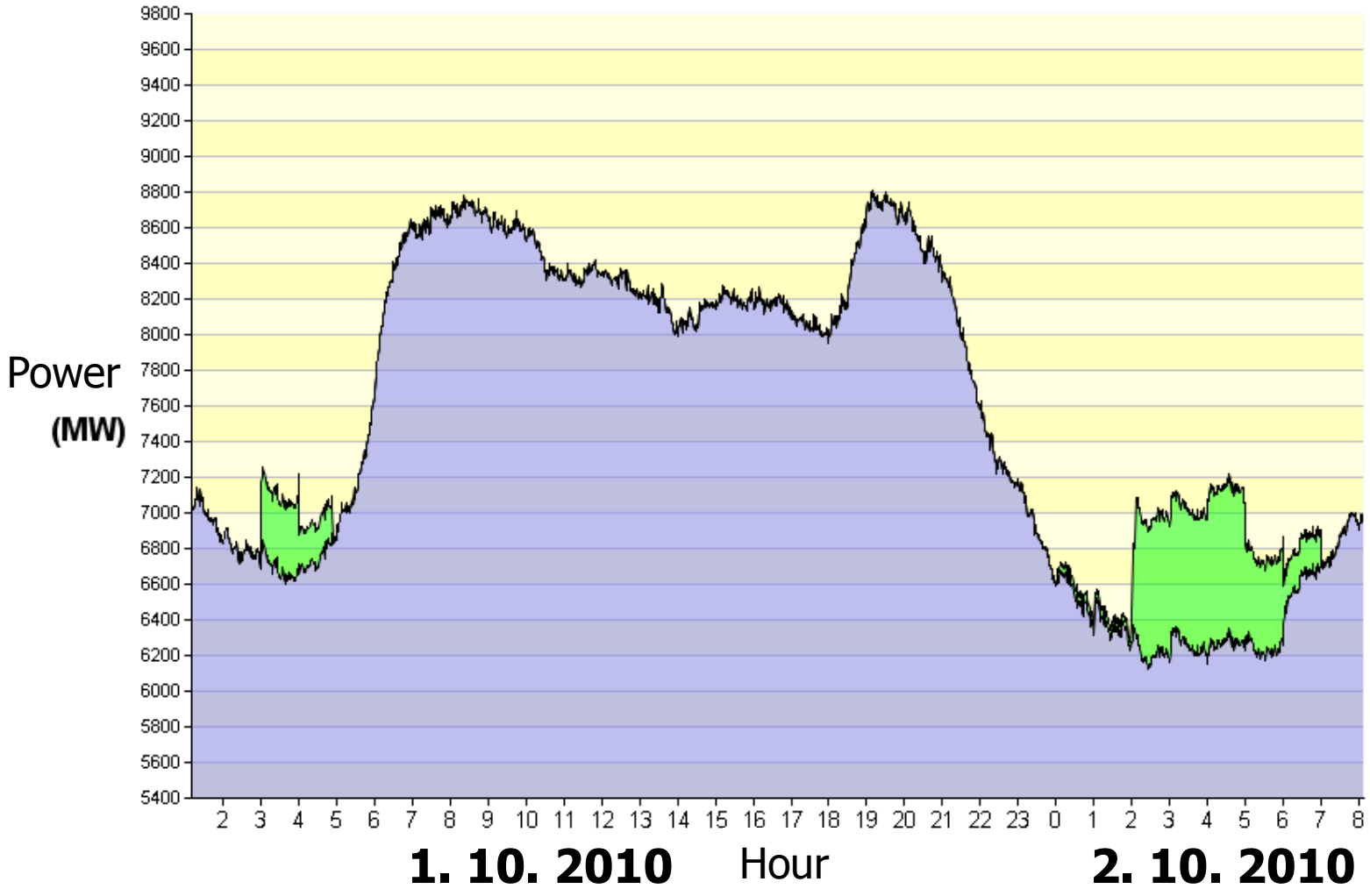
# Smart grid

- The development of the system will lead to a system similar to today's Internet
- It will be free to start the business and trading on electricity market. The vision is to create a new market structure, where the electricity will purchase and deliver to the agreed points and network nodes.
- The development will connect networks across Europe and will increase flows of cross-border supply of electrical energy. It will support the development of support services. Within the European network new legislation will have to be created
- This calls the need of a mini and micro grids.
  - Networks consist of both production (local sources) and consumption, which will be balanced and controlled by automatics. If failure occurs, the network will be able to operate alone until the network is restored

# Smart grid

| Existing Grid | Smart Grid |
|---|---|
| One-Way Communication | Two-Way Communication |
| Centralized Generation | Distributed Generation |
| Hierarchical | Network |
| Few Sensors | Sensors Throughout |
| Blind | Self-Monitoring |
| Manual Restoration | Self-Healing |
| Failures and Blackouts | Adaptive and Islanding |

# Electricity consumption in CZ



# RES development

- Support and development of renewable source is leading to several problems with energy saving in times of high production and its usage during the production decrease

- Have to be solved the problem how to efficiently transport the electricity over long distances from places distant from consumers. For example, if the planned wind farms in the North Sea or solar farms in deserts would be built.

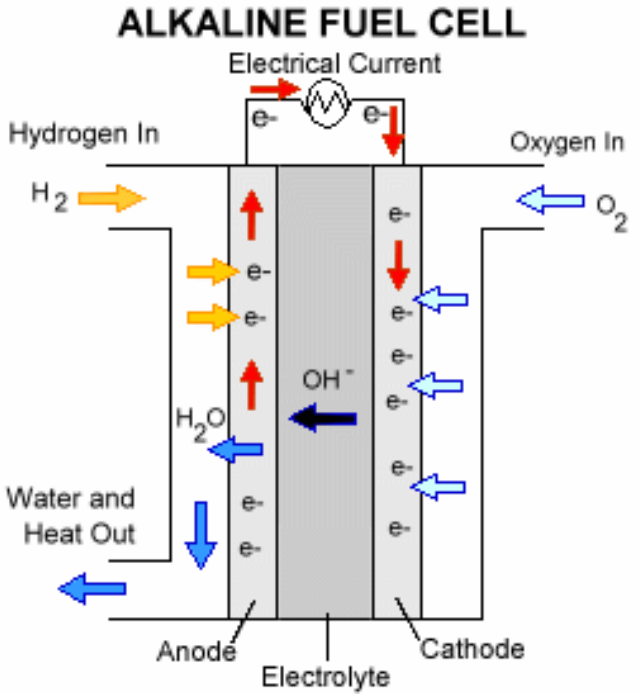
- There are several solutions:
  - The first is the hydrogen technology application
  - Build long AC lines with a voltage of 750 kV or higher.
  - Or DC transmission

# Modern energy storage technologies

- Today are several possible ways to store energy:
- Battery
  - Useful for energy storage up to about 8 hours
  - Battery prices are around $ 3 000 / kW
  - Used to cover consumption at the time of peak load, also to improve the stability of transitional phenomena
- Flywheels
  - Help to improve the frequency fluctuations and voltage stability, used to power supply during voltage interruption at consumer place
  - Efficiency is more than 85%, better than chemical batteries
- Superconducting magnetic systems for energy storage
  - Energy is stored in the magnetic field created by the direct current flow through superconducting coil
- Ultracapacitors
  - Devices with high energy density, capable to supply and consume this energy in very fast cycles

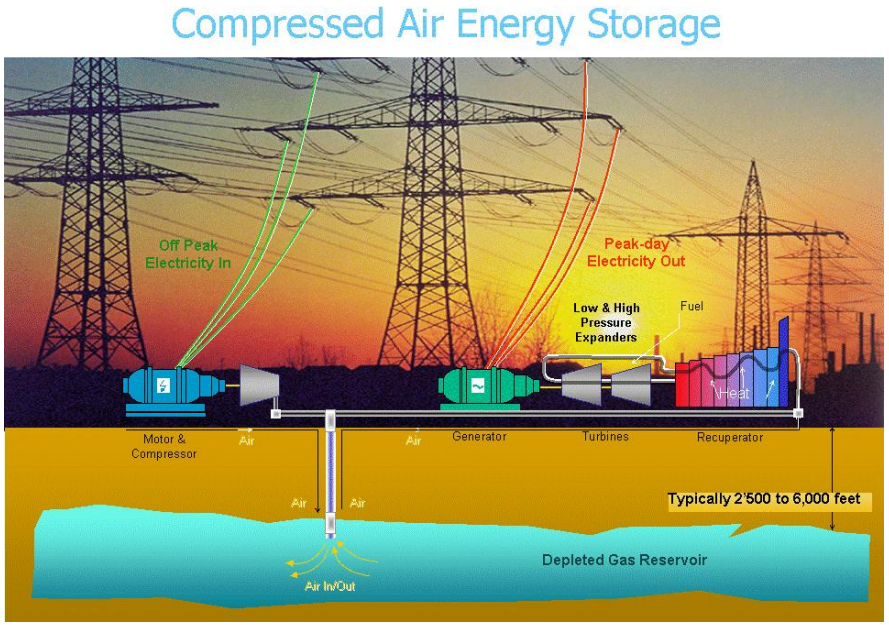
# Modern energy storage technologies

- Fuel cell
  - First, hydrogen produced by electrolysis or other way, which can then be used in fuel cell
  - Galvanic cell that generates electricity from the energy released during a chemical reaction
  - It consists of two electrodes separated by a membrane
  - Consumes fuel at the anode (hydrogen) and oxidant on the cathode (oxygen)
    - Chemical reaction
    - Anode: $2H_2 \rightarrow 4H^+ + 4e^-$
    - Cathode: $O_2 + 4e^- \rightarrow 2O^{2-}$
      $2O^{2-} + 4H^+ \rightarrow 2H_2O$
    - Final: $2H_2 + O_2 \rightarrow 2H_2O$

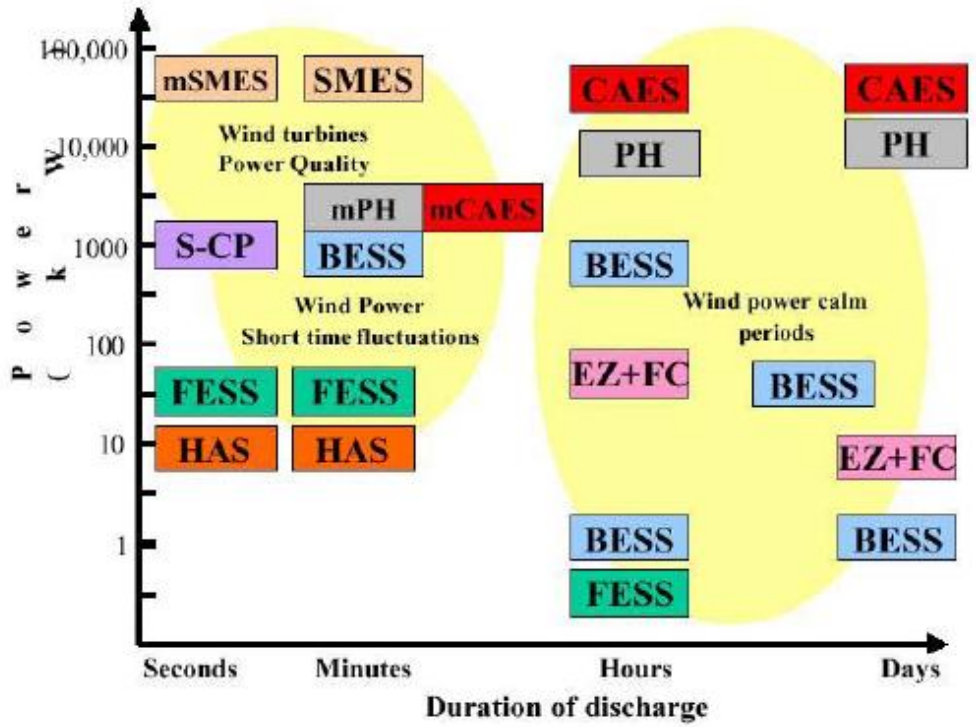


# Modern energy storage technologies

- Compressed Air
  - This project has been known since the 70th years under the acronym CAES (Compressed Air Energy Storage)
  - The principle is similar to the pumped storages, when during the period of low electricity consumption it used to compress air into the tank and vice versa in times of demand is released through the turbine and generator
  - Disadvantage:
  - during compression the air should be cooled down and vice versa when releasing heated (using natural gas)
  - The efficiency is around 50%



# Modern energy storage technologies




LEGEND
m – prefix used to indicate small scale
BESS = batteries
CAES = compressed air energy storage
EZ+FC = hydrogen and fuel cells
FESS = flywheels energy storage system
HAS = hydraulic accumulator system
PH = pumped Hydro
S-CP = supercapacitor
SMES = superconducting magnetic energy

# Smart metering

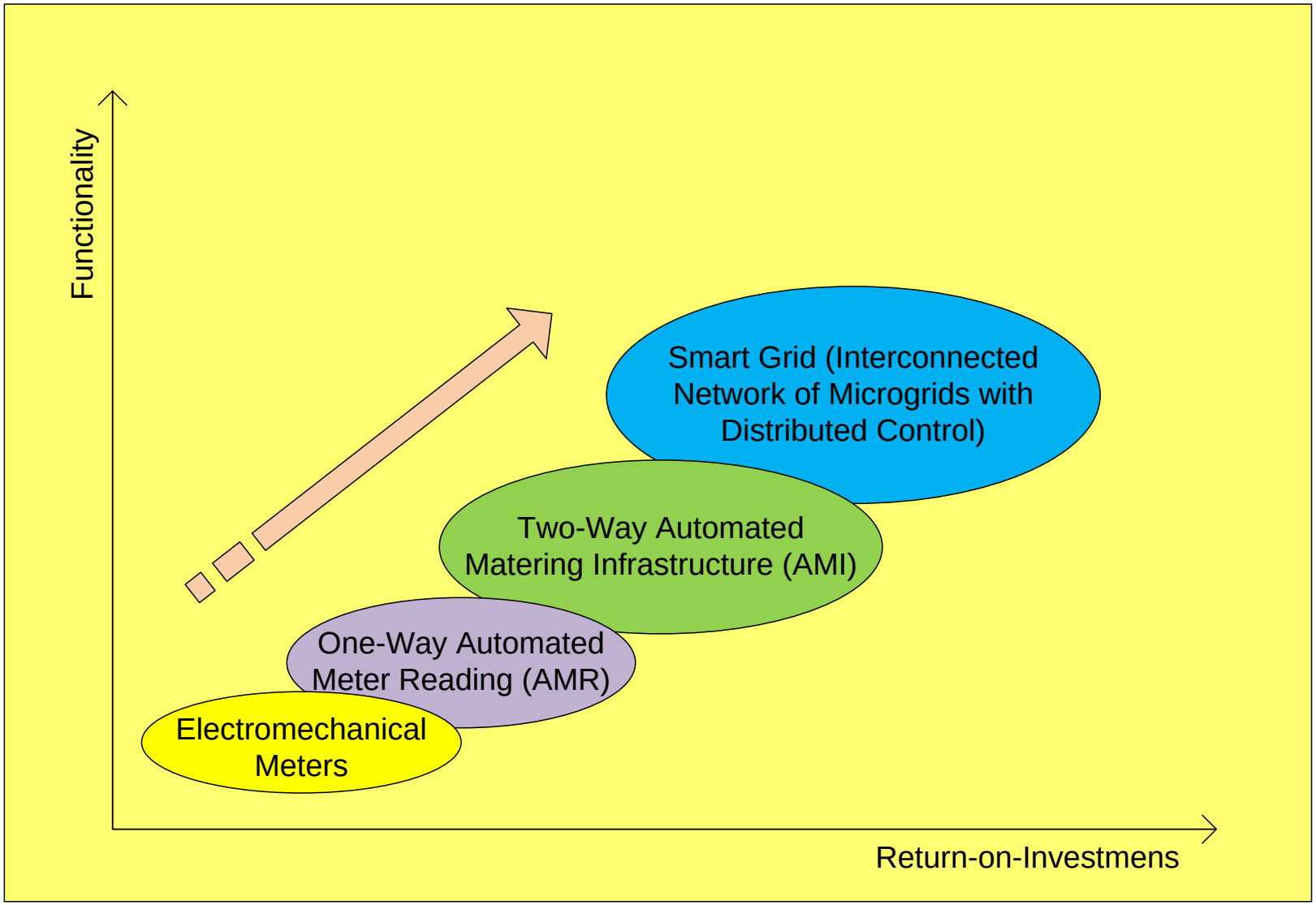
## Benefits for distributor:

- New tariff rates according to the new consumption technology
- Extending the competitive range of products of energy traders

## Benefits for consumer:

- The benefits in the form of smart home applications, home display, …
- Choice of more tariff rates
- The possibility to influence consumption by switching appliances at bargain tariffs
- Opportunity to sell free energy back to the distributor

# Smart metering



# AMM – Automated meter management

- Smart metering, or intelligent measurement network are the basics of smart grids
- AMM is represented by new measurement technology that has bidirectional communication between customer and supplier of electric energy
- Possibility of load controlling at multiple levels
- The topology of AMM system: data from multifunction electric meter are stored in a data concentrator placed in the node. From this node the data are sent to the control center. In the center data are evaluated and processed
- The new electrical meters will have this attributes:
  - Measuring and transfer data in the real-time
  - Remote controlling of  measurement equipment (possibilities of customers disconnection)
  - Possibilities of value measurement for another energetic grids (water, gas)

# AMM – Automated meter management

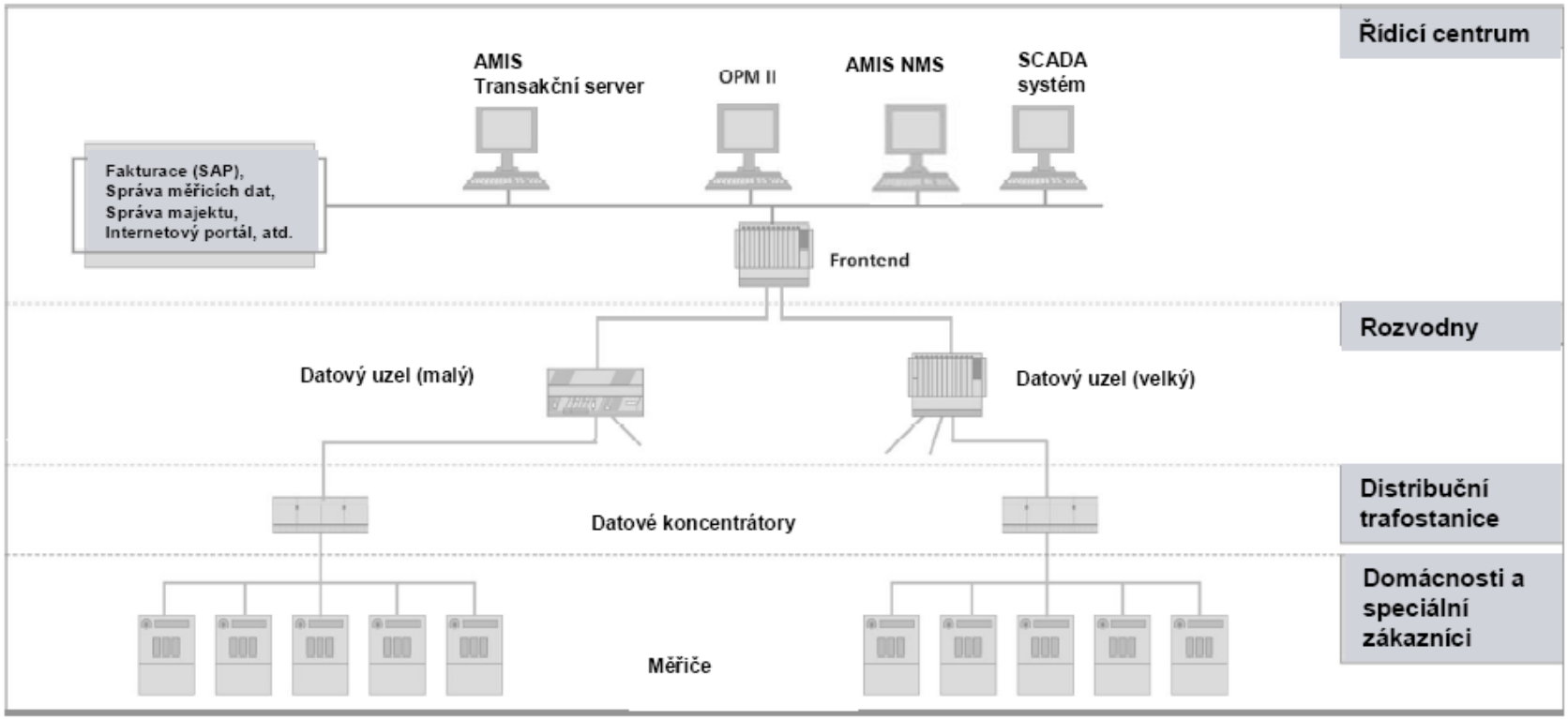
- Benefits are at lower cost of measurement, saving of investments
- The products and tariffs from distributor are rapidly increasing
- The customer will have overview of consumption, price and quality of electrical energy
- Flexible tariffs – in a various time, various price
- Credit system – i.e. like mobile phones
- Lower losses
- Customer portal –overview of consumption and costs through internet

# AMM – Automated meter management

- Disadvantage of AMM is high installing costs
- Communication channels problem is not solved and they must be installed
- Communication standards are not precisely formulated
- Necessity of all electric meters exchange for new ones
- Appliances are not yet prepared for smart metering

# Benefits AMM

- Distributor will have control over illegal consumptions
- Scheme of network for AMM:



# Smart metering

- Three-phase and one-phase electric meter, load switch control (Siemens)

# Smart metering

- **Data concentrator (Siemens)**


# Smart grids in the world

- In the map are shown project (round) or pilot project (triangle)
- Red is for electricity, blue for water project and green for gas project

# Smart grids in the Europe

# Virtual power plant (VPP)

- A virtual power plant is a cluster of distributed generator installations (such as micro combined heat and power, wind-turbines, small hydro, back-up gen. sets etc.) which collectively run according to a central control entity.

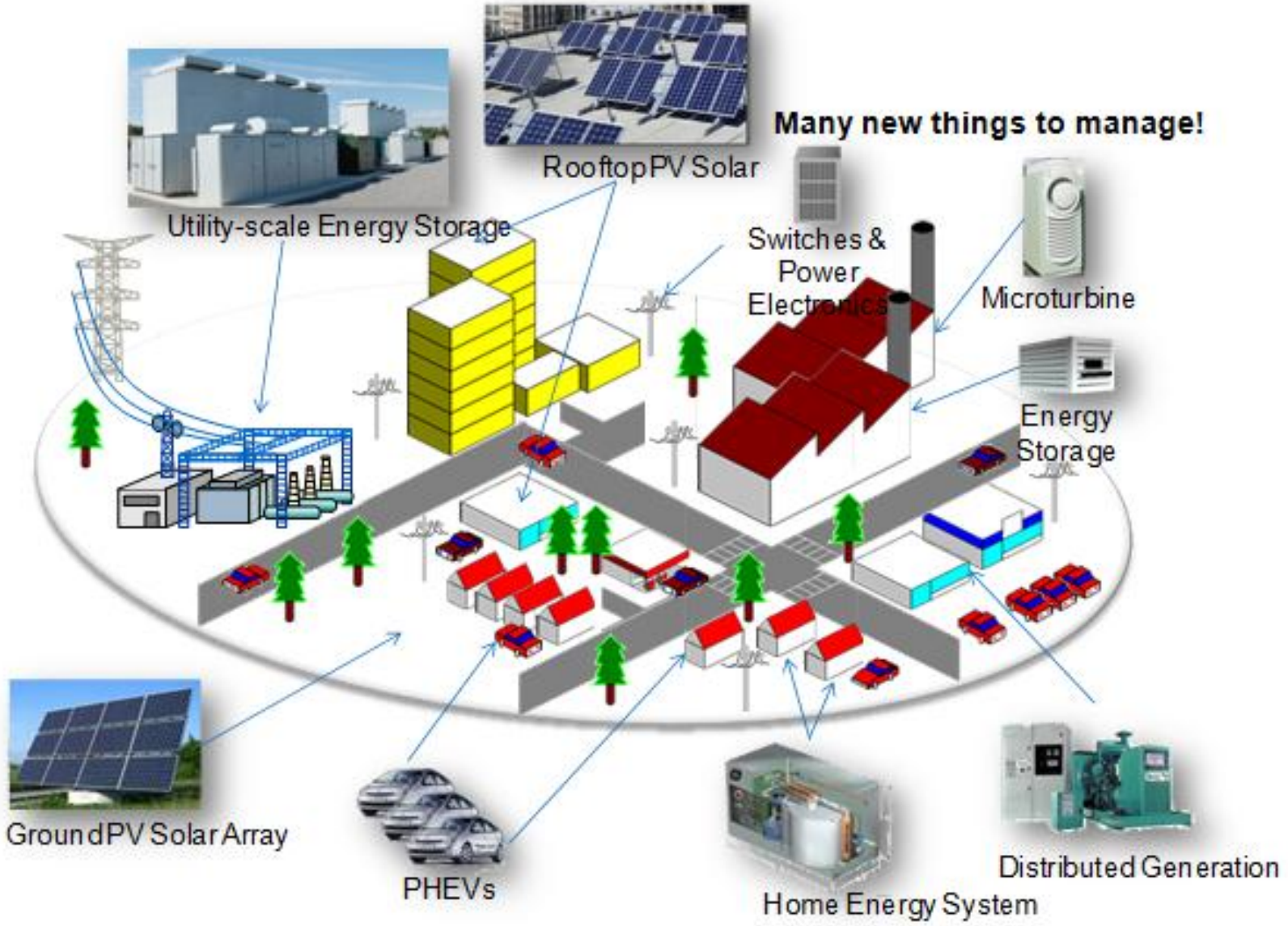
- The concerted operational mode delivers extra benefits such as the ability to deliver peak load electricity or load-aware power generation at short notice. VPP can replace a conventional power plant while providing higher efficiency and more flexibility.

- More flexibility allows the system to react better to fluctuations. However, a VPP is also a complex system requiring a complicated optimization, control, and secure communication methodology

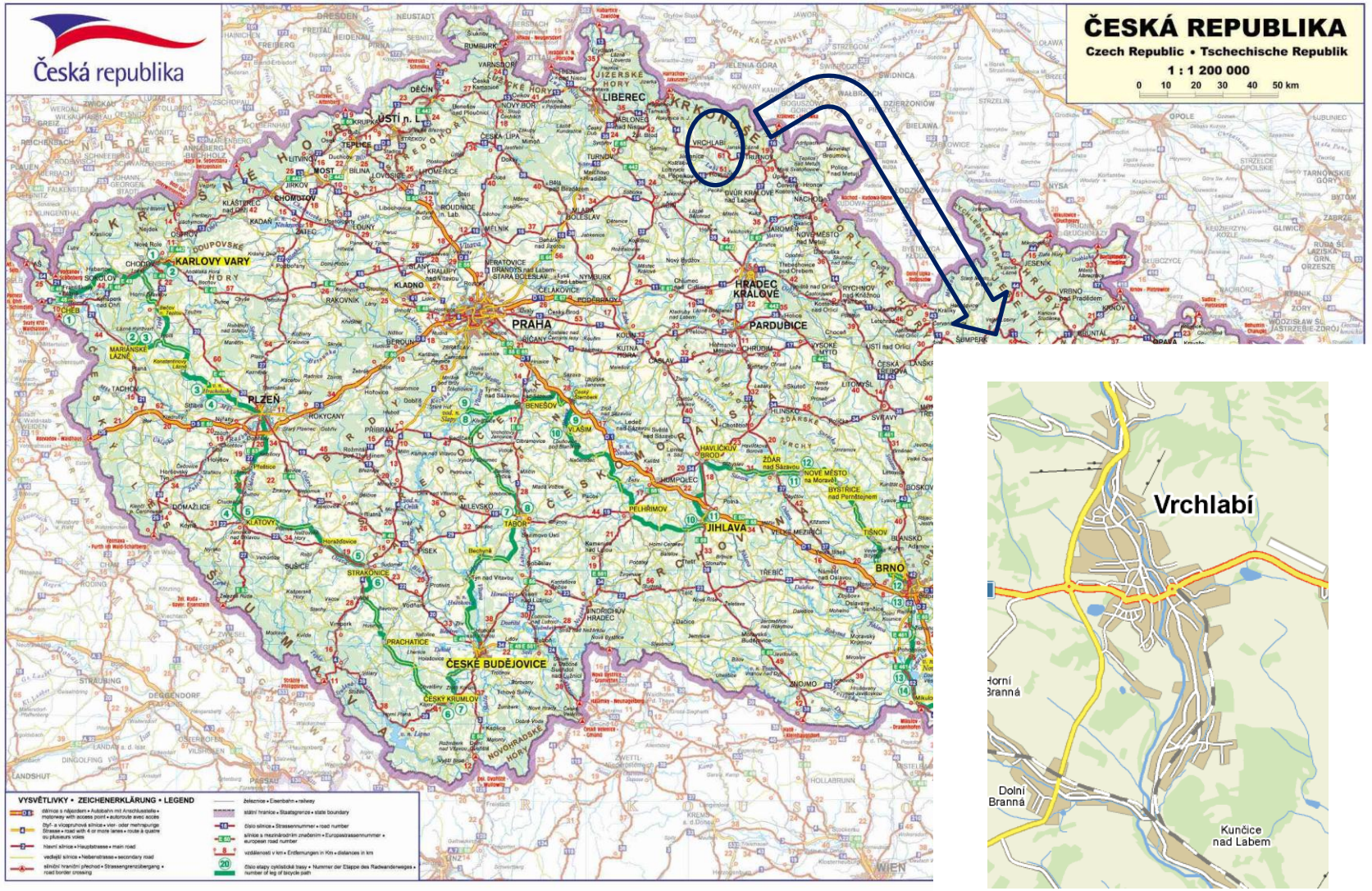
# Virtual power plant

- Benefits of concept:
  - Lower investments than new classic power plant
  - Non-emission power sources
  - New job position
  - Multiplication economical effect – the money stays in region where is energy consumed
- Disadvantages of concept:
  - Wind power plants and solar power plants are instable sources of electrical energy
  - More of this sources can endanger reliability of delivery electrical energy
  - Sources by consumer leads to problems by distributor and bad controlling of flow energy

# Micro and mini grids



# Vrhlabi pilot project



# Vrhlabi pilot project

- Region Vrchlabí is choose because of:
  - City with 14th thousand residents
  - Source and consumption diversity
  - Ecological aspects due to the protected landscape area
- This locality will by equipped with charge station for electrical vehicles
- Expansion of electrical vehicles and alternative hybrid motors

# What is needed to be done

- Make stronger legislation and prepare for the new smart grids concept
- Build new technical standards for communication
- Integrate legislation through all EU
- Find agreement with concept – today is problem with disunity of all concepts