International Finance Corporation
World Bank Group

# Power System Planning and Trends
## *Relevance to renewables*


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GLOBAL ENVIRONMENT FACILITY
INVESTING IN OUR PLANET

# Presentation Outline

- ***Why should you care about power system planning?***
- ***How decisions are made to build new power plants (what type and size; also when)?***
- ***Key concepts such as peak demand, reserve margin, etc.***
- ***Trends and challenges associated with the integration of renewables in power system planning and operation***

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# Five guiding principles of Energy Sector Directions Paper

1. ***Engage holistically to catalyze transformation of energy sector in the context of long-term system-wide planning, and apply a framework for assessing climate impacts of projects in that context***
2. Emphasize improvements in financial, operational, and institutional environment
3. Seek market solutions and help foster private sector participation and investment
4. Embrace a multi-stakeholder, inclusive approach to energy development
5. Tailor approach to individual country circumstances

# Long-term System-wide Planning

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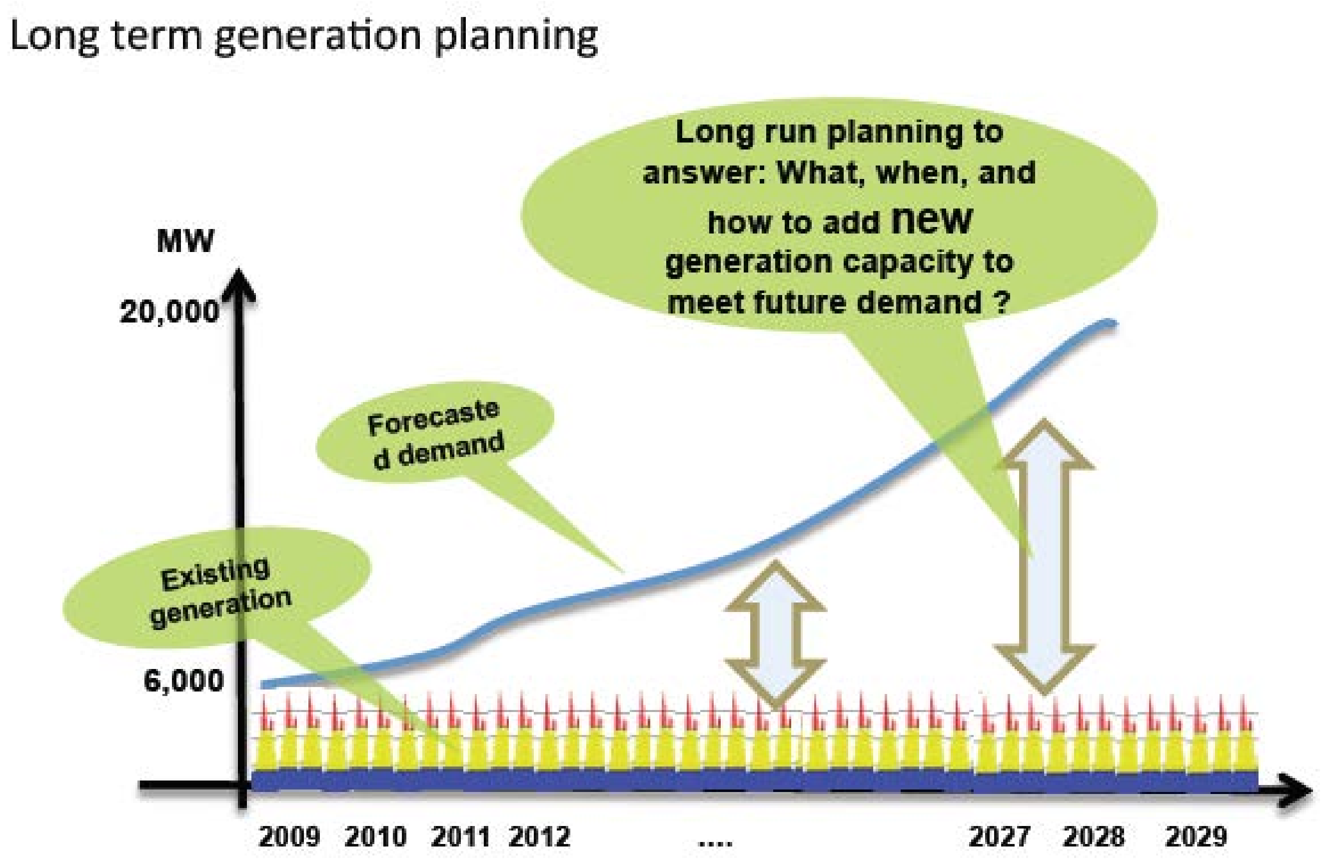
- Move away from narrow focus on project level technology choice to delivery of cost-effective results system-wide; ***from projects to sector wide planning***

- Country engagement to be under-pinned by planning approach with all options on the table:
  - Long term horizon
  - System-wide optimization
  - Supply/demand integration
  - Regional vision

# Typical power system planning problem



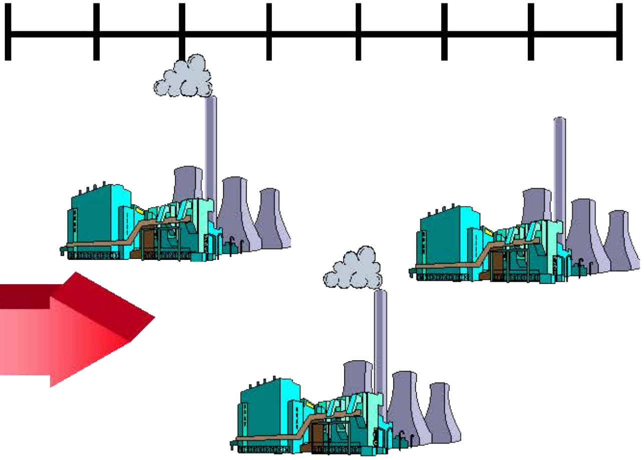
# Generation Expansion Planning
# Typical Model

## INPUT

- Load forecast
- Existing system
- Candidates
- Constraints
  - Reliability
  - Financial
  - Implementation

**ELECTRIC**
**(WASP-III+)**
**Power System Analysis**

## OUTPUT

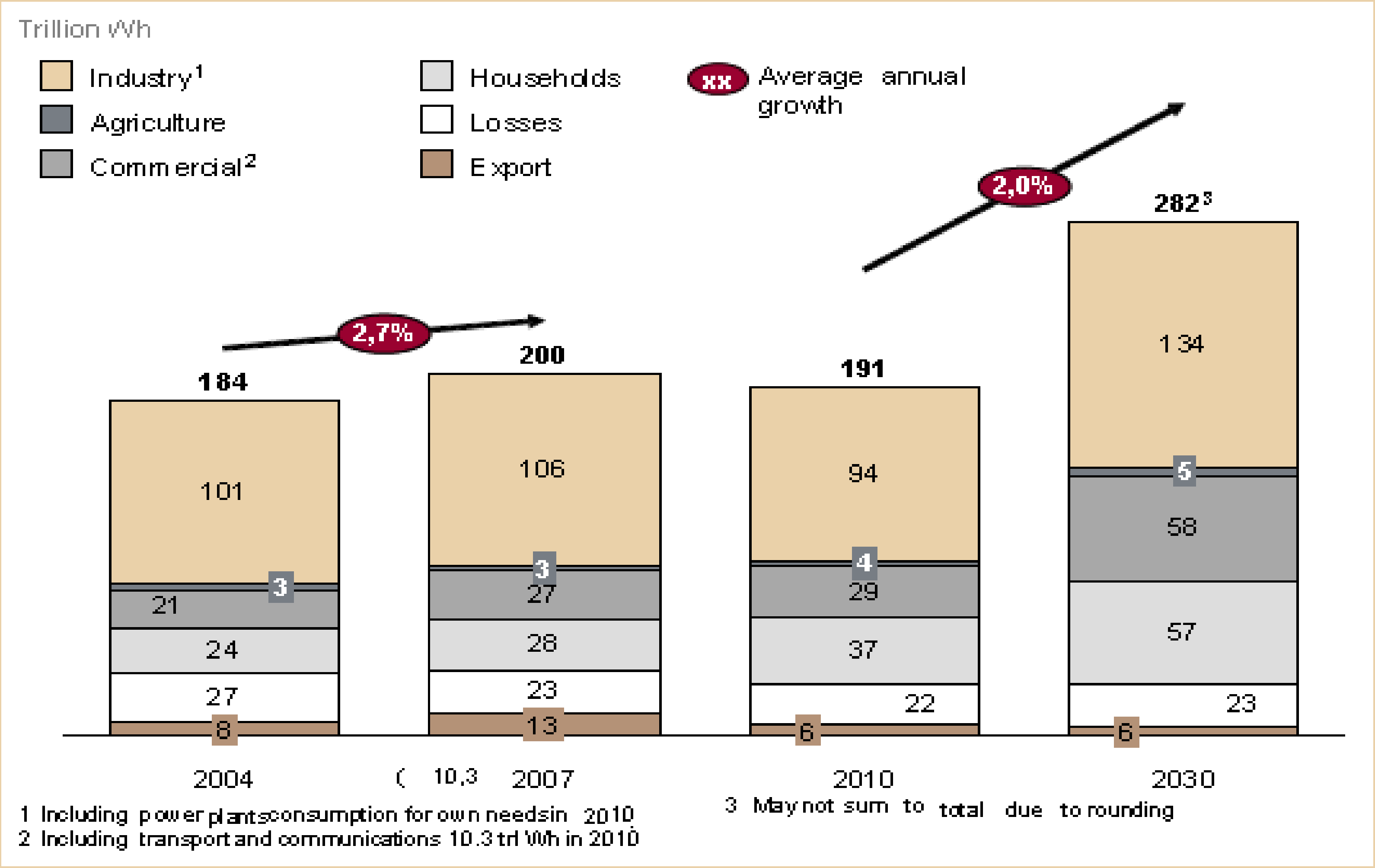


- Build schedule
- Costs

# Key Inputs to Power System Planning

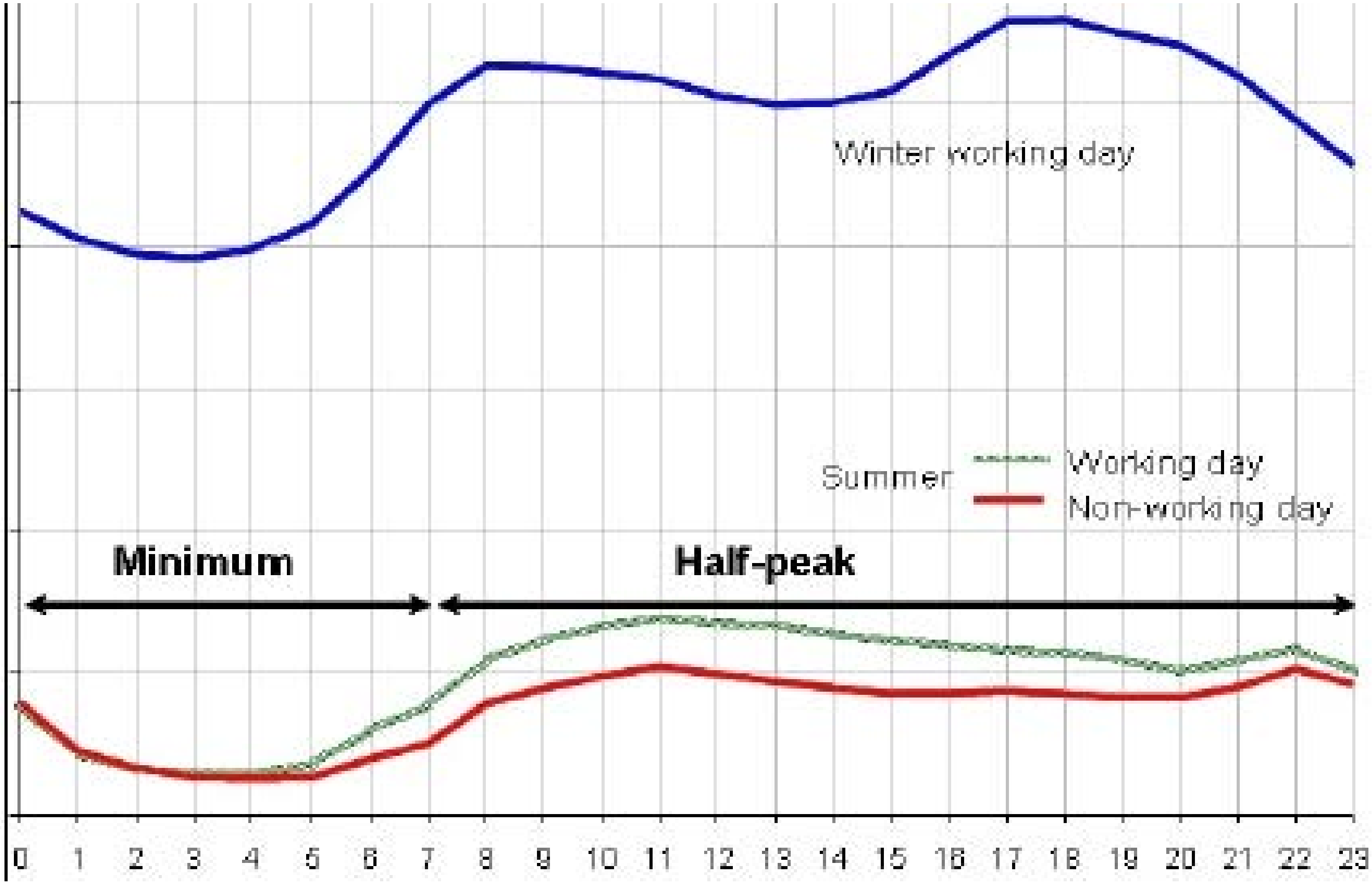
- *Forecast of power demand (annual and peak)*
- ***Existing power system (installed and available capacity; retirements; planned outages; hydro seasonality; etc.)***
- ***New candidates (size limitations; capital and O&M costs; construction schedule; etc.)***
- ***Power system reliability requirements***
- ***Constraints (energy resources; financial; environmental; max capacity additions per year or per site)***

# Annual Energy Demand Forecast
## Example: Ukraine (2012-2030)

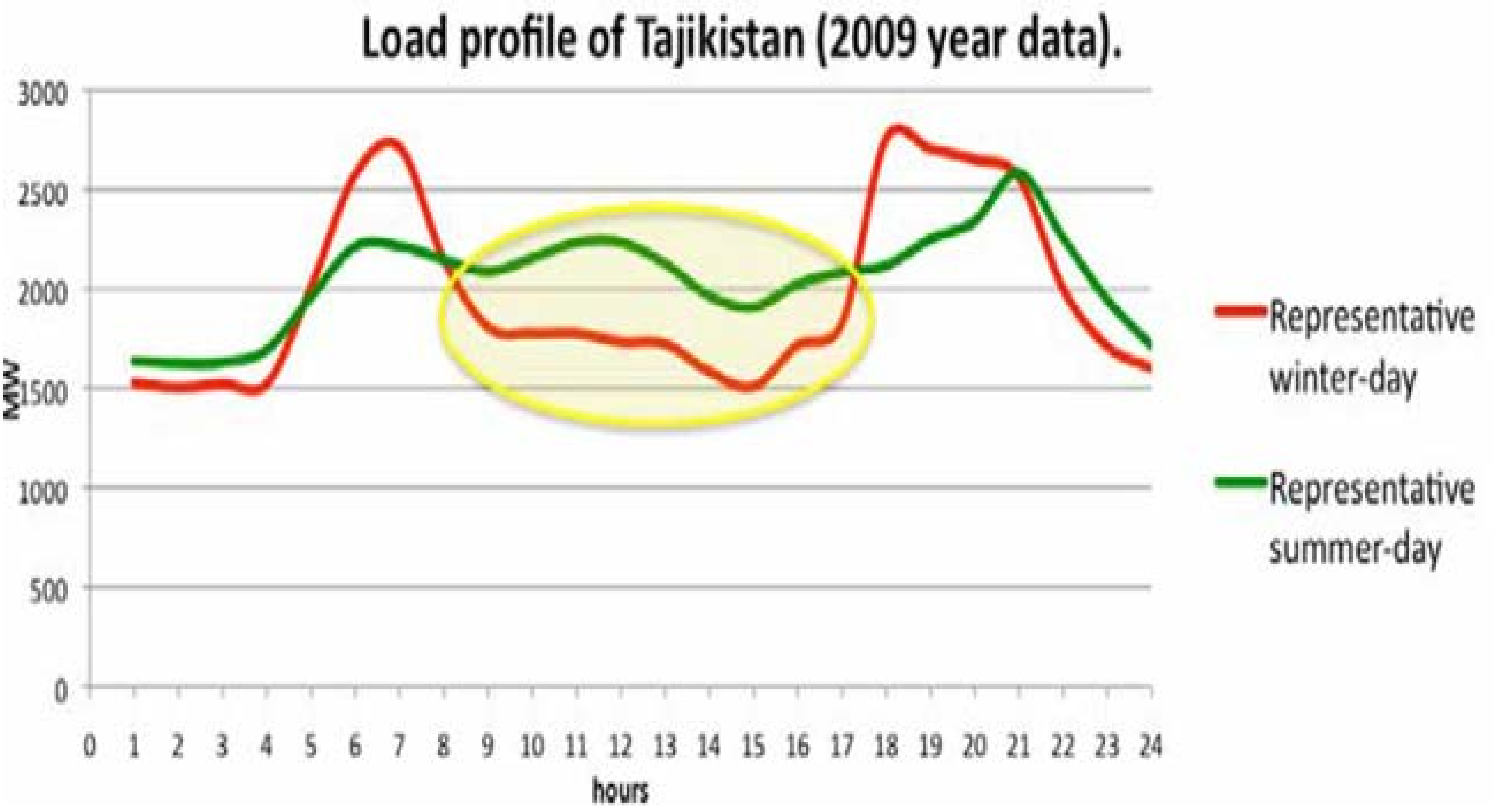



*Source: Updated Energy Strategy of Ukraine until 2030 (June 7, 2012)*

# But demand variability needs to be considered
# Daily fluctuations of demand
## *Every day is different!*

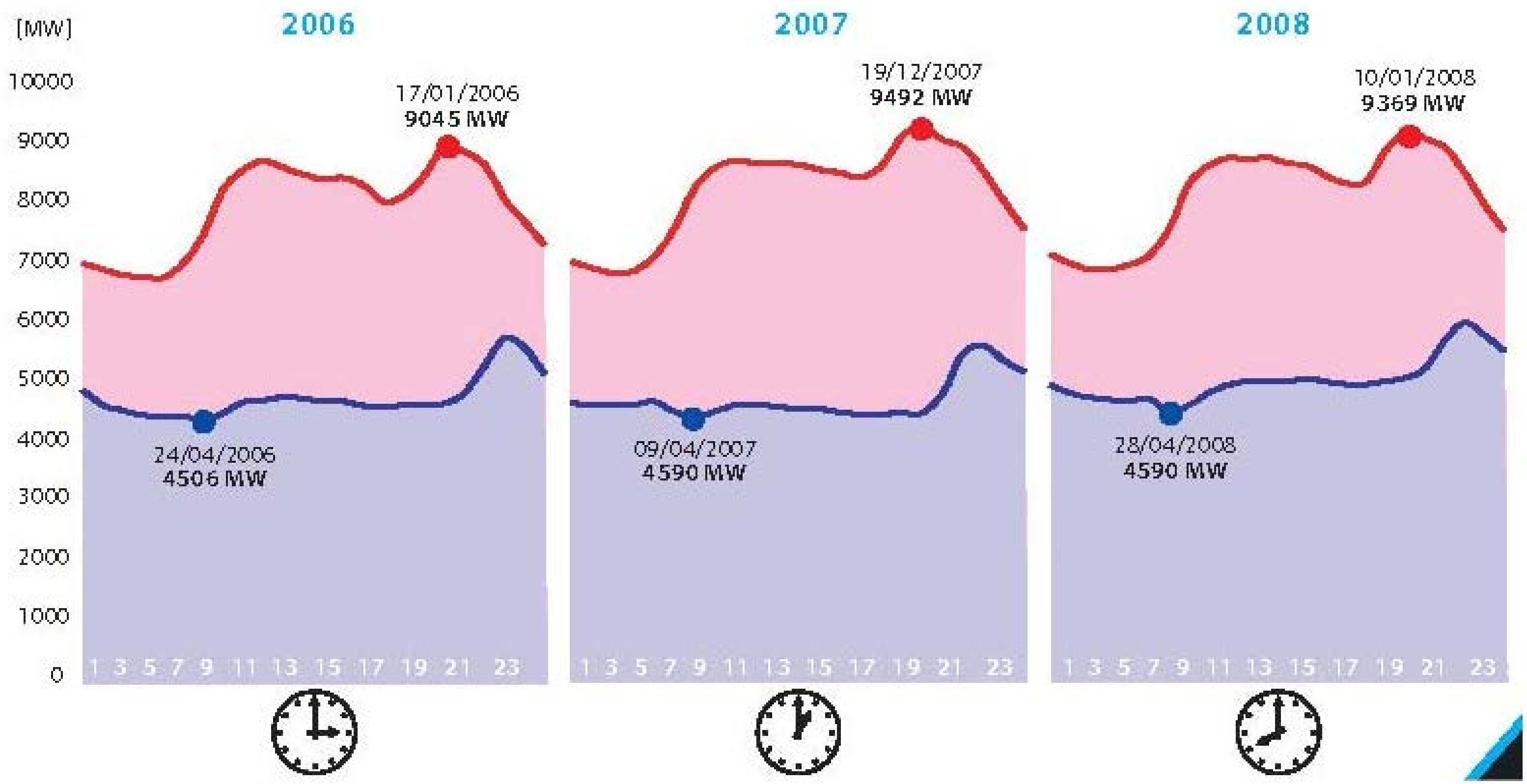


# Example: Daily Demand Profile of Tajikistan




*Source: Mercados, Central Asia Study (2010)*

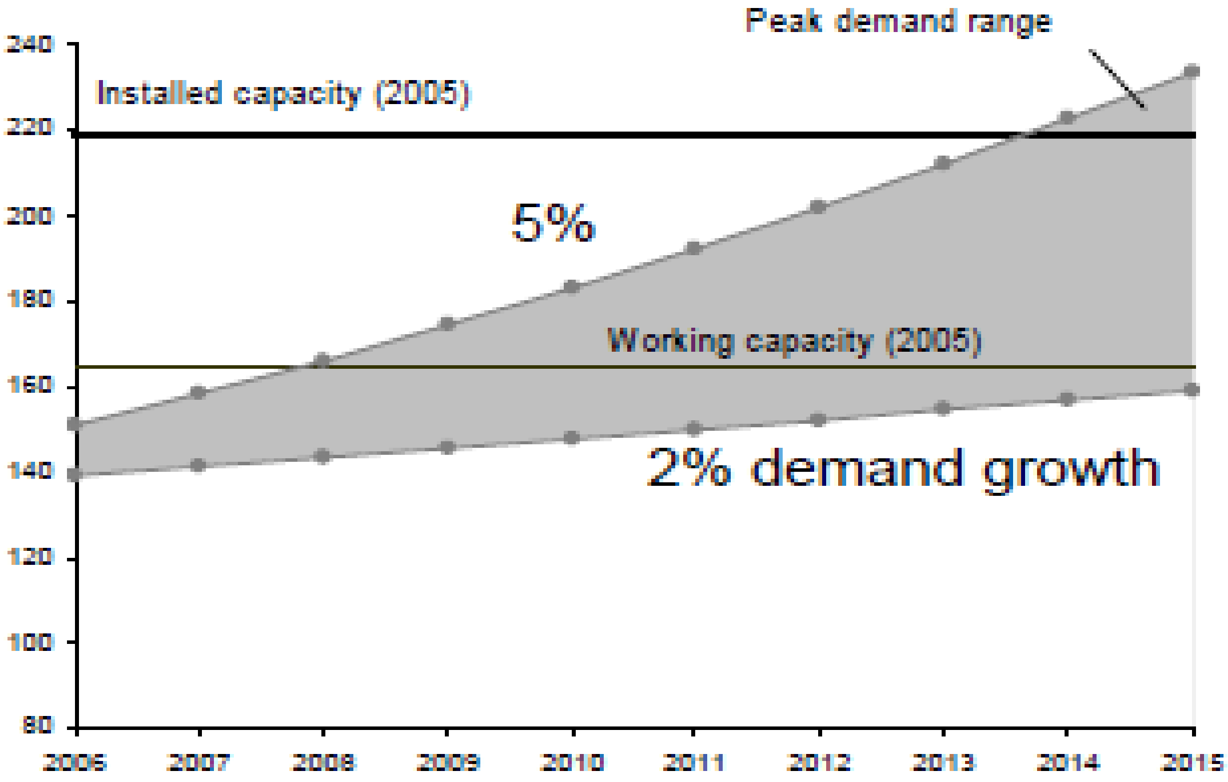
# Example: Romania/Peak demand growth




*Source: Tonci Bakovic, IFC*

# Peak demand determines the need for capacity additions

*Example: Russia Power system (as it was viewed in 2005)*




Demand growth vs. existing capacity, MW

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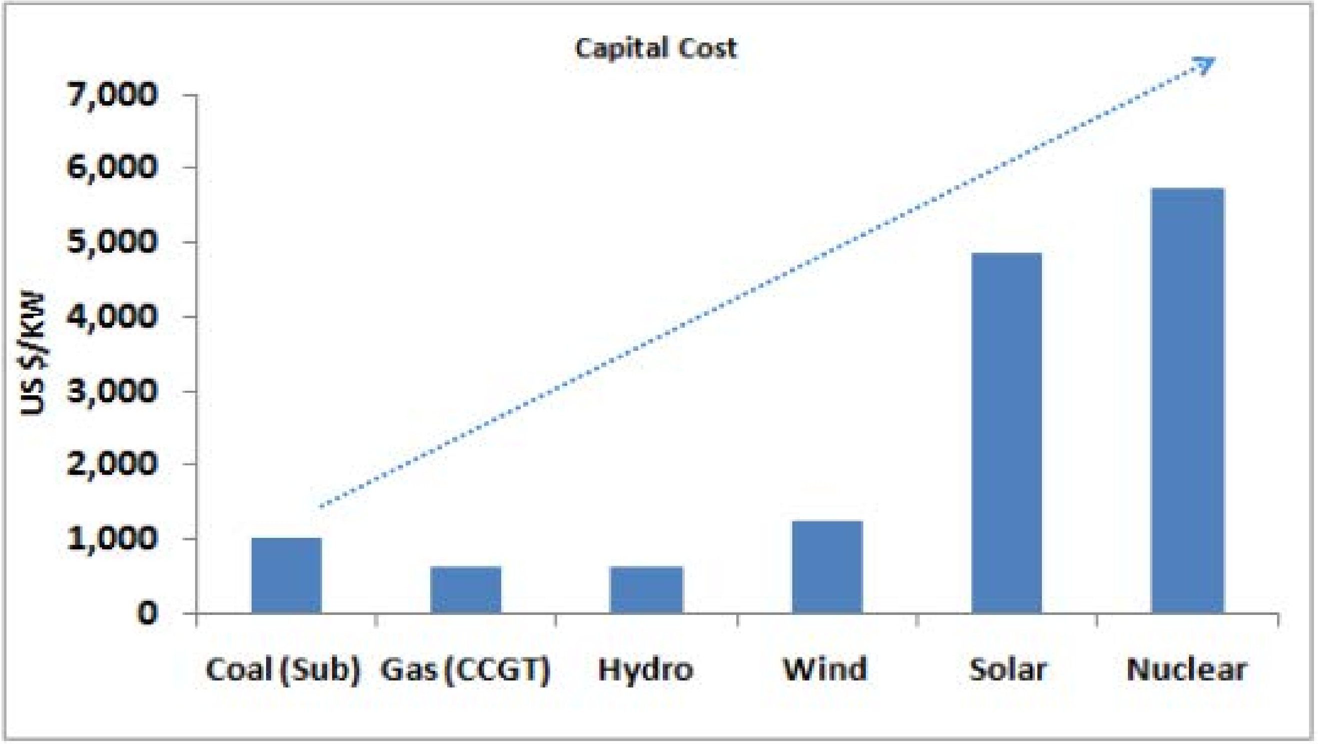
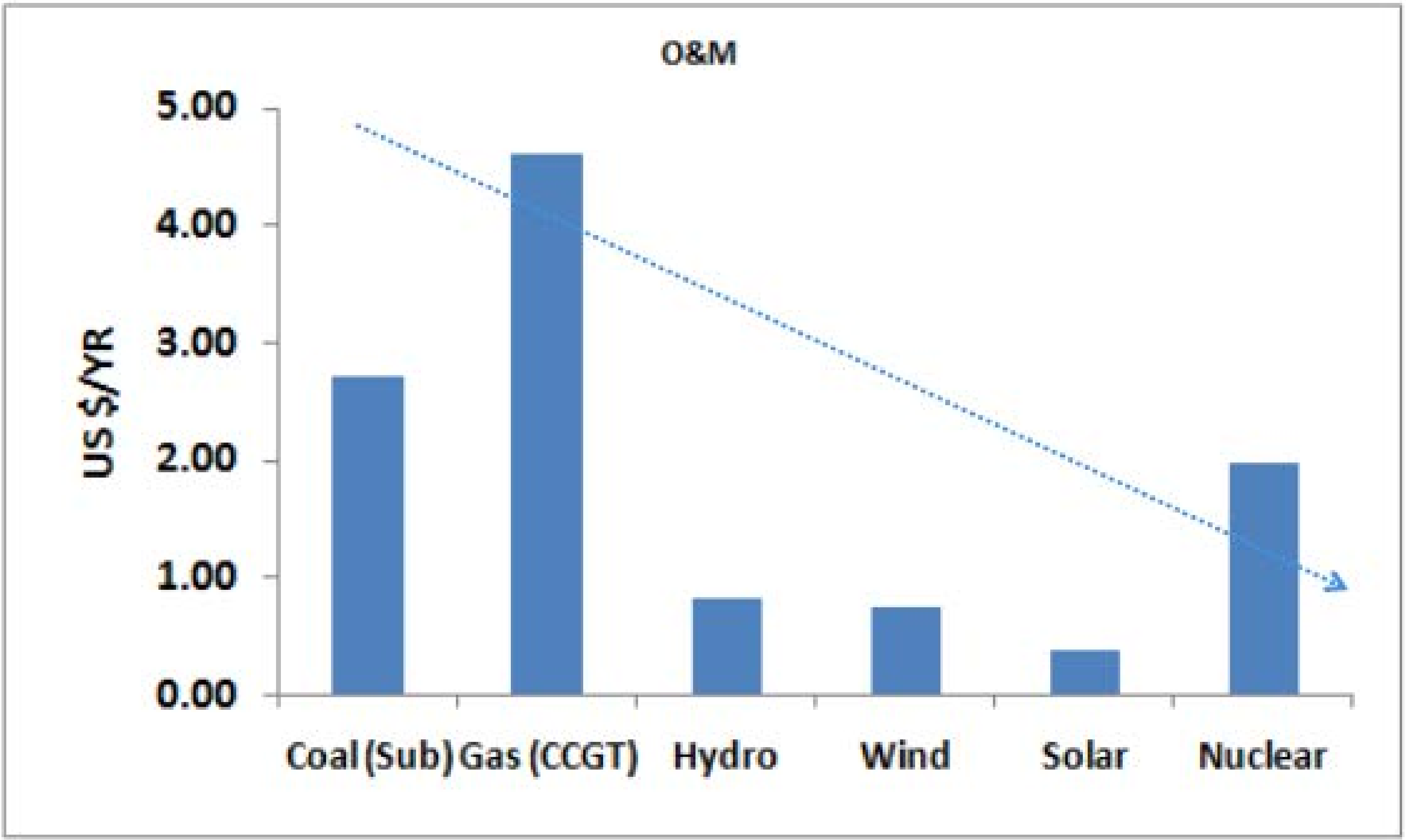
# Capital costs of some technologies




*Source: Own calculation with data from "Technical and Economic Assessment of Off-grid, Mini-grid and Grid Electrification Technologies", World Bank / ESMAP. 2007*

# Variable O&M costs of some technologies




*Source: Own calculation with data from "Technical and Economic Assessment of Off-grid, Mini-grid and Grid Electrification Technologies", World Bank / ESMAP. 2007 and International Energy Agency. "Projected Costs of Generating Electricity 2010 Edition,"*

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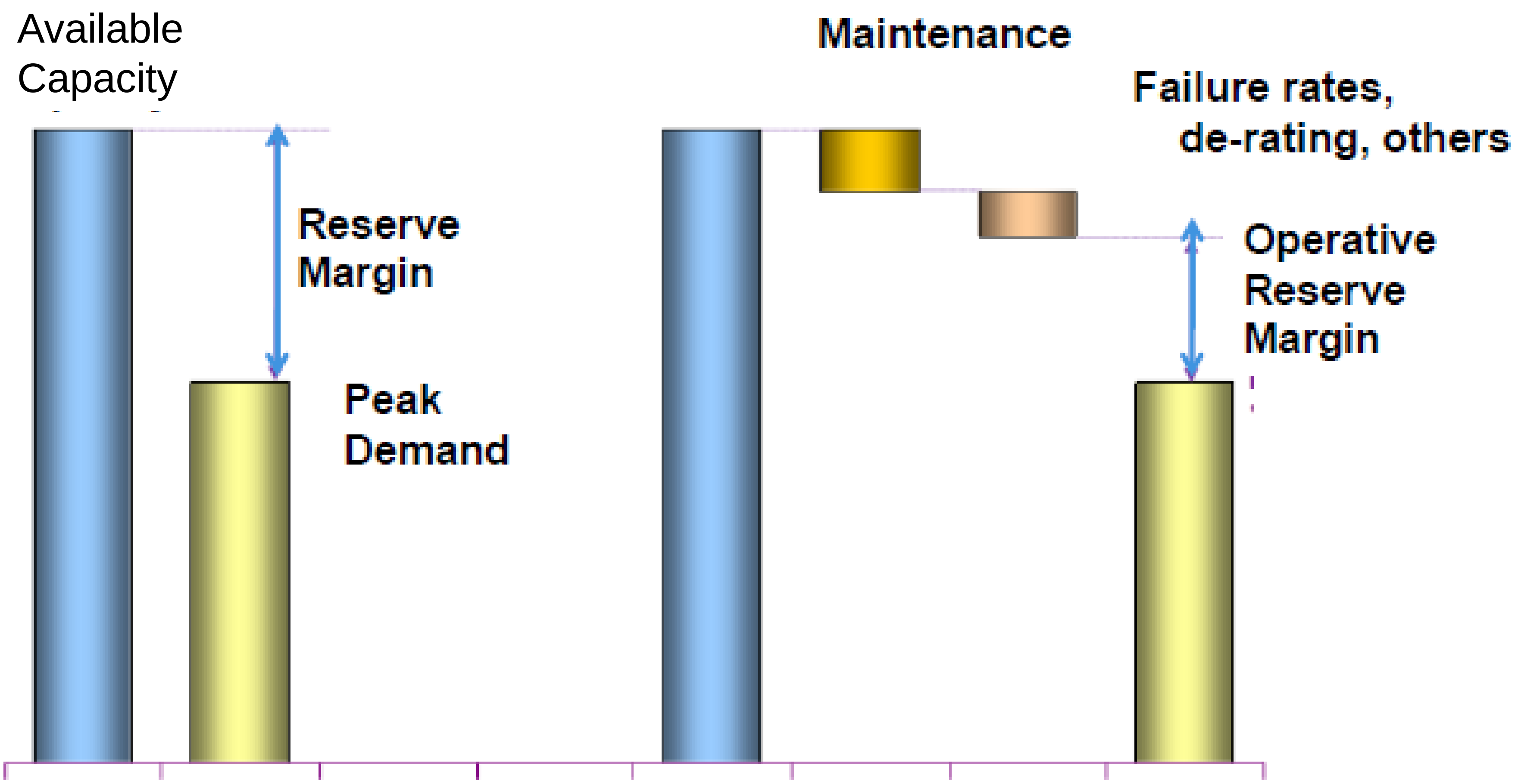
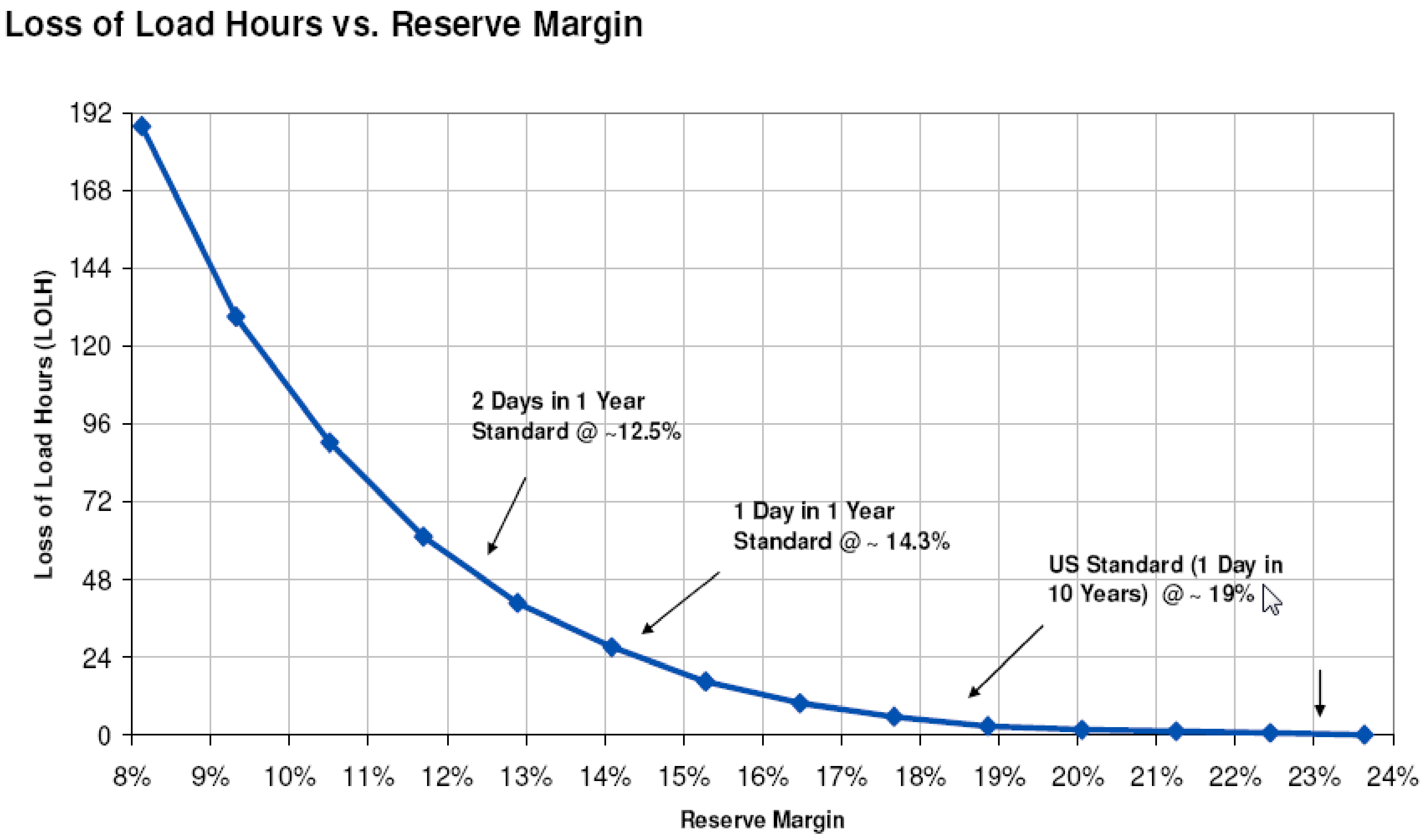
# Reserve Margin and Operative Reserve Margin



# Setting the reserve margin of the power system



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# Objective Function

**Levelized cost of electricity:**

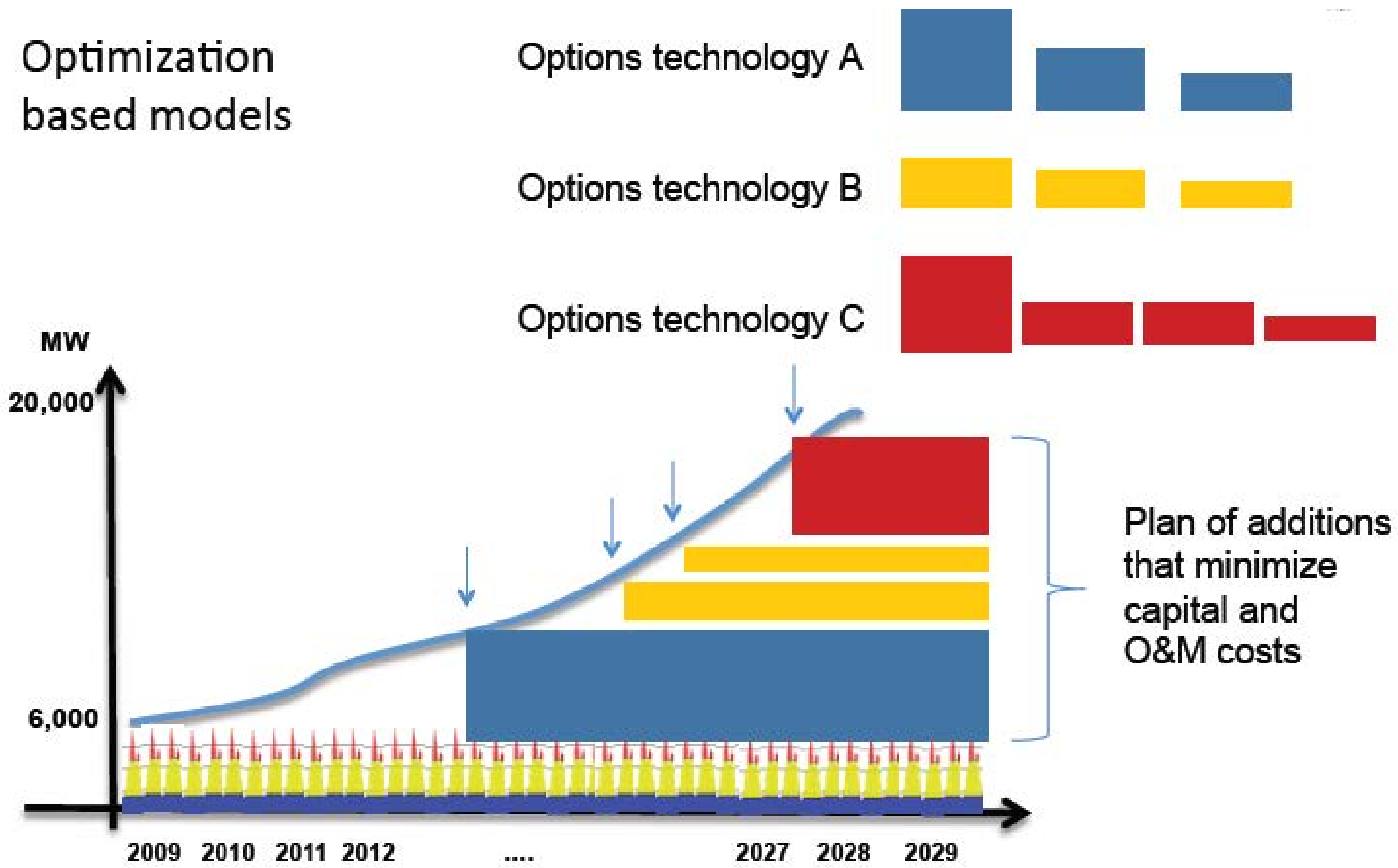
Equivalent cost per KWh including capital, operational, and a return on the investment (discount factor)

**LCE = LCCC + LCFO&M + VO&MC + FC** **($/KWh)**

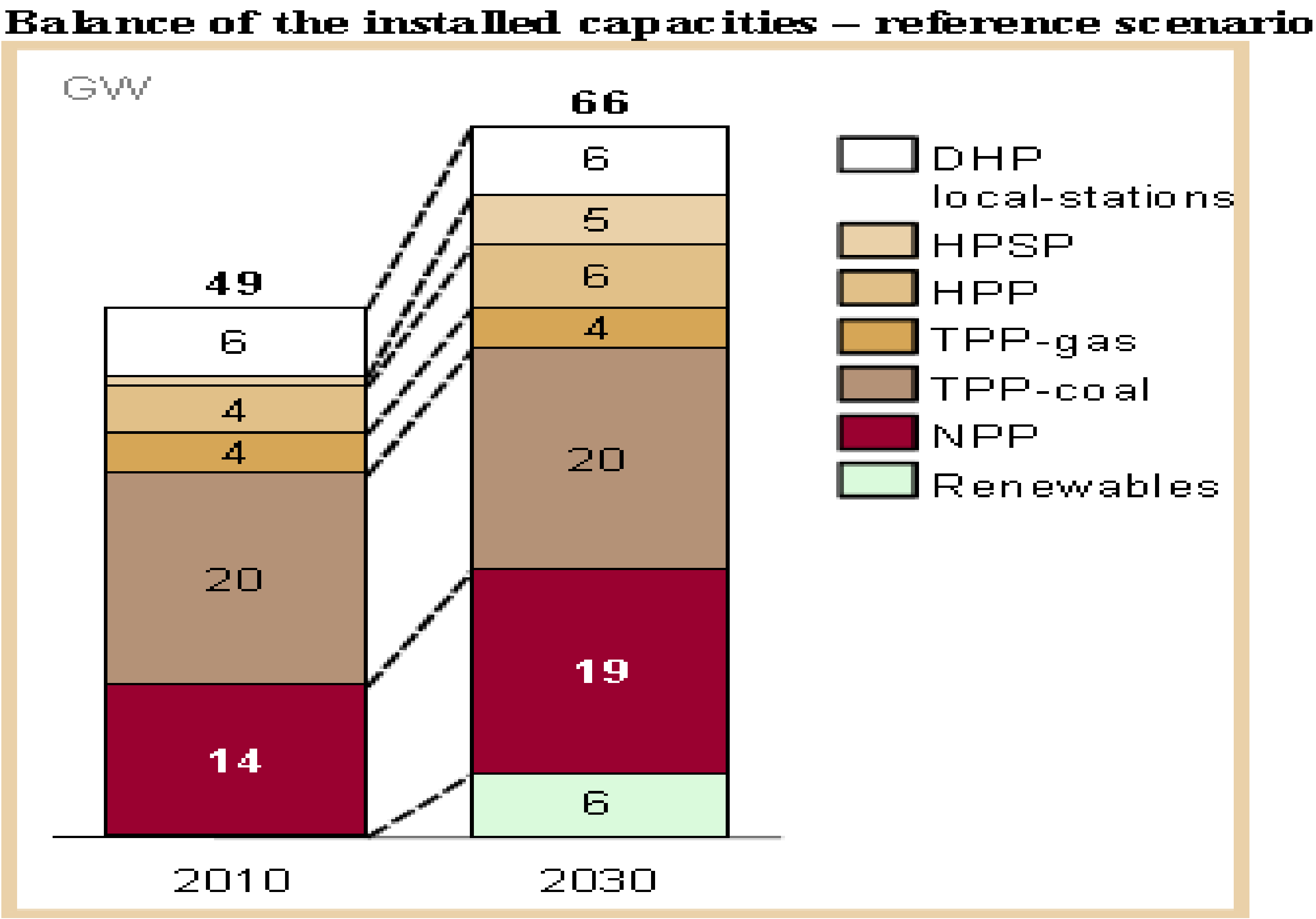
- LCCC: Levelized capital cost
- LCFO&M: Levelized Fixed O&M cost
- VO&MC: Variable O&M Cost
- FC: Fuel Cost

## Plus environmental externalities

# Typical output of generation expansion planning



# Example of planning output: Ukraine (2010-2030)




*Source: Updated Energy Strategy of Ukraine until 2030 (June 7, 2012)*

# Trends and challenges in power system planning

## Especially, regarding integration of renewables

- ***Is planning relevant in a deregulated market?***

- ***If so, who is responsible for planning?***

- ***Increasing importance of environmental and social aspects; also, energy security***

- ***Particularly for renewables:***
    - ***How do you predict firm capacity?***
    - ***How do you balance supply-demand***
    - ***How do you adjust planning to take into account the rapidly growing contribution of distributed generation (e.g., roof-top energy systems)?***

# Who is responsible for planning?

- ***Before Deregulation: Vertically integrated power company in collaboration with the Ministry for Energy***

- ***After deregulation, "indicative planning" by one of the following:***
    - ***Ministry of Energy***
    - ***Energy Regulator***
    - ***Power System Operator***

# Energy planning is changing

- ***Traditional Planning:***
  - ***Demand forecasting***
  - ***Least-cost expansion planning***
  - ***Environmental assessment as an afterthought***

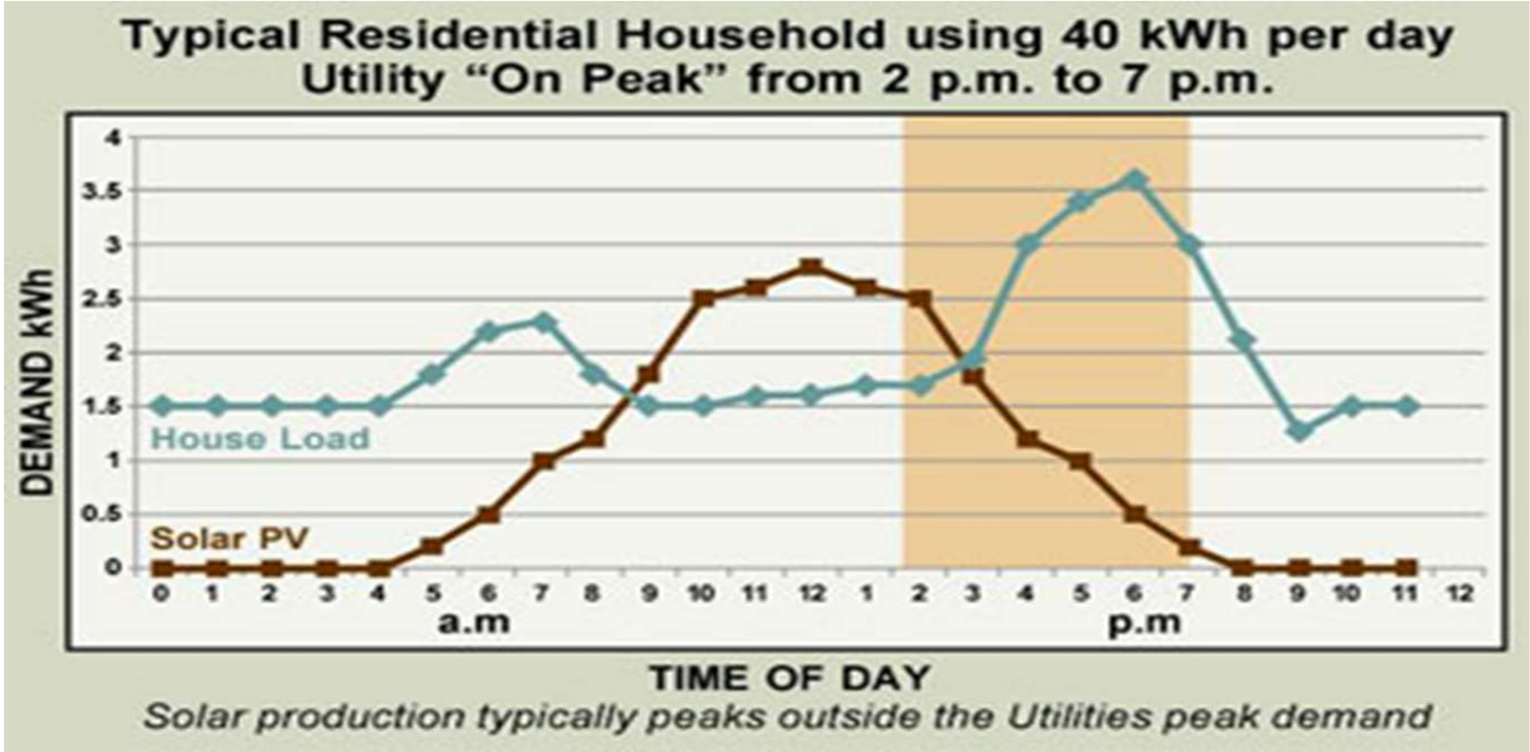
- ***Modern Planning:***
  - ***Integrated resource planning (energy efficiency/DSM; peak-shifting)***
  - ***Least-cost expansion planning integrating environmental externalities; ESIA***
  - ***More attention to renewables and hydro***
  - ***Energy security considerations***

# Challenges for Renewables

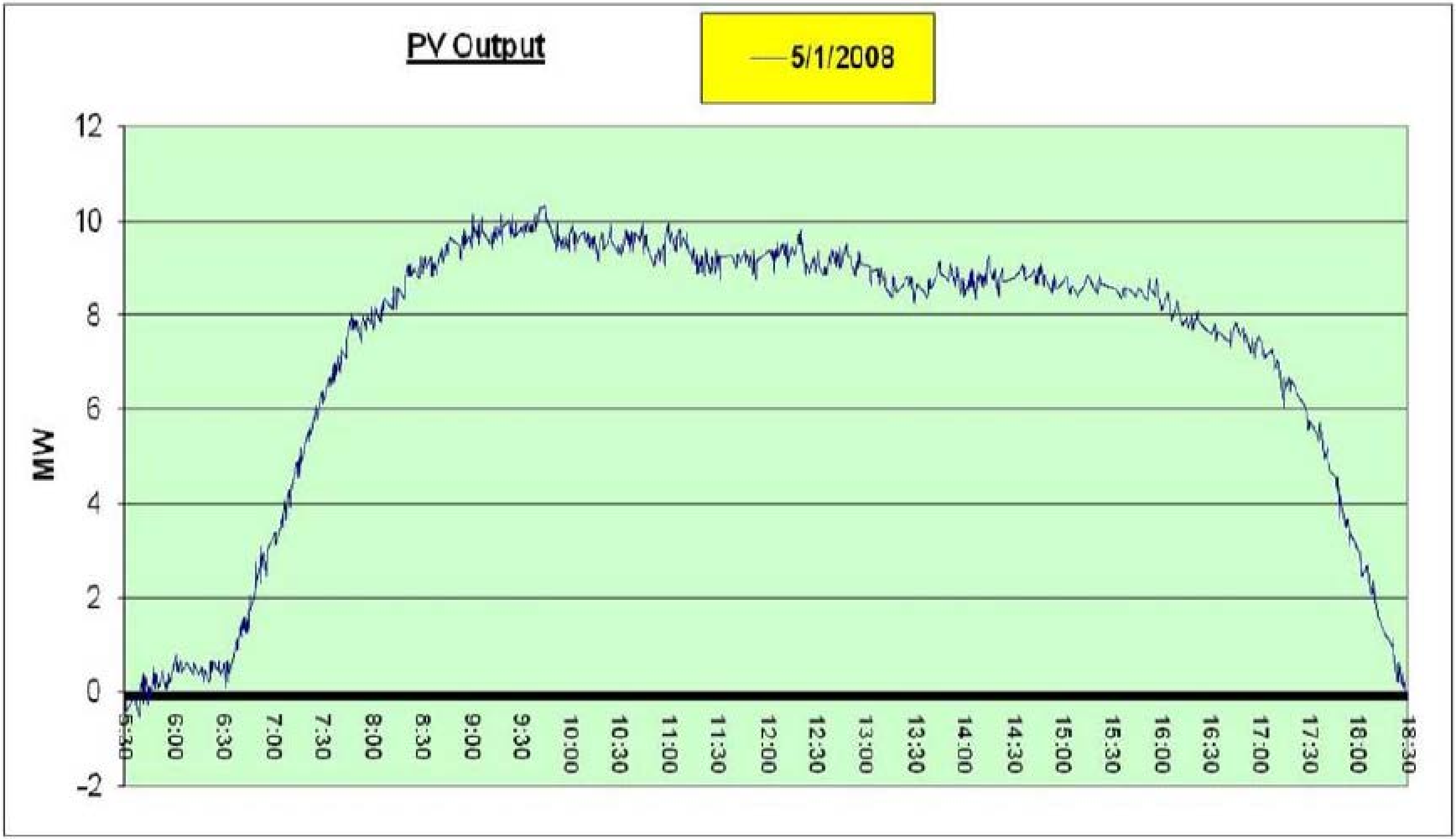
# Renewables have different characteristics than traditional energy options

Solar and wind, in particular:

- Intermittent/variable
- Firm capacity much lower than installed capacity
- Not always matching the demand profile

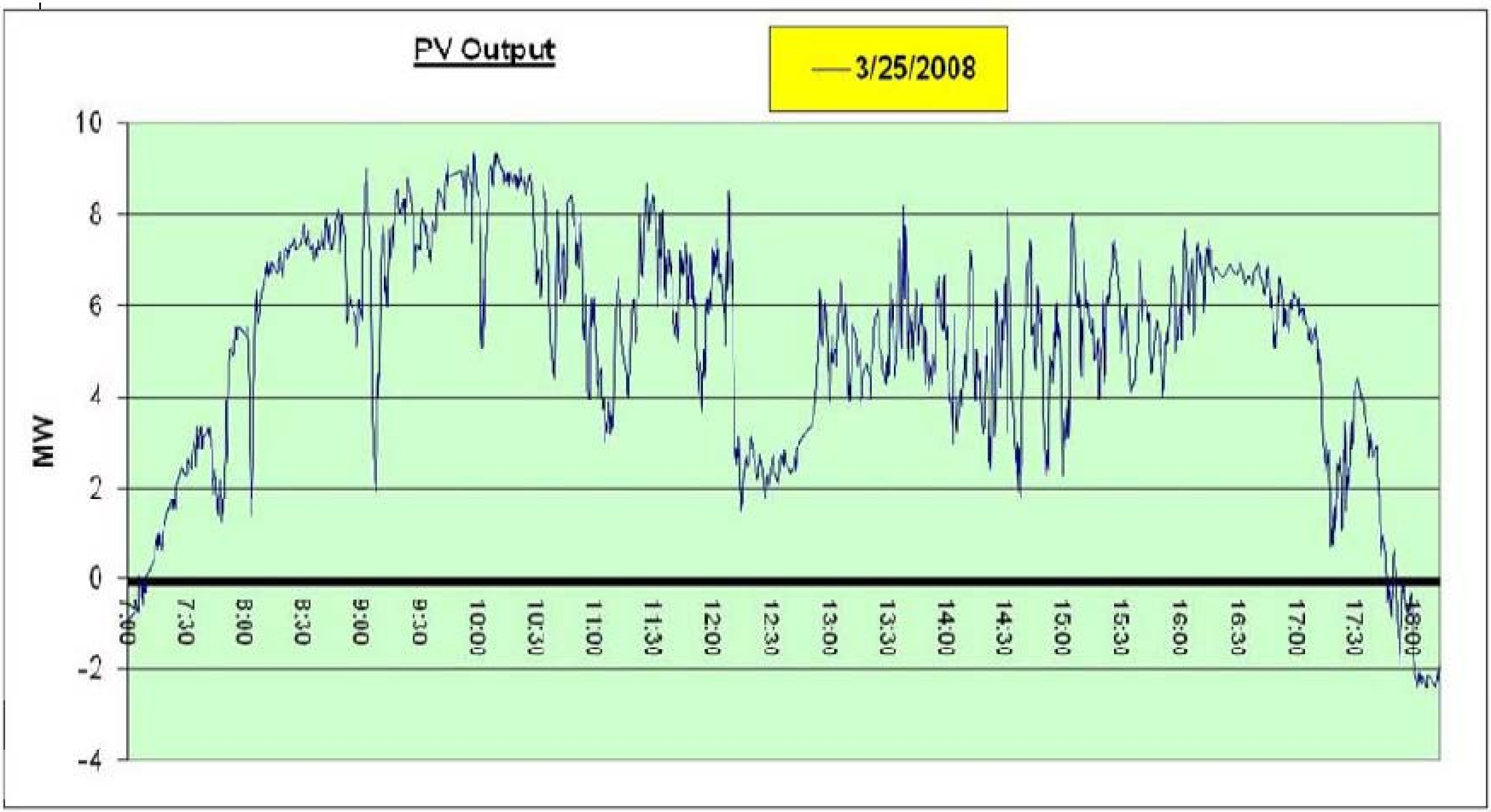


# PV plant output on a sunny day (Sampling time 10 seconds)



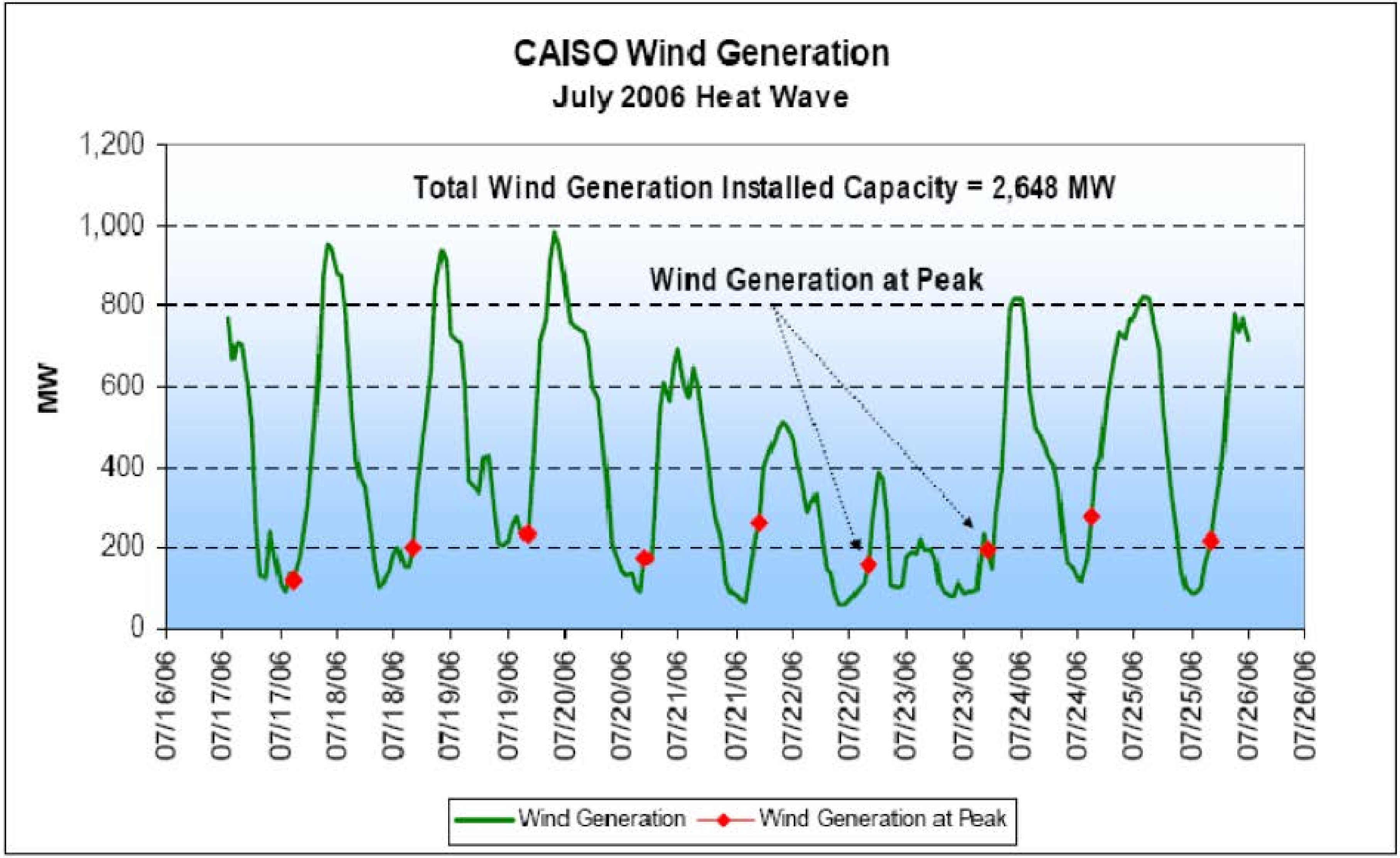

Source: NERC (2009), page 28

# PV Plant output on a partly-cloudy day (Sampling time 10 seconds)




Source: NERC (2009), page 28

# So, how do you predict firm capacity at peak demand?

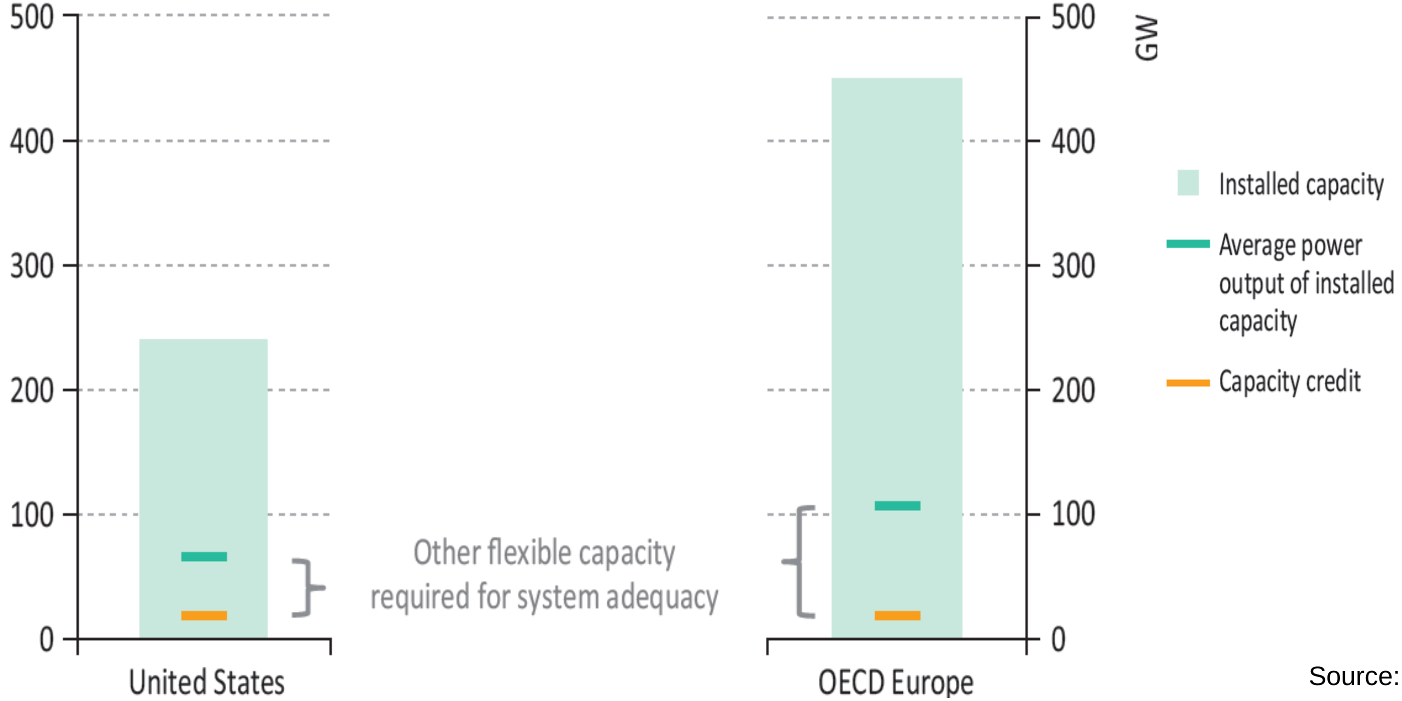



Source: NERC (2009), page 37.

# Firm Capacity

- "Firm" capacity that can be relied upon at time of peak demand
  - Renewables and hydro (other than dam storage) are intermittent; a percentage of the installed capacity is usually unavailable to meet peak demand
    - IEA estimates the combined average capacity credit of wind and solar at 9%, but it is location and project specific

**Capacity of wind and solar PV and their system effects for the US and OECD Europe, 2035**




Source: WEO 2011

# Firm Capacity

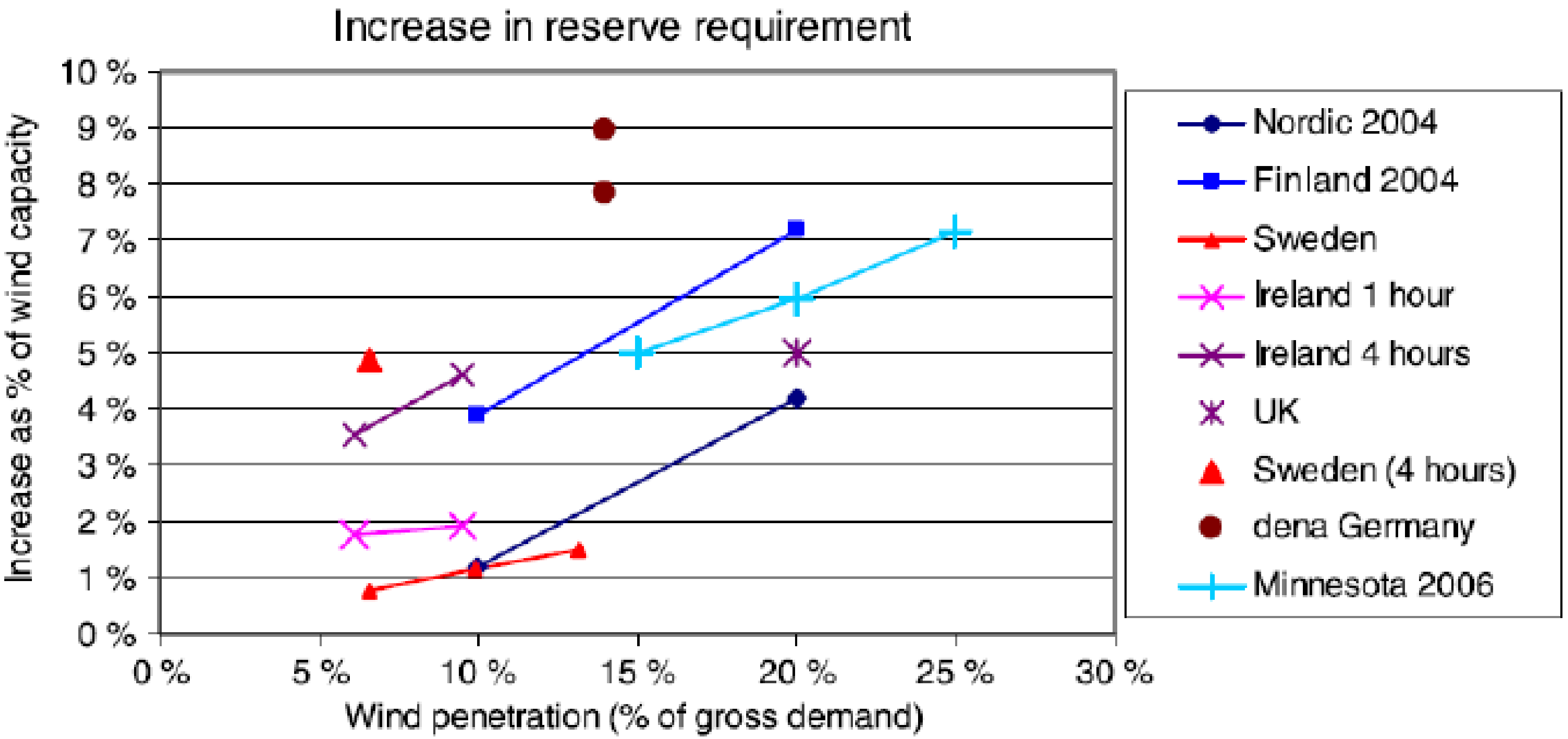
- Planner’s perspective:
  - 10- to 20-year outlook
  - No firm capacity? IEA guide (9%)? proportional to Capacity Factor?

- The system operator’s perspective:
  - Spot and day-ahead markets: Some firm capacity based on weather forecasts and improving predictive models
  - But be prepared for potential curtailment to deal with local grid congestion

# How do you balance supply-demand?

- Increased system reserve margin
- Increased installed capacity for back-up (reserve)
- Increased need for storage hydro and natural gas power plants (example: Ukraine, hydro from 9GWs to 15 GWs)
- Take into account growth of distributed generation

# The cost of short-term impacts..




*Source: IEA Task 25 Design and Operation of Power Systems with Large Amounts of Power*

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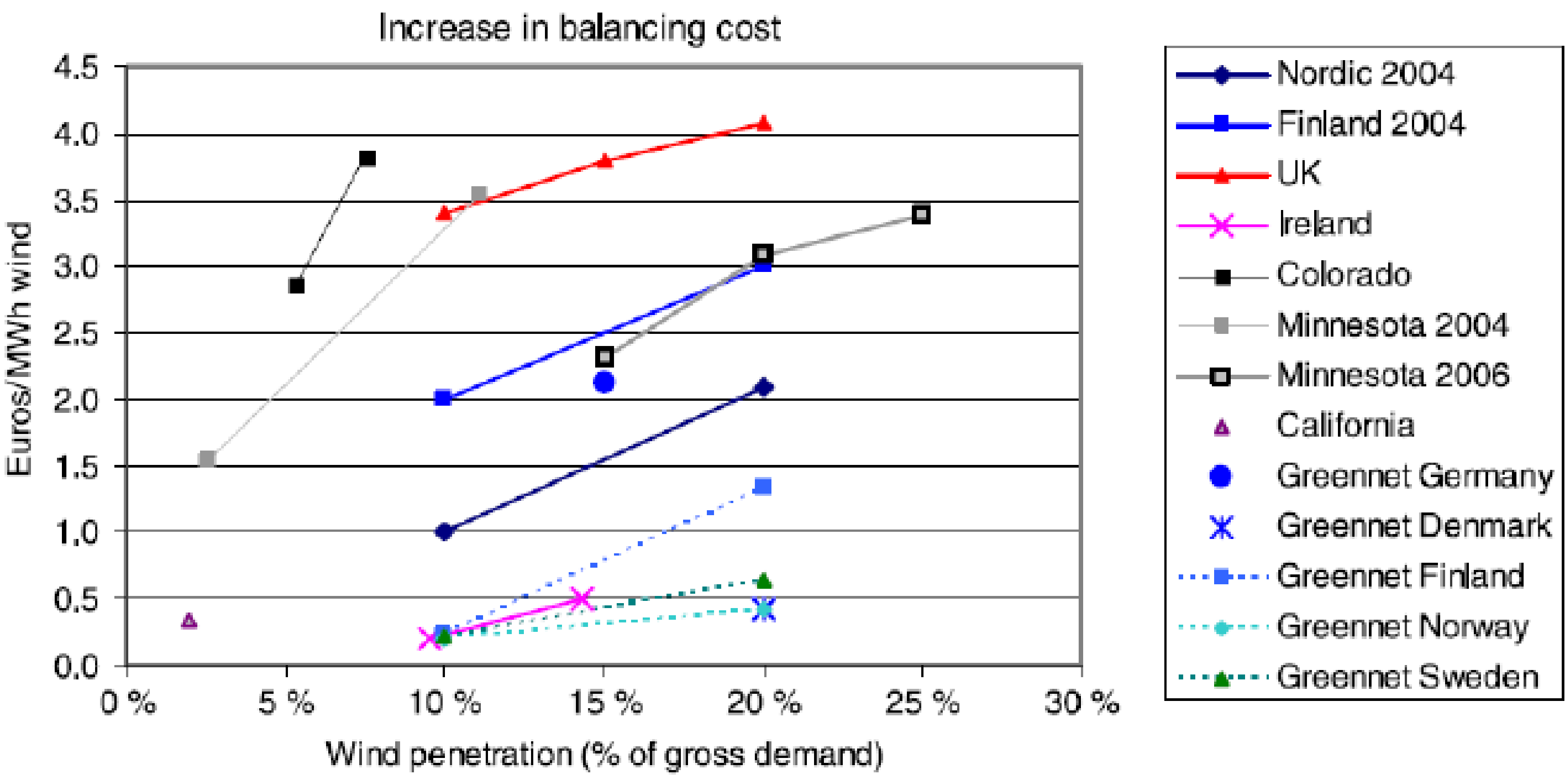



*Source: IEA Task 25 Design and Operation of Power Systems with Large Amounts of Power*

# Wind Penetration – Impacts on Power System

- <5-10% market penetration: Costs negligible; no major issues
- 10-20%: Noticeable impacts; transmission strengthening maybe needed; comprehensive power system studies needed (re. local congestion; balancing; curtailment rules; need for reserve margin increase; etc.)
- >20%: Need for comprehensive assessment of power system design and operation; impact on competitive markets; etc.

# Summary

- Power system planning: A well-established process; yet ever changing to accommodate new requirements (more emphasis on EE; environmental externalities; renewables; power market structure)

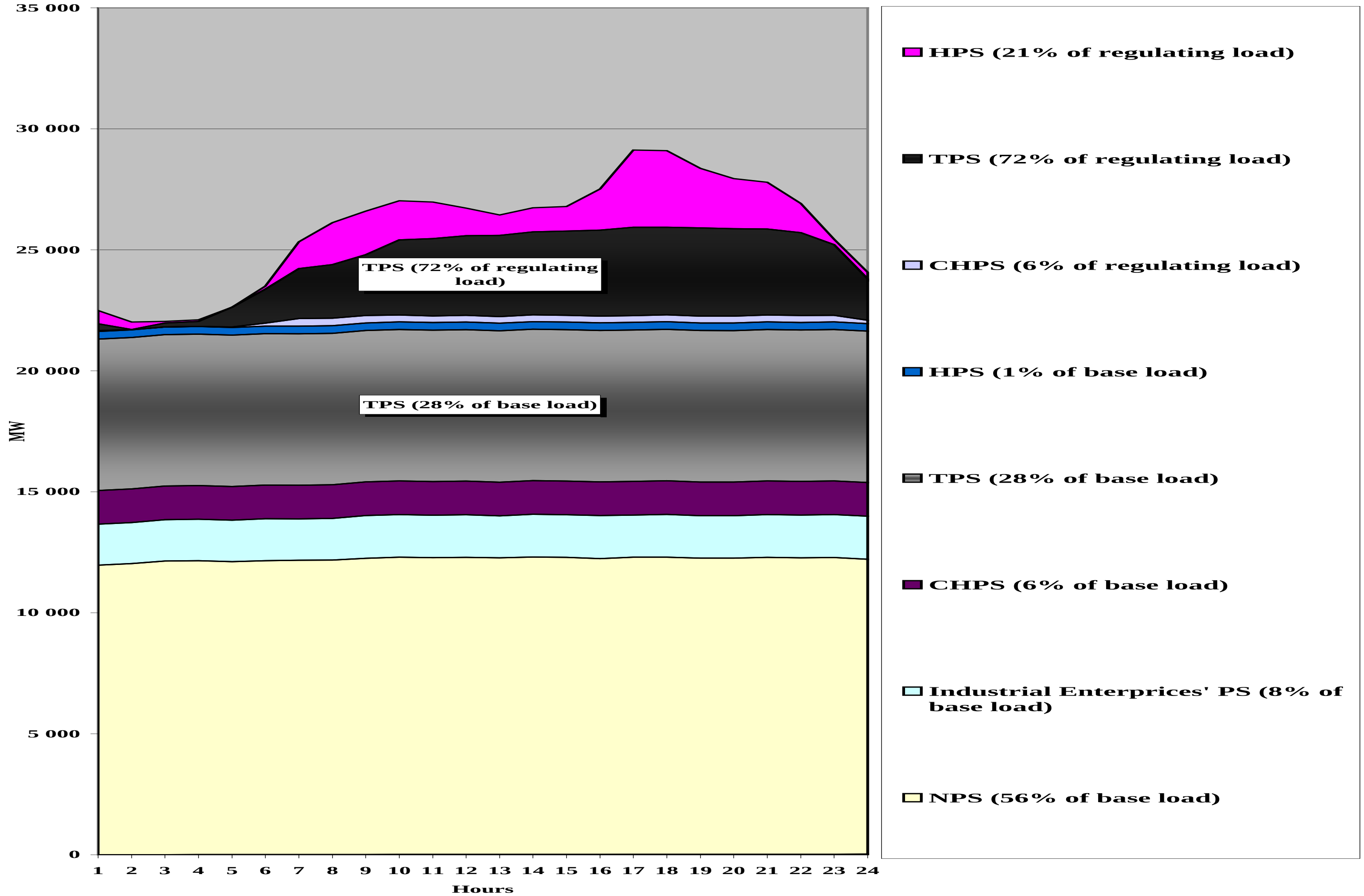
- Planning is still essential!

- As long-term prediction of firm capacity for renewables becomes more accurate, their role in power system planning will be enhanced further

# *Questions?*

# Extra slides

# Typical Hourly Load Curve in Ukraine (Winter Day)




*Source: NEC Ukrenergo*