Electricity supply

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Outline of the presentation

- Generation technologies
- Short-run costs of generation
  - Fuel costs
  - Operation and maintenance costs
  - CO2 impact on the electricity generation
- Long-run costs, technology choice and investment decisions

ENERGY COOPERATION BETWEEN THE EU, THE LITTORAL STATES OF THE BLACK & CASPIAN SEAS AND THEIR NEIGHBOURING COUNTRIES
Power generation

- Converting one form of energy into electric energy

Electricity generation
- Fossil: combustion $\rightarrow$ heat $\rightarrow$ steam cycle
- Nuclear, geothermal: heat $\rightarrow$ steam cycle
- Direct: wind, hydro

- Investment creates generating capacity (MW)
- Electricity can be produced up to the capacity limit of a generation unit
Classical method of power generation
Open cycle gas turbine (OCGT)
Combined-cycle gas turbine (CCGT)
Costs of generation

- Total cost (TC) = Fixed cost (FC) + Variable cost (VC)
- Variable costs change with the production volume, fixed costs do not
- Classification depends on the time frame
- Fixed costs
  - capital costs
  - wages
  - depreciation
  - O&M
- Variable costs
  - fuel
  - O&M
  - CO2
Marginal cost

- The incremental cost of generating 1 MWh more
- Mainly the cost of additional **fuel** burnt
- Potentially also the cost of **CO2** emission allowances
- Production dependent **O&M** costs
  - classification is difficult
- Approximately constant over various capacity usage levels
- But:
  - minimum generating load
  - startup costs
  - sharp increase close to the capacity limit
Estimating fuel costs

- Fuel conversion into electricity: short run marginal cost (SRMC) of generation
  - Cost of fuel ($/GJ, $/ton, $/m3 etc.)
  - Fuel calorific value (GJ/ton, MJ/m3)
    - gross (GCV) or net (NCV)
  - Conversion of fuel energy content into electric energy
    - heat rate (MJ/MWh) or efficiency (%) of conversion
    - losses
    - self-consumption
How to learn about fuel prices?

- Transparent market benchmarks
  - Coal: ARA (Amsterdam, Rotterdam, Antwerp)
  - Gas: Henry Hub (US), EEX (EU)
  - Fuel oil: port prices
- Long-term contract prices
- Oil-indexation formulas in natural gas trade
- Self-reporting
- Extraction cost estimates in case of own fuel base
  - e.g. integrated generation and lignite mine
## Coal prices

### Estimates from a power market study

<table>
<thead>
<tr>
<th>Fuel prices 2010</th>
<th>Coal €c/GJ</th>
<th>Lignite €c/GJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albania</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Austria</td>
<td>158</td>
<td>162</td>
</tr>
<tr>
<td>Bulgaria</td>
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<td>Bosnia</td>
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<td>162</td>
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<td>Croatia</td>
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<td>Czech</td>
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<td>Estonia</td>
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<td>Macedonia</td>
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<td>Germany</td>
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<td>132</td>
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<tr>
<td>Greece</td>
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<td>Hungary</td>
<td>276</td>
<td>175</td>
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<td>Italy</td>
<td>191</td>
<td>162</td>
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<td>Lithuania</td>
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<td>Latvia</td>
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<td>Poland</td>
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<td>167</td>
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<td>Romania</td>
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<td>Serbia</td>
<td>263</td>
<td>162</td>
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<td>Montenegro</td>
<td>-</td>
<td>-</td>
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<td>Slovakia</td>
<td>191</td>
<td>216</td>
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<tr>
<td>Slovenia</td>
<td>191</td>
<td>162</td>
</tr>
<tr>
<td>Turkey</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: KEMA (2005)

### Daily trading information

<table>
<thead>
<tr>
<th>21-May $(/mt)</th>
<th>21-May €(/mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Atlantic</strong></td>
<td></td>
</tr>
<tr>
<td>CIF ARA (6,000 kcal/kg)</td>
<td>86.50 70.10</td>
</tr>
<tr>
<td>FOB Barge ARA (6,000 kcal/kg)*</td>
<td>90.20 73.10</td>
</tr>
<tr>
<td>FOB Richards Bay (6,000 kcal/kg)</td>
<td>88.25 71.52</td>
</tr>
<tr>
<td>FOB Bolivar (6,300 kcal/kg)</td>
<td>76.00 61.59</td>
</tr>
<tr>
<td>FOB Bolivar (6,450 kcal/kg)</td>
<td>76.50 61.99</td>
</tr>
<tr>
<td>Poland Baltic (6,300 kcal/kg)</td>
<td>80.50 65.24</td>
</tr>
<tr>
<td>Russian Baltic (6,400 kcal/kg)</td>
<td>81.00 65.64</td>
</tr>
</tbody>
</table>

Source: Platts (2010)
Fuel oil prices

Fuel oil prices track the crude price closely:

Linear regression results:

\[ \text{FO} = 6.026 \times \text{BR} - 77.03 \]

\[ R^2 = 0.941 \]
Example: oil-indexed pricing formula for Russian gas imports into Hungary

\[ NG = NG_0 \times (0.5 \times GO/GO_0 + 0.5 \times FO/FO_0) \]

- \( NG \): natural gas import price
- \( GO \): average of last 9 months gasoil price in Mediterranean ports
- \( FO \): average of last 9 months MED light fuel oil price in Mediterranean ports
- \( NG_0 \): natural gas price base (287.98 USD/tcm)
- \( FO_0 \): light fuel oil price base (302.093 USD/ton)
- \( GO_0 \): gasoil price base (541.562 USD/ton)

Crude oil-gas price link can be estimated
# Fuel conversion efficiency

Source of estimates: KEMA (2005)

<table>
<thead>
<tr>
<th>Year</th>
<th>Gas/Oil ST</th>
<th>Coal ST</th>
<th>Nuclear ST</th>
<th>CCGT Gas</th>
<th>Gas/Oil GT</th>
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<tbody>
<tr>
<td>1960</td>
<td>37.0</td>
<td>35.0</td>
<td>25.0</td>
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<tr>
<td>1970</td>
<td>39.0</td>
<td>37.0</td>
<td>27.0</td>
<td></td>
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<tr>
<td>1980</td>
<td>41.0</td>
<td>39.0</td>
<td>29.0</td>
<td></td>
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<tr>
<td>1990</td>
<td>43.0</td>
<td>41.0</td>
<td>31.0</td>
<td>50.0</td>
<td>34.0</td>
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<tr>
<td>2000</td>
<td>45.0</td>
<td>43.0</td>
<td>33.0</td>
<td>55.0</td>
<td>36.0</td>
</tr>
<tr>
<td>2010</td>
<td>46.0</td>
<td>43.0</td>
<td>33.0</td>
<td>58.0</td>
<td>38.0</td>
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<tr>
<td>2020</td>
<td>49.0</td>
<td>43.0</td>
<td>33.0</td>
<td>60.0</td>
<td>40.0</td>
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<tr>
<td>2030</td>
<td>52.0</td>
<td>43.0</td>
<td>33.0</td>
<td>62.0</td>
<td>41.0</td>
</tr>
<tr>
<td>2040</td>
<td>55.0</td>
<td>45.0</td>
<td>45.0</td>
<td>64.0</td>
<td>42.0</td>
</tr>
</tbody>
</table>

Increasing efficiency over time
Magnitude of losses in power generation

The figure is only presented for the illustration of magnitudes.

Sources: IEA/OECD, 2008

FIGURE 16: ENERGY FLOWS IN THE GLOBAL ELECTRICITY SYSTEM
Deciding about maintenance costs

- The total maintenance cost varies with increasing amount of preventive maintenance.
- Optimum level of preventive maintenance at minimum total maintenance cost.
CO2 costs

► CO2 emissions from burning fuels have a negative „external” effect on the environment (global warming)
  ◆ this is a cost caused to others that is not borne by the generator

► For socially optimal production decisions, generators must face these costs as well
  ◆ paying a carbon tax
  ◆ buying CO2 emission allowances
  ◆ …for each ton of CO2 emitted into the atmosphere

► Typical variable (marginal) cost elements
Components of CO2 costs

CO2 emission factors

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>CO2 emissions [kg/GJ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard coal</td>
<td>93.7</td>
</tr>
<tr>
<td>Lignite</td>
<td>112.1</td>
</tr>
<tr>
<td>Natural gas</td>
<td>55.8</td>
</tr>
<tr>
<td>Heavy fuel oil</td>
<td>77.0</td>
</tr>
<tr>
<td>Light fuel oil</td>
<td>73.7</td>
</tr>
</tbody>
</table>

CO2 allowance prices

CO2 cost (€/MWh)

Efficiency of fuel conversion
Example: Marginal cost calculation

- CCGT unit
- 53% fuel conversion efficiency (gas to electric energy)
- 5% self-consumption of electricity generated
- Natural gas price: 20 €/MWh
- O&M cost (variable part): 5 €/MWh
- CO2 allowance price: 20 €/ton
- CO2 emissions factor for gas: 200 kg/MWh
- Marginal cost ≈ 53 €/MWh
Marginal costs are similar

Coal is cheaper

CCGT is cheaper

Marginal costs

Marginal cost

€/MWh

$\frac{\text{€}}{\text{MWh}}$

0

20

40

$\text{CO}_2\text{ cost}$

$\frac{\text{€}}{\text{t}}$

SRMC (CCGT)

SRMC (Coal)

Figure for illustration purposes.
Investment into generation

How to choose which type of generation to invest in?
- coal, gas, nuclear, renewable, …

Additional information is needed:
- cost of building and maintaining capacity ($/kW)
- capacity factor (annual utilization rate)

Assessment of the risks involved during the lifetime of the project
Load/price duration curves and capacity factors

![Graph showing load/price duration curves and capacity factors for various energy sources: Coal (hard, lignite, nuclear), GT/CHP, CCGT, Pump Storage, Oil Plants, Running Water, and Operating Hours. The graph includes a legend for different energy types and their corresponding capacity factors (CF) and operating hours. The graph also highlights peak, mid-mid merit, and base load areas.]
Determinants of investment decisions

- Investment decisions depend on many factors:
  - Market size
  - Market type
  - Market liquidity
  - Capacity need
  - Extent of regulation
  - Investors risk appetite
  - Investor’s company structure (IPP, integrated company, government entity etc.)
  - Cost of capital
  - Return expectation
  - Government policy
  - Country risks
  - …
Illustrative lifetime costs of a coal project

Finance costs = Tax + Interest + Dividends

- Finance: 40%
- Construction: 23%
- Development: 1%
- O&M: 9%
- Fuel: 27%

Source: ERRA training (2010)
Cost of capital

- Weighted average cost of equity and debt
  - Cost of equity (e.g. 12%)
  - Cost of debt (e.g. 10%)
  - Financing structure (e.g. 70% equity and 30% debt)
  - WACC = 0.7 × 12 + 0.3 × 10 = 11.4%

- Debt and equity costs depend on several factors:
  - business risk
  - sector/country risk
  - legal protection for creditors
  - global liquidity, …
Role of risk analysis in investment

- Things can and do go wrong, money can be lost
- Risk management
  - identifying all the potential risks
  - devising strategies to allocate responsibilities and define liabilities
- Liabilities may be covered by
  - liquidated damages
  - insurance
  - acceptance of consequential cost (or combinations)
Key risks in investment

- Power purchaser counterparty credit risk
  - will the buyer be able/willing to pay?

- Fuel supply risk
  - can continuous fuel supply be ensured?

- Power evacuation
  - will the network be strong enough for intake?

- Water supply risk
  - will cooling water (or a reservoir) be available?

- Construction risks
  - will construction be finished without delays?

- O&M risks
  - what happens if something breaks later on?
The counterpart of investment: exit decision

Risk may become unmanageable…
- Inability to deliver the expected returns, performances
- The owner changing its market strategy
- The market changing significantly
- New privatization / nationalization strategy
- Not adequate financial return, bankruptcy
- Regulatory system changing too frequently and not transparently
- Too strict environmental regulation

„Everything can be sold, if the price is right.”