The Optimisation of the supply-demand balance, the role of interconnections, and the impact of nuclear shutdown in Germany for EDF

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Role, challenges and principles of optimisation at EDF
Maximising the consolidated gross margin

- Structural diagram:
  - The objective is to make the Producer, the Optimiser and the Supplier responsible for their own activities within an explicit mandate.
  - There is a joint objective, to maximise the gross margin, driven primarily by the Optimiser.

**Responsibilities**

- **Producer**
  - Ensuring the availability of generation facilities
  - Controlling maintenance operating costs

- **Optimiser**
  - Optimising the Upstream/Downstream balance
  - Maximising the consolidated gross margin
  - Managing risks

- **Supplier**
  - Maximising supply margins
  - Guaranteeing market shares
Optimiser's relations with the supplier and producer

- The producer undertakes to provide the optimiser with:
  - its best estimate of the availability of generation facilities
  - complete transparency on its constraints and costs

- The supplier undertakes to provide the optimiser with:
  - its best estimate of the development of its customer portfolio and volumes consumed by its customers
  - Full transparency on products sold to its clients, including embedded optionalities with the associated risks

- The optimiser undertakes to provide the producer and supplier with:
  - economic signals so that each entity will manage their portfolios in order to maximise the gross margin.
Optimisation at EDF

- The main role of the optimiser is to ensure that the upstream resources are managed in a way that meet the commitments to the customers downstream (and other counterparties). By minimising the cost of supply and maintaining an accurate representation of the downstream portfolio, the Optimiser can ensure that the gross margin is maximised within a level of risk limited by the Group risk management policy:

  - **upstream resources**: generation facilities, long-term electricity purchasing contracts, bilateral purchasing agreements, purchases on wholesale markets, obligations to purchase from decentralised producers
  
  - **downstream commitments**: long-term supply contract, bilateral sales agreements, sales to end users, sales on wholesale markets

- The optimiser looks after costs, manages stocks, and transacts (through the trader) on the wholesale markets.

- The supply-demand balance is forecast over the different time horizons.

- The upstream/downstream balance must be simulated at regular intervals, as there are many fluctuations and uncertainties.
Financial components of optimisation

France

- Weather fluctuations
- Tens of millions of euros for an unusual cold snap
- Optimisation of shutdowns of nuclear plants for refueling and maintenance
- More than €1 Bn/year for the nuclear fleet
EDF: upstream portfolio and downstream portfolio (2010)

**Wholesale markets**
- 2010: 19 TWh

**Upstream**
- 2010: 520 TWh
  - Nuclear power: 408 TWh
  - Hydro power: 45 TWh
  - Fossil-fired power: 17 TWh
  - Long-term & structured purchases: 6 TWh
  - Mandatory purchases: 31 TWh

**Downstream**
- 2010: 520 TWh
  - Sales to End Users: 418 TWh
  - Auctions (VPP): 39 TWh
  - Structured sales: 69 TWh

**Bought/Sold**
- 2010: 19 TWh
  - Fossil-fired power: 17 TWh
  - Hydro power: 45 TWh
  - Nuclear power: 408 TWh
Optimisation levers for upstream/downstream portfolio

Wholesale markets
- Bought/Sold: 19 TWh
- Long-term & structured purchases
- Mandatory purchases
- Fossil-fired power
- Hydro power
- Nuclear power

Output/Purchases
- Flexibility of outage placement
- Management of hydro reservoir stocks and outage placement
- Scheduled shutdowns

Sales
- Tariff based demand reduction e.g. Peak day reduction (EJP)
- Auctions (VPP)
- Structured sales
- Sales to End Users

EDF France excluding Island activities
The upstream/downstream balance is fairly erratic over different time periods

- Thermo-sensitivity of consumption: temperature has a strong influence on demand: in winter, one degree less equals to 2,300 MW of higher consumption in France

- Variations in water levels ⇒ major variation in generation potential from year to year (10 to 15 TWh between a dry year and a rainy year)

- Unplanned unavailability of production facilities (nuclear power, fossil-fired power, ...)

- Mandatory purchases from smaller producers (decentralised): strong fluctuation in contribution of renewable energies (up to 4,000 MW from one day to another on the French wind power generation)

- Sales on the wholesale markets: optionalities at the hand of our counterparties
Use of the wholesale market

- When there is a difference between the sum of the upstream and downstream positions, the optimiser balances the difference by transacting on the wholesale market.

- It is possible to transact different products over different time periods:
  - Medium term: purchase or sale of annual products for the year N+1/N+2/N+3
  - Short term: same principle with purchases/sales today for the next day (spot) or over the next few hours of the day
  - Intermediate products (quarterly products over two to three coming quarters and weekly products over two to three coming weeks) also exist

- The optimiser can directly contact its potential counterparties or go through the organised markets:
  - OTC (over the counter) bilateral agreement: direct trade with counterparty
  - Regulated exchanges: pooling of supply and demand by a market organiser and settlement of trades (Epexspot in France, Belpex in Belgium, etc.)

- The optimiser for France accesses the market exclusively via EDF Trading.

(1) or via a broker
Daily optimisation in practice and role of international exchanges
Cost optimisation
Scheduling of generation facilities based on variable costs

The optimiser schedules the operation of generation facilities, ranking according to their merit order until the estimated demand is met.
Daily optimisation: preliminary optimisation by each producer

- Before the market, each producer determines the resources required to meet a given level of demand.
- It classifies its available generation facilities from the least expensive to the most expensive.
- It then determines the marginal cost of purchases/sales on the market to meet the supply-demand balance of its own portfolio:

![Chart showing electricity sources and their costs](chart.png)

- Price = €65/MWh
- "must run" generation
- Nuclear power
- Thermal power
- Hydro power
- Fuel oil
- Electricity generator's portfolio (e.g. EDF)
Continuous adjustments with the wholesale market

- The optimiser then compares its marginal production cost with the market price. This is used to determine a buy/sell strategy:

**CASE NO. 1**

- Market price = €100/MWh
- Output sold on the market

**CASE NO. 2**

- Market price = €60/MWh
- Purchase from market up to cost of substitution (65/MWh)

**OPTIMISATION with EDF Trading**

Total generation facilities more expensive than the market
Determination of the spot price

In most European countries, spot electricity prices for the next day are established by fixing on the exchange:
- Each producer determines the price-quantity ratio that it wants to sell and transmits it to the market operator.
- The market operator then groups all the producers' offers in order of increasing price.
- The same is done on the supply side.
- The spot electricity price for the next day is determined by taking the intersection of the supply curve and the demand curve (assumed here not to be price-sensitive).

![Graph showing supply and demand curves for electricity generation sources.](image-url)
Spot price history (France)

- The determination of the spot price is therefore closely linked to:
  - the level of demand
  - the availability of production fleets and demand management
  - fossil fuel prices
  - the country's energy mix

Source: Powernext

Spot price since 2009 (Moyenne glissante 7j)

- Lower availability of the generation fleet
- Cold snap
- Heat snap
- Post summer activity recovery
- Demand rise
- Temperatures rise And demand fall
- Cold snaps
- Heat snaps
- Cold snaps
- Heat snap
- Slack supply/demand balance
- Post summer activity recovery

Source: Epexspot
Importance of the generation mix in price determination

The table below shows the breakdown of the French and German fleet by increasing order of variable costs.

<table>
<thead>
<tr>
<th>Estimated variable costs in €/MWh</th>
<th>Installed capacity in France (GW)*</th>
<th>Installed capacity in Germany (GW)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind power 0****</td>
<td>5.6</td>
<td>27</td>
</tr>
<tr>
<td>Solar power 0****</td>
<td>0.8</td>
<td>17</td>
</tr>
<tr>
<td>Nuclear power 10</td>
<td>63.1</td>
<td>20.3</td>
</tr>
<tr>
<td>Lignite 20</td>
<td>0</td>
<td>20.5</td>
</tr>
<tr>
<td>Gas 50</td>
<td>9</td>
<td>18.1</td>
</tr>
<tr>
<td>Coal 65</td>
<td>7.9</td>
<td>24.6</td>
</tr>
<tr>
<td>Fuel oil 150</td>
<td>10.4</td>
<td>1.2</td>
</tr>
<tr>
<td>Hydropower**** Variable</td>
<td>25.4</td>
<td>8.6</td>
</tr>
</tbody>
</table>

Consequently, the last unit called on in Germany can be less expensive than the last unit called on in France (particularly in winter).

* Based on average fuel prices at end-April 2011
** at 31/12/2010, source RTE
*** at 31/12/2010, source EEX
**** wind and solar energy are unavoidable energies. Hence their marginal cost is nil.
***** hydropower is divided into two categories: run-of-river, which is an unavoidable energy, and impoundment. Both are sources of energy at the generator's disposal, optimally recovered based on system costs.
German wind energy output

German wind energy output varies considerably from day to day, causing spot prices to fluctuate.
Impact of the shutdown of 7 nuclear reactors in Germany ("electric island")

- **Assumption**: no interconnection between Germany and France
- **Consequence**: the price increases, but settles at a different level depending on the level of “must run” generation output

Before shutdown of 7 reactors, little wind

Before shutdown of 7 reactors, strong wind

After shutdown of 7 reactors, little wind

After shutdown of 7 reactors, strong wind

Price rises from €50/MWh to €65/MWh

Price rises from €20/MWh to €50/MWh
Impact of the shutdown of 7 nuclear plants in Germany (Germany connected to France)

- **Assumption**: Germany and France are linked by an interconnection.

- **Consequence**: Electric flows are made from the least expensive country to the more expensive country until the prices are equalised in both countries, subject to physical saturation of the interconnections.

- **Example based on cases presented in previous slides**:

<table>
<thead>
<tr>
<th>Level of « must run » generation in Germany</th>
<th>Spot price - Germany</th>
<th>Spot price - France</th>
<th>Direction of flows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>€65/MWh</td>
<td>€60/MWh</td>
<td>F -&gt; G</td>
</tr>
<tr>
<td>High</td>
<td>€50/MWh</td>
<td>€60/MWh</td>
<td>G -&gt; F</td>
</tr>
</tbody>
</table>

In other words, if Germany is marginal for fossil-fired energy and France is marginal for nuclear energy, France will export to Germany. Conversely, if wind power output is high in Germany and France is marginal for fossil-fired energy, it is unlikely that France will export to Germany.
Since 16 March, France has exported to Germany on average, but has not saturated the interconnection (physical limit: about 2,500 MW), the main reasons being the warm weather in April in France and low wind in Germany.

France continues to import periodically from Germany, particularly when “must run” generation output (wind/solar power) is high.
Impact of the shutdown of 7 nuclear reactors in Germany on nuclear output in France
The output of the nuclear fleet predominantly depends on its availability

- The nuclear fleet operates on baseload: output relies mainly on availability (Kd) … at the right time of the year:
  - In 2011, a Kd target of 78.5% corresponds to available energy of 434 TWh
- However, this target is reduced by utilization factor (Ku) reflecting:
  - Environmental constraints and necessary contribution to ancillary services (19.5 TWh in 2010)
  - Periods of low demand during which there is no market for nuclear output (about 6.5 TWh in 2010, i.e. about 1.5% of Ku)
- In 2011 output target is 408-415 TWh with a Kd of 78.5% at least

Reactor shutdowns are therefore scheduled in order to maximise the Ku of the fleet in light of the estimated Kd

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**Ku / Kd / Kp**

Availability factor, Kd:
the available energy as a percent of the maximum energy that could be generated if the installed capacity was operated all year long

Utilization factor, Ku:
the energy generated as a percent of the energy available

Load factor, Kp:
the generated energy compared to the maximum theoretical energy (constant operation of the installed capacity throughout the year)

\[ K_p = K_d \times K_u \]
The moratorium in Germany will not cause any increase in EDF nuclear output

- The shutdown of 5 German reactors (2 already shut down at the time of the decision), accounting for about 5 GW, must be considered in relation to day-to-day wind energy output variations in Germany (up to 17-18 GW)

- Periods when France can export nuclear power to Germany are periods when demand is low and France is marginal for nuclear power. This occurred 5-6% of the time in 2010

- In such case, the interconnections with Germany are usually already saturated

The temporary or permanent shutdown of nuclear plants in Germany will therefore have no impact in nuclear output in France. However, Germany will import more from its neighbors as a result of a deterioration in its generation mix.
Appendices
Example of EDF client consumption forecasts

Sunday in May
(25/5/08)

Business day in January
(Wednesday, 7/1/09)
Consumption in France: highly seasonal and temperature-sensitive

- Greater seasonality of consumption
  - from 30 to 35 TWh in summer months
  - sometimes over 50 TWh in December and January

- 1°C temperature difference in France:
  - in winter ≈ 2,300 MW
  - in summer ≈ 450 MW

Source: DTI for the UK, UCTE for Germany and Italy, RTE for France

Average daily consumption gradients, winter 2010-2011, summer 2009
Weather derivatives

Weather risk:
- Many companies have exposure to the weather
- To stabilise the results, a company may choose to cover weather risk by buying weather derivatives (listed products for temperature, wind, precipitation)

Weather derivatives based on temperature:
- These products are in HDD (*Heating Degree Day*) over winter, with an associated value in €/HDD (1 HDD = €1,000)
- The HDD value depends on the temperature (colder the winter, higher is the value)
- Monthly or long period products (e.g. November-March)
- Temperatures are measured in a reference station
  - In Europe: Paris Orly, London Heathrow,…
Weather risk at EDF

- French consumption highly thermo-sensitive…
  - Colder the weather, higher is the electricity consumption (heating)
  - Comparatively, other European countries consumption is less sensitive to temperature fluctuations

- …and market price higher than retail prices…
  - Colder the weather, higher is the risk of spot prices to increase

- …resulting in exposure to cold waves
Market coupling: example of France and Germany: when there is no coupling

Price difference
Germany
Market coupling: example of France and Germany: when there is coupling and no physical limit to the border

Price convergence between France and Germany
Market coupling: example of France and Germany: when there is coupling and physical limit to the border

Due to the limited interconnections, spot prices are not established at the same level in France and in Germany. The residual spread, called congestion rent, is paid to transmission System Operators*.

* The amount is deposited into a fund helping to build new infrastructure to eliminate bottlenecks. The remaining surplus, if any, is deducted from TURP.
Nuclear shutdowns seasonality

Forcasted demand for electricity and number of nuclear shutdowns

- Number of nuclear shutdowns forecasted
- Weekly consumption in France in GW

Weekly consumption in France in GW