Document number

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Simulatie van het EU-wijde elektriciteitsysteem

Modellering van de elektriciteitsmarkt en de hierin gebruikte elektriciteitsinfrastructuur

Presentatie voor Kivi Niria
Utrecht, 16 April 2013

KEMA DNV

Agenda

- What is the European electricity system?
- What kind of models are used?
- What does the European Market Model look like?
- What are capabilities and limitations?
- Topics:
  - Influence of extreme, long-lasting and EU-wide weather circumstances in case of large RE share,
  - Influence of energy storage,
  - Influence of demand response.

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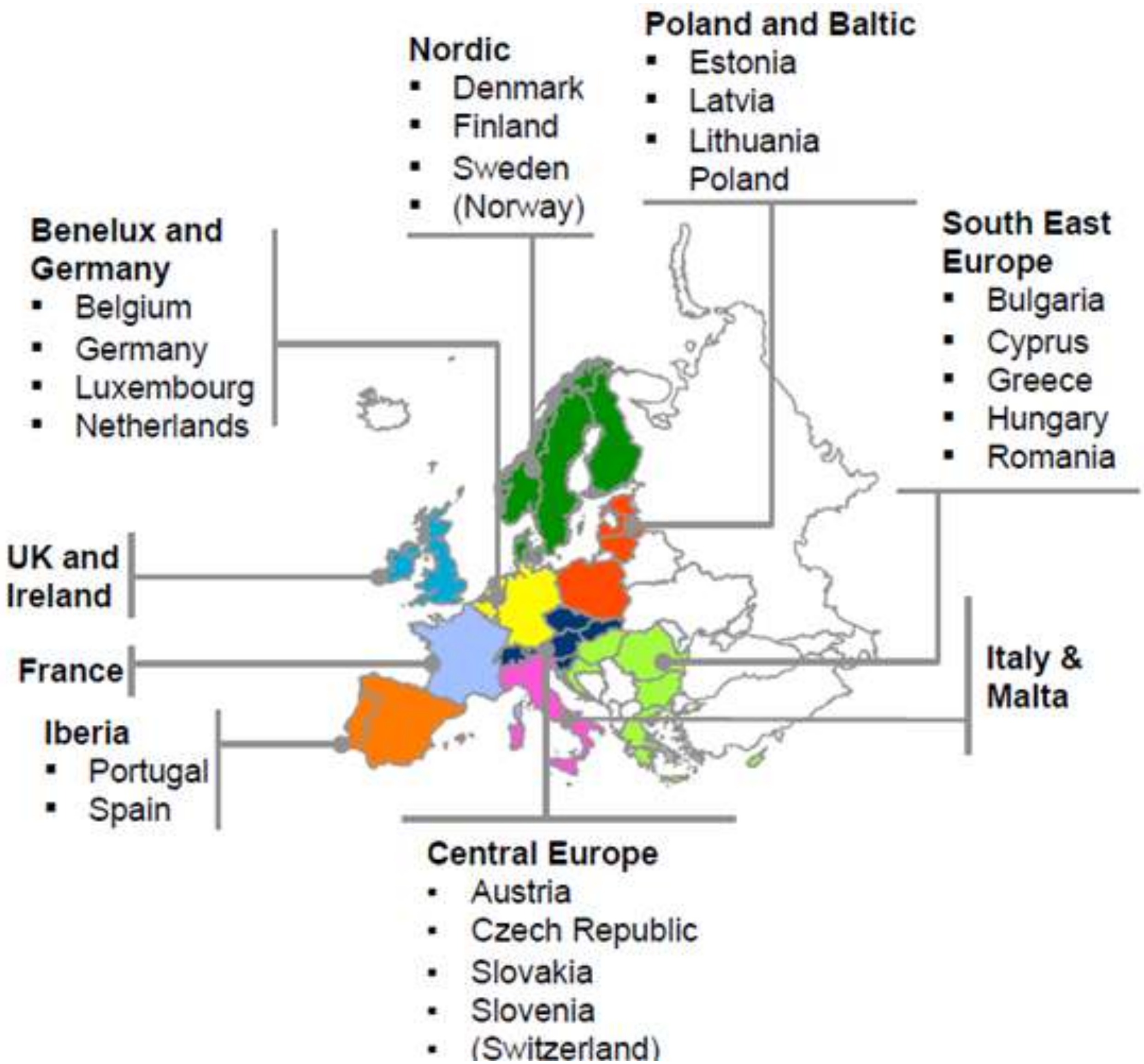
What is the European electricity system?



What is the European electricity system?

The interconnected electricity system of 27 countries

- Generation:
  - Players, Generation portfolios
  - Fuel mix, fuel prices
  - CO_2 prices/obligations
- Transmission:
  - ENTSO-E
  - Reserve sharing
- Markets:
  - European rules, directives, regulation, ideas (market coupling, ….)
  - ETS, EU energy targets
  - Day-ahead, Intraday, Reserves (primary, secondary, tertiary),

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What kind of models are used?

Many models for market analysis and simulation

- Dispatch models
- Expansion models
- Network models
- Commercial models – own models

Depending on the objective a mix of models may be used

Explanation based on the DNV KEMA suite of models

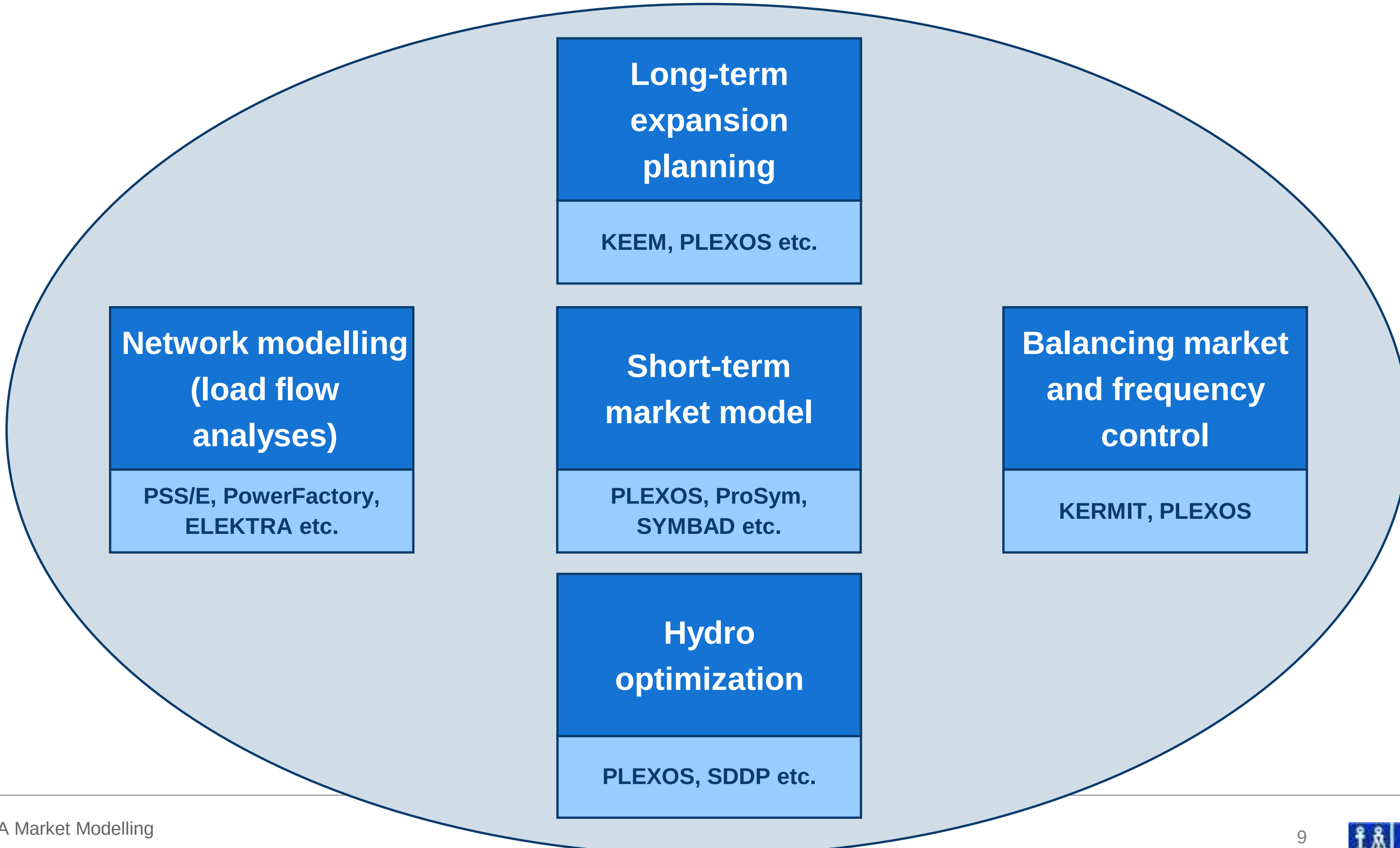
DNV KEMA modelling suite - Overall concept

A modular portfolio of several powerful tools enable a comprehensive simulation of electricity markets and power systems

- DNV KEMA use a modular portfolio of simulation tools for comprehensive electricity market analysis and modeling, combining several powerful simulation models.
- Our models allow the simulation of …
  - …commercial as well as technical market and system aspects (Market and system operation).
  - …the whole time horizon from long-term expansion planning up to real time simulation of load flows and frequency control.

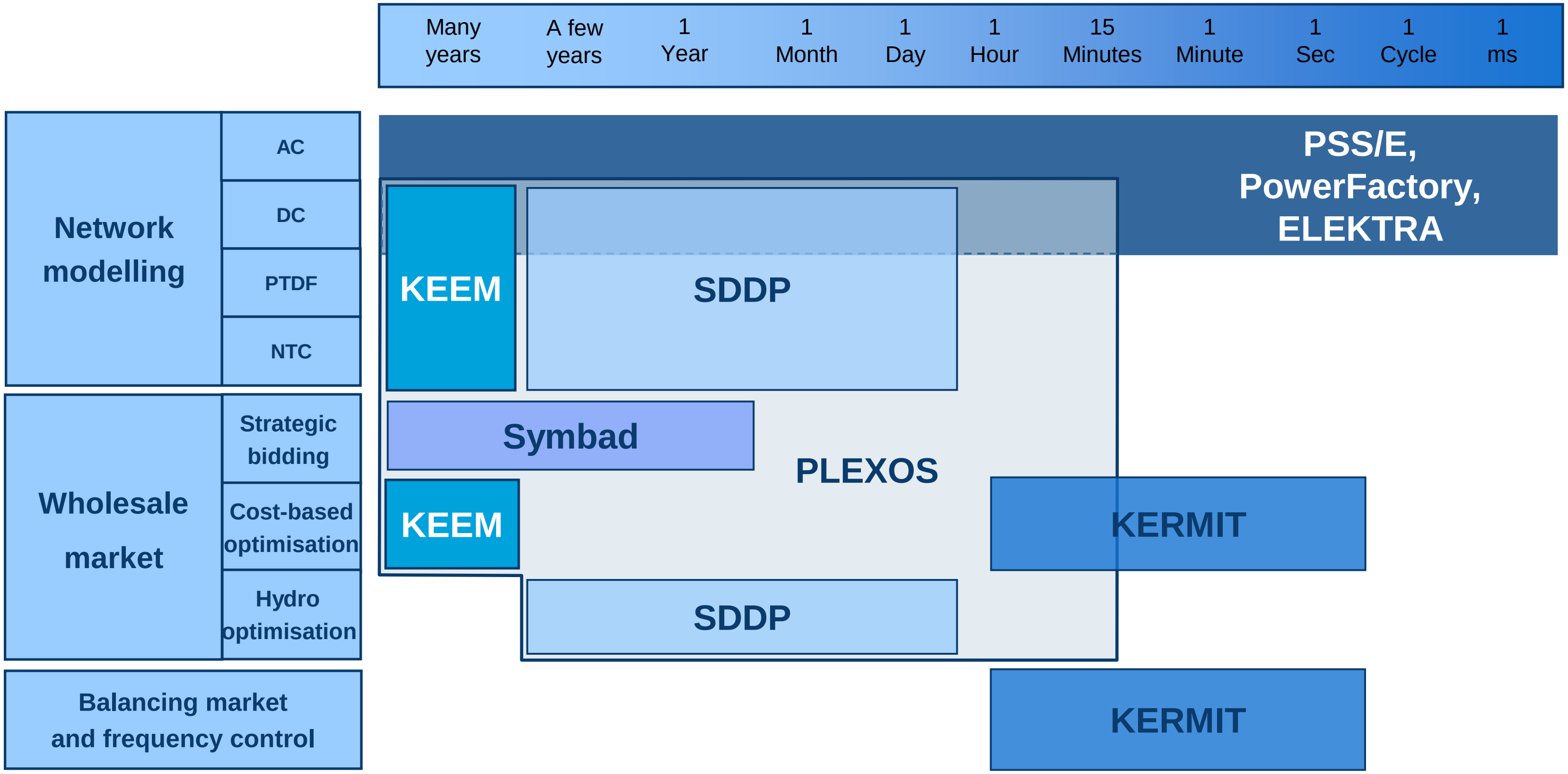
DNV KEMA modelling suite - models

Our modeling approach is based on a flexible portfolio of different modules covering a wide range of technical and commercial aspects



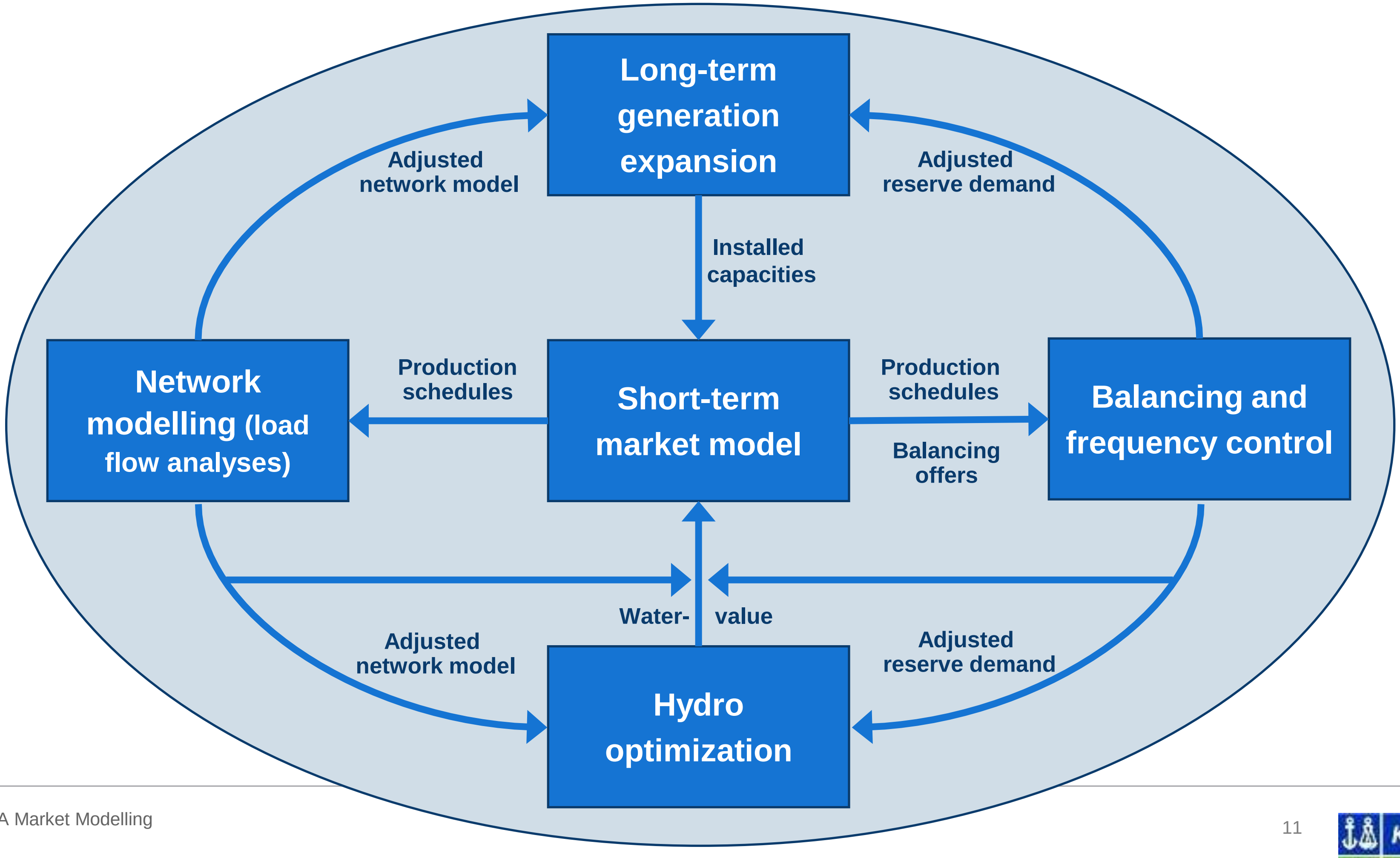
Time horizon and scope of simulation

Our models cover the whole range from many years ahead to real time – and generation as well as network and system operation

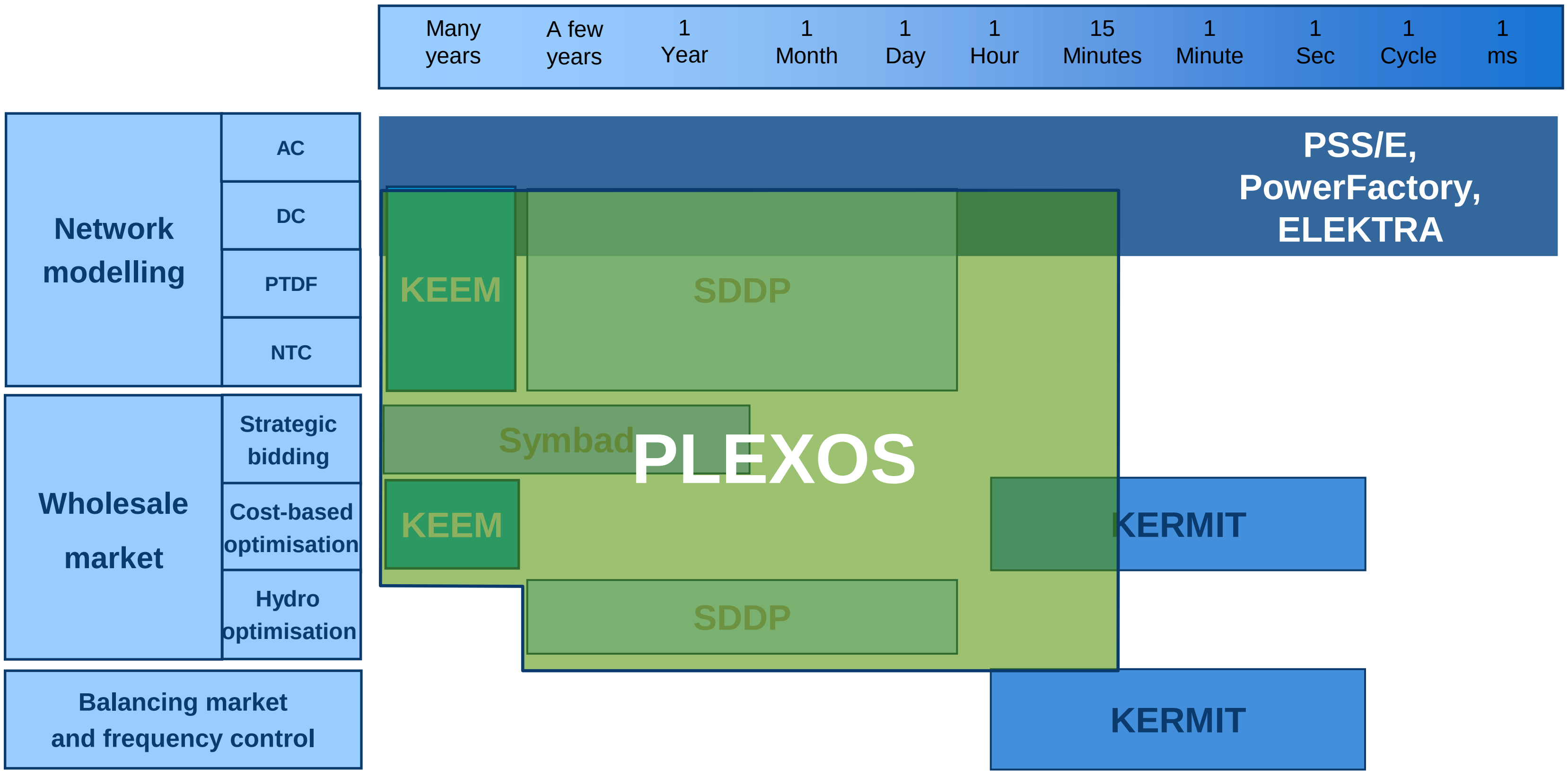


Interaction between models

A suite of specialized tools with well-developed interfaces enables a comprehensive analysis of all relevant issues



Time horizon and scope of simulation



PLEXOS covers the most important issues and timeframe for market simulation – if necessary we can use other models for further analysis

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General market model based on PLEXOS

PLEXOS provides for an integrated approach from long-term expansion planning to spot and real-time markets

Input Data

- Load data
- Reserve margin
- Exist. generation structure
- Network constraints
- New built options
- Fuel prices and availability
- CO_2 prices & emission cap
- (Spin.) reserve requirements
- etc.

PLEXOS:

Integrated optimization of capacity expansion & dispatch

Long-Term Schedule

(capacity expansion)

Medium-Term Schedule

(inter-temporal constraints)

Short-Term Schedule

(unit commitment)

Optimal expansion plan

- Generation expansion
- Transmission expansion

Optimal resource allocation

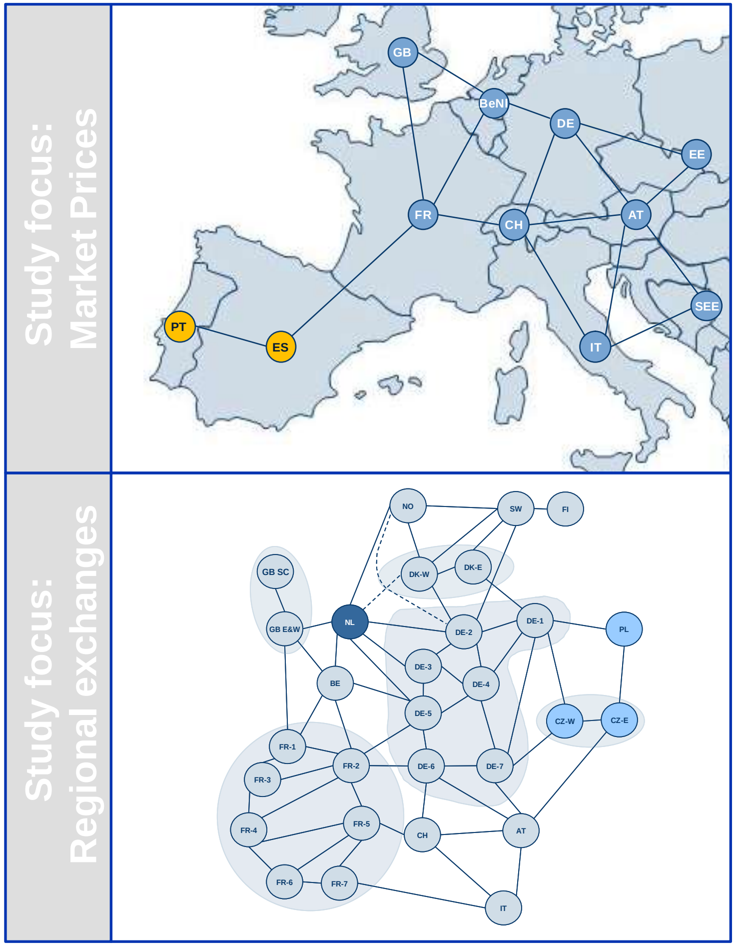
- Emission targets
- Fuel contracts / usage
- Hydro optimization

Optimal dispatch

- Unit commitment & dispatch
- Power & Reserve prices
- Fuel consumption & emissions
- Load flows / Exchanges

European market model – features

- Market model based on least-cost unit commitment and dispatch
- Representation of the regional market, model set-up adjusted to actual project requirements
- Aggregation of generation and transmission on a regional level with detailed technical and commercial parameters
- Use of NTC or PTDF
- Co-optimization of energy and various types of reserves
- Regional data for wind generation (incl. correlation of forecast errors)



European market model – market data

- Due to our extensive project experience in the NW-European region, most of the required data is available to us, including up-to-date information on:
  - Fuel and CO_2 prices
  - Installed capacity by fuel/technology
  - Electricity demand and load profile
  - Trans-border transport capacities
  - etc.
- We cross-check our information against public and private data sources, covering

Public data sources:	Private data sources:
• ENTSO-E • TSOs • Eurelectric (Europrog) • Ministries / Regulators • Generation companies • Platts	• DNV KEMA's power plant database • DNV KEMA's renewable generation database (modelling volatility) • DNV KEMA's network of local experts • DNV KEMA's executed projects

European market model – market data

- We collect and use data from more than one source and cross-check and reconfirm the data accuracy.
- We undertake a comparative analysis and filter-out the best data quality for market modelling. Our selection criteria are:
  - Consistency and plausibility,
  - Cross-checks,
  - Source reliability,
  - Local expert knowledge
  - In house knowledge of the power industry[(1)]
- From our experience, this approach significantly minimises data gaps and the need to make data estimations
- We summarize the information in a concise way to facilitate decision making on executive level

(1) *DNV KEMA have many experts on generation (GT, CCGT, CHP, coal plant, nuclear and renewable energy like wind, solar and biomass).*

Market model – typical model inputs

Power plant inputs

Units	7	-
Max Capacity	400	MW
Min Stable Level	160	MW
Heat Rate Base	562.2005	GJ/hr
Heat Rate Incr	4.61	GJ/MWh
Heat Rate Incr2	2.40E-08	GJ/MWh²
VO&M Charge	1.4	EUR/MWh
Start Cost	3600	EUR
Min Up Time	2	hrs
Min Down Time	5	hrs
Max Ramp Up	28	MW/min.
Max Ramp Down	28	MW/min.
Maintenance Rate	7.3	%
Forced Outage Rate	3.2	%
Mean Time to Repair	24	hrs
Min Time To Repair	2	hrs
Max Time To Repair	48	hrs

Information heat rate curve; another option is through load points and associated heat rates

Variable operations and maintenance costs

Information for random distribution of forced outages

A scenario approach is adopted to assess the impact of changes in particular parameters

Other required inputs:

- Load data
- Representative wind and solar irradiation profiles
- Interconnector values
- Fuel and CO_2 prices

Possibilities are there to also incorporate modeling of:
- Reserve markets
- Various types of regulation
- Steam/ heat supply requirements
- Congestion within certain areas (requiring detailed load and network data)

Market model – exemplary model outputs

Category		Potential model results	Granularity
Generation	-	Dispatch schedules	Hourly, by power plant
	-	Reserve provision	
	-	Dispatch of hydro stations	
	-	Costs (O&M, fuel, CO_2)	
	-	Revenues (for energy and reserves)	
	-	Emissions	
Grid	-	Load flows between potential market areas	Hourly, by line
	-	Congestion rent	
Electricity prices and commercial exchanges	-	Cost reflective electricity prices for each market area	Hourly, by market area
	-	Electricity im-/exports between and neighbouring countries	Hourly, by border
Reserves	-	Reserve provision	Hourly for each reserve type
	-	Costs and prices for reserves	

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What are capabilities and limitations?

Capabilities required for Roadmap-like studies

- Future fuel mix (capacity and energy)
- Network expansion
- Costs of scenarios (based on targets)
- Detailed dispatch
- Reliability (will the system work?)

Capacity expansion (first three items)

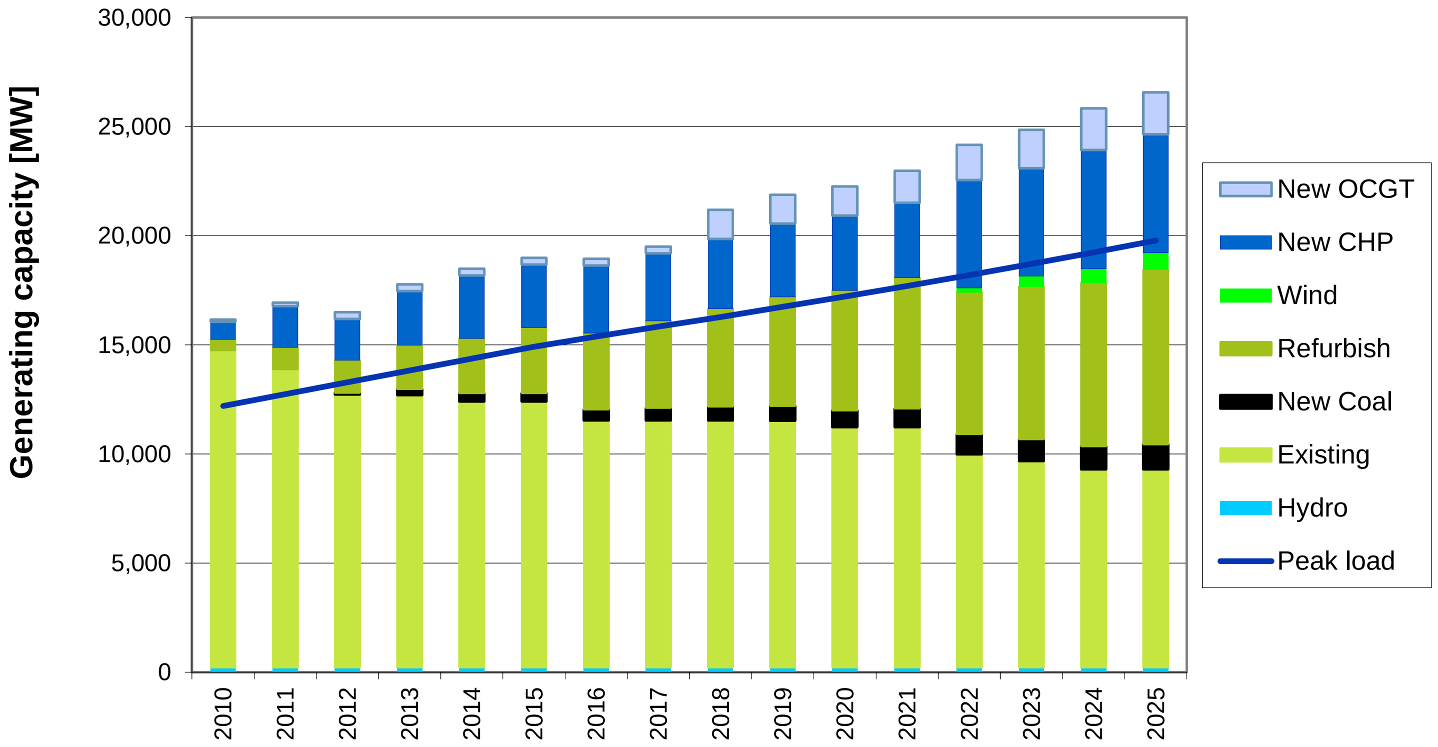
System operation (last two items)

First three items are output of Least Cost Expansion analysis and show the future electricity supply system

Last two can be investigated with short term commitment and dispatch analysis and are used to check whether the model is a reasonable representation of the real system

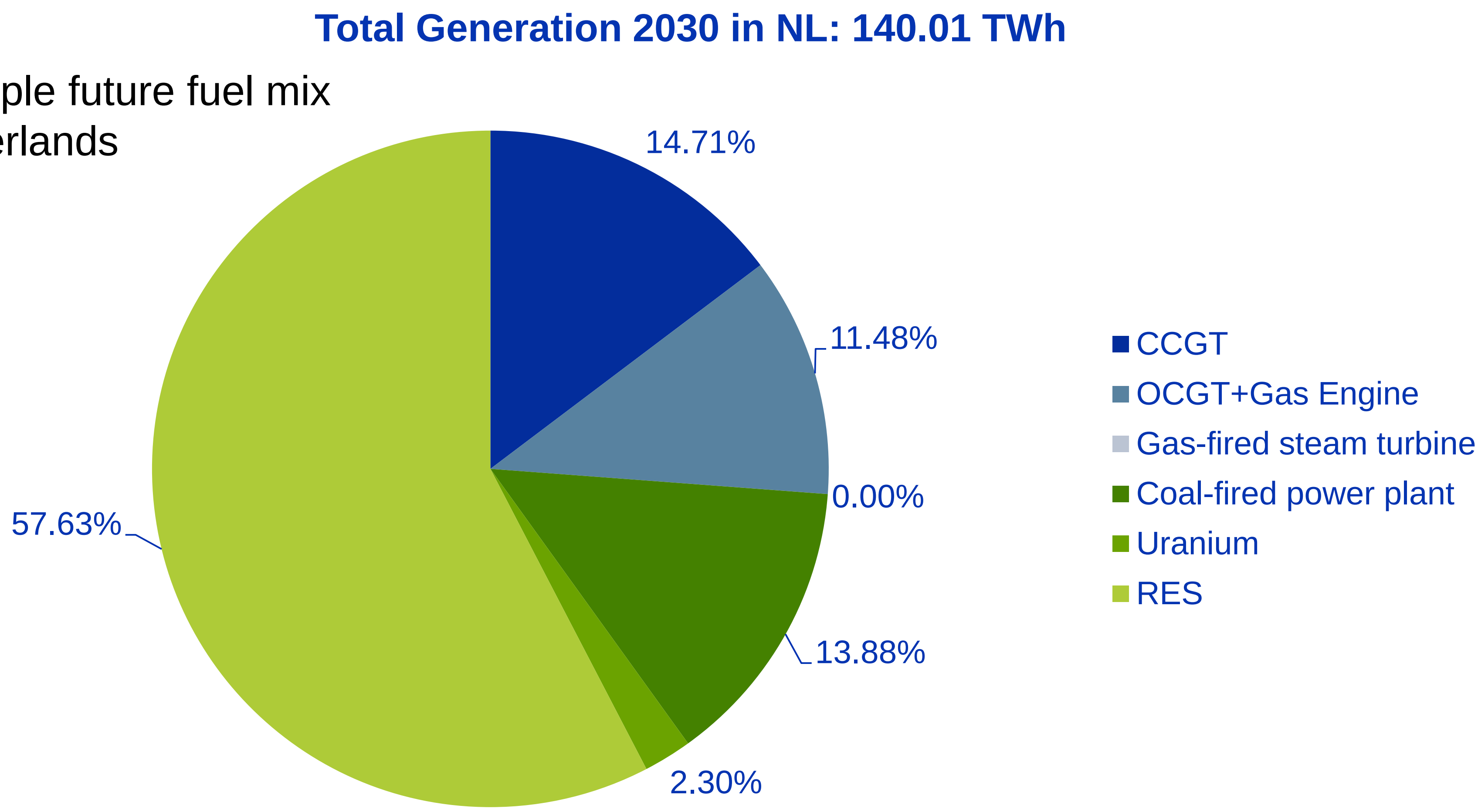
What are capabilities and limitations? - Capabilities

Example Least Cost Expansion analysis (Asian country)

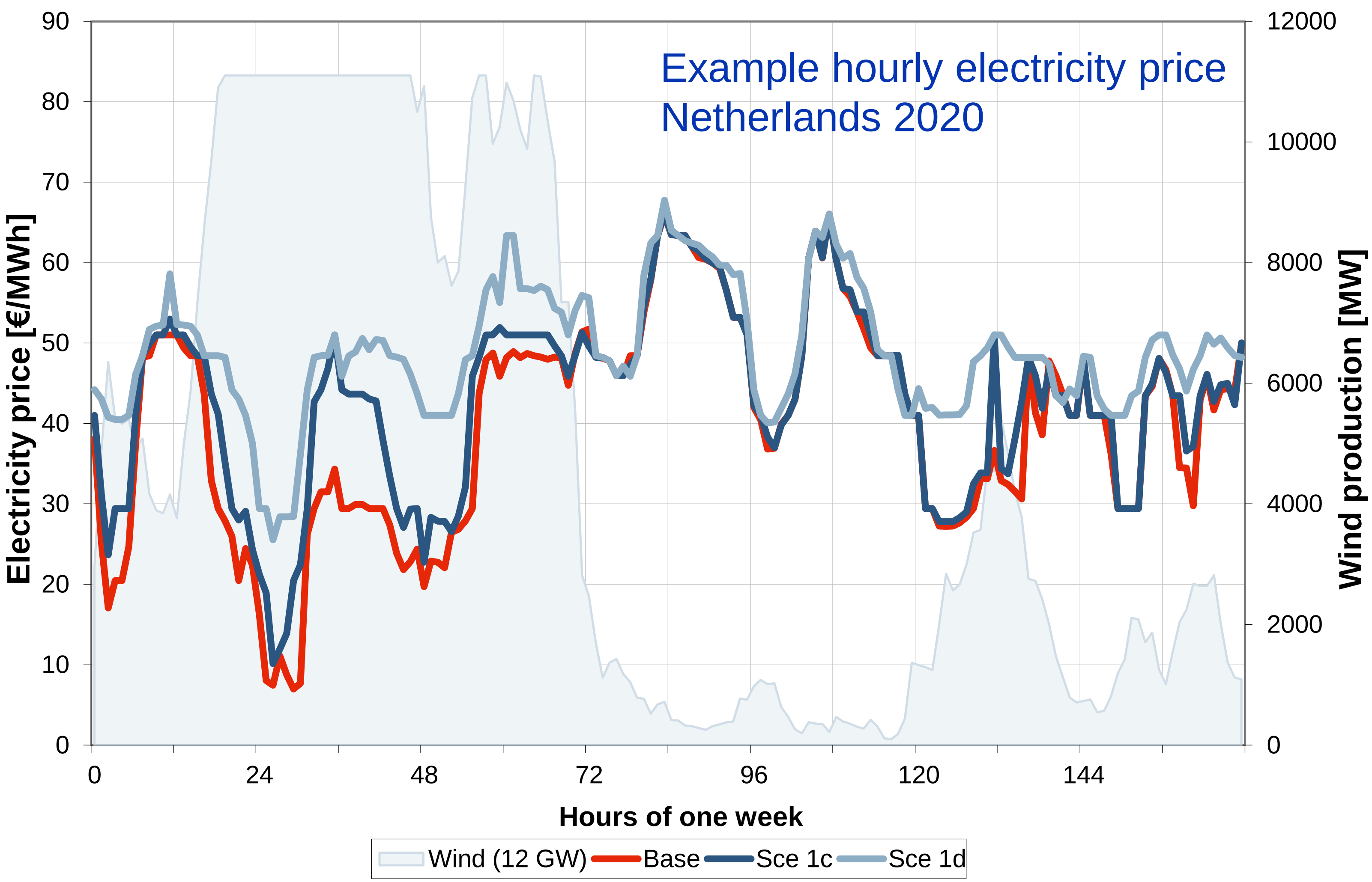


What are capabilities and limitations? - Capabilities

Example future fuel mix Netherlands



What are capabilities and limitations? – Capabilities



What are capabilities and limitations? - Limitations

Major limitations:

- A model is merely a model (what you may discover only later)
  - Garbage in – garbage out (commercial info)
  - Simulations often cost based (actual prices mostly higher, more volatile)
  - Real market behaviour (and competition) difficult to predict and model
  - Too much detail will blow the model

- The world in 2050 is hard to predict
  - Electricity market
  - Fuel and CO_2 prices
  - Cost of technology

- The present energy only market will most probably fail
  - Market prices and contribution conventional plants drop (investment incentives?)

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What are capabilities and limitations? - Limitations

Overcoming limitations:

- Deviation in prices => Tuning with historical price information
- Future fuel and CO_2 prices
- Cost of technology

} Sensitivity scenarios

- New market model => Introduce capacity markets/mechanisms?

Often relative outcome is more important than absolute values:

- What technologies will help us to meet energy targets?
- Will the system work

The right choice of input and scenarios is a major challenge for modellers

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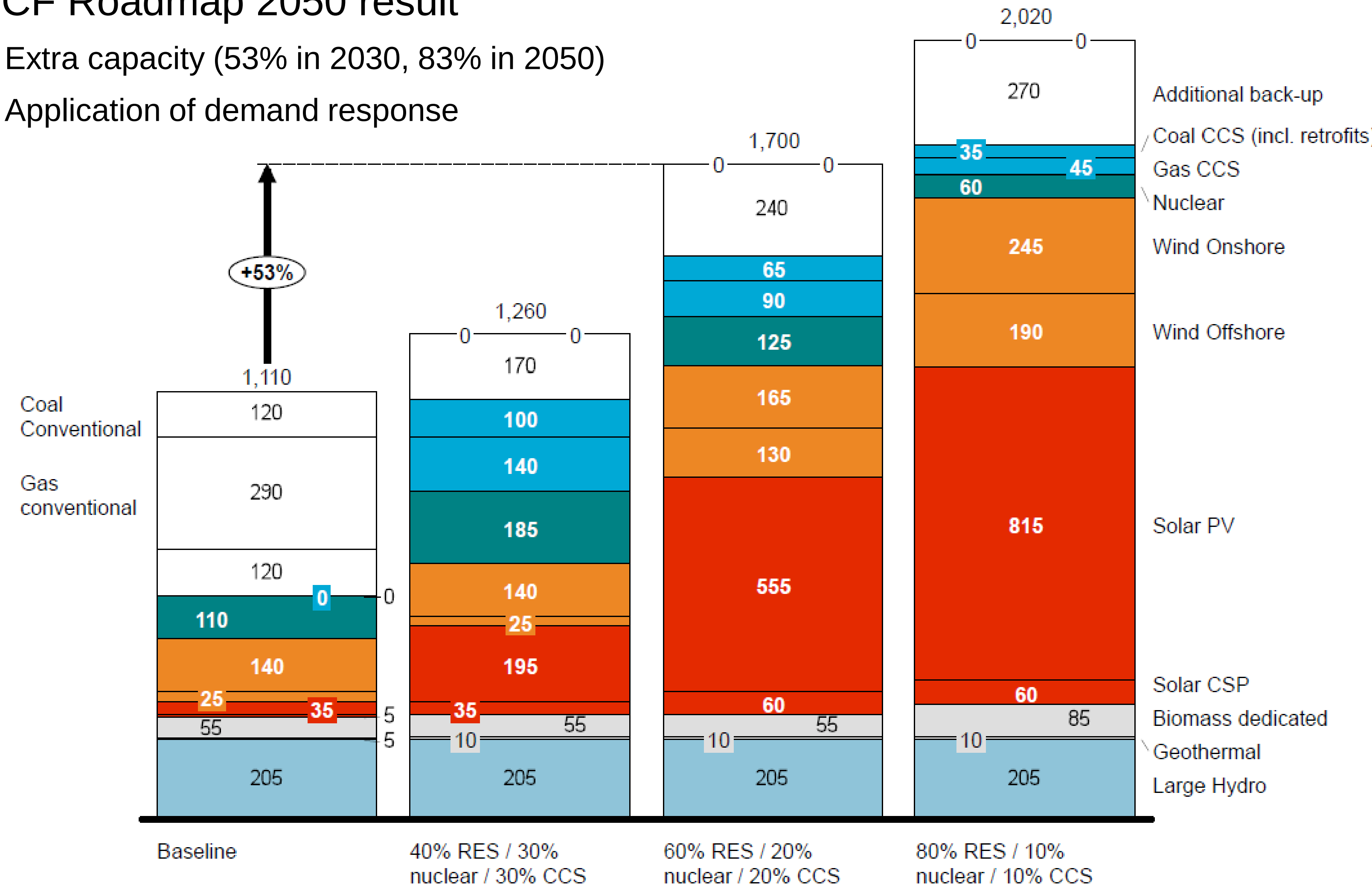
Topics - Influence of weather circumstances

- Influence of extreme, long-lasting and EU-wide weather circumstances in case of large RE share,
  - Security of supply
  - Extra reserves for back up during times with low wind / solar

- Simulation based on correlation between weather systems
- Clear dependence of wind in NW Europe
- Large differences possible for solar
- Stochastic input or sensitivity analysis

Topics - Influence of weather circumstances

- ECF Roadmap 2050 result
  - Extra capacity (53% in 2030, 83% in 2050)
  - Application of demand response



Topics - Influence of weather circumstances

- Influence of extreme, long-lasting and EU-wide weather circumstances in case of large RE share,
  - Security of supply
  - Extra reserves for back up during times with low wind / solar

- Capacity credit of wind is limited
- Much more total capacity with high RE share
- Contribution Demand Response
- Large extension of interconnection capacity

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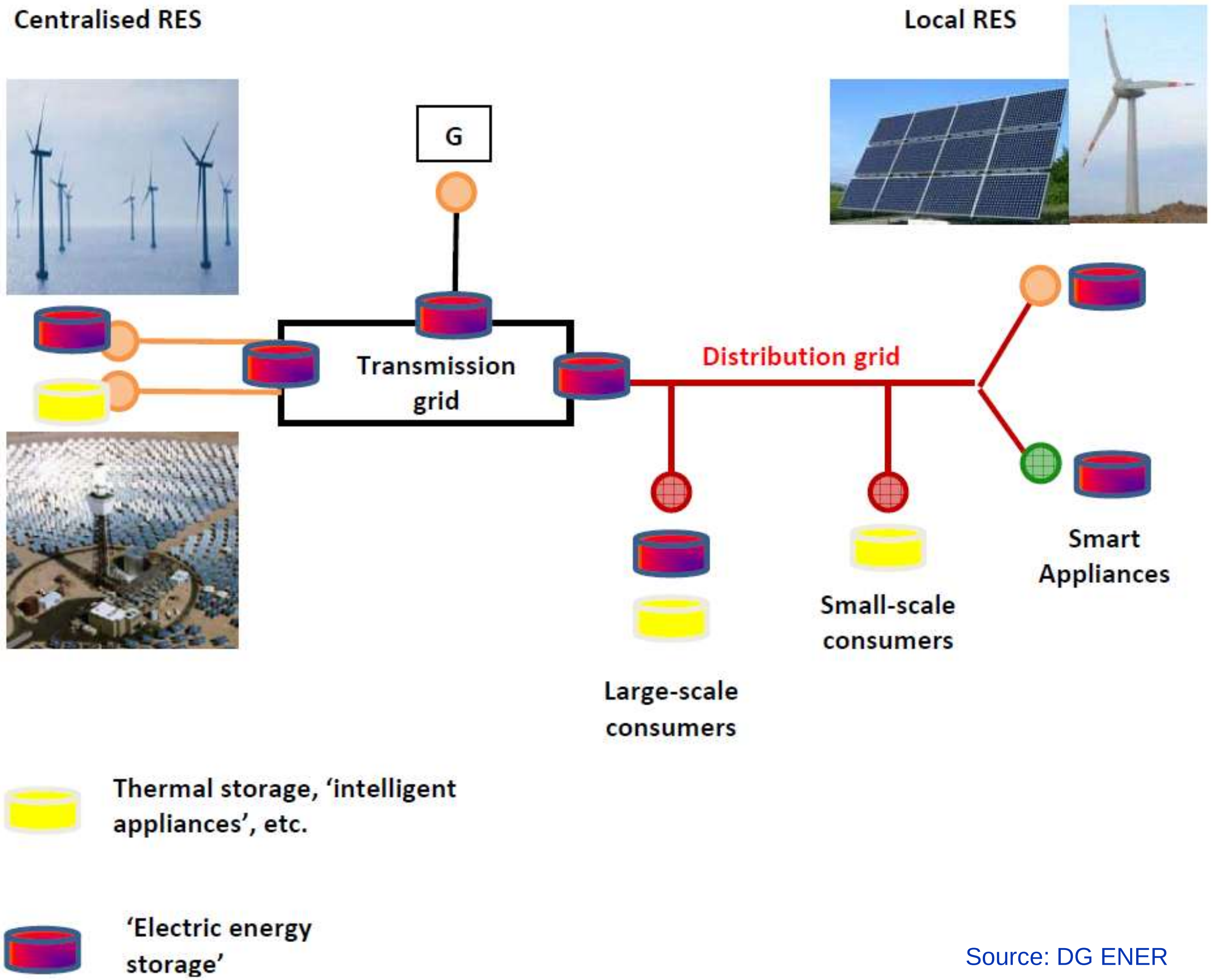
Topics - Influence energy storage

Storage at

- Transmission
- Distribution
- End user

- Electric
- Thermal



Source: DG ENER

Topics - Influence energy storage

- Large bulk energy (GW):
  - Thermal storage, pumped hydro;
  - Compressed Air Energy Storage (CAES);
  - Chemical storage (e.g. hydrogen - large scale >100MW, up to weeks and months)
- Grid storage systems (MW) able to provide:
  - Power: super-capacitors, Superconducting Magnetic Energy Storage (SMES), flywheels,
  - Energy : batteries such as Lead Acid , Li-ion, NaS & Flow batteries Energy & Power: LA & Li-ion batteries
  - Hydrogen Energy Storage / CAES / Pumped Hydro Energy Storage (PHES) (small scale, 10MW< P > 100MW, hours to days)
- End-user storage systems (kW):
  - Power: super-capacitors, flywheels
  - Energy: batteries such as Lead acid and Li-ion
  - Energy & Power: Li-ion batteries

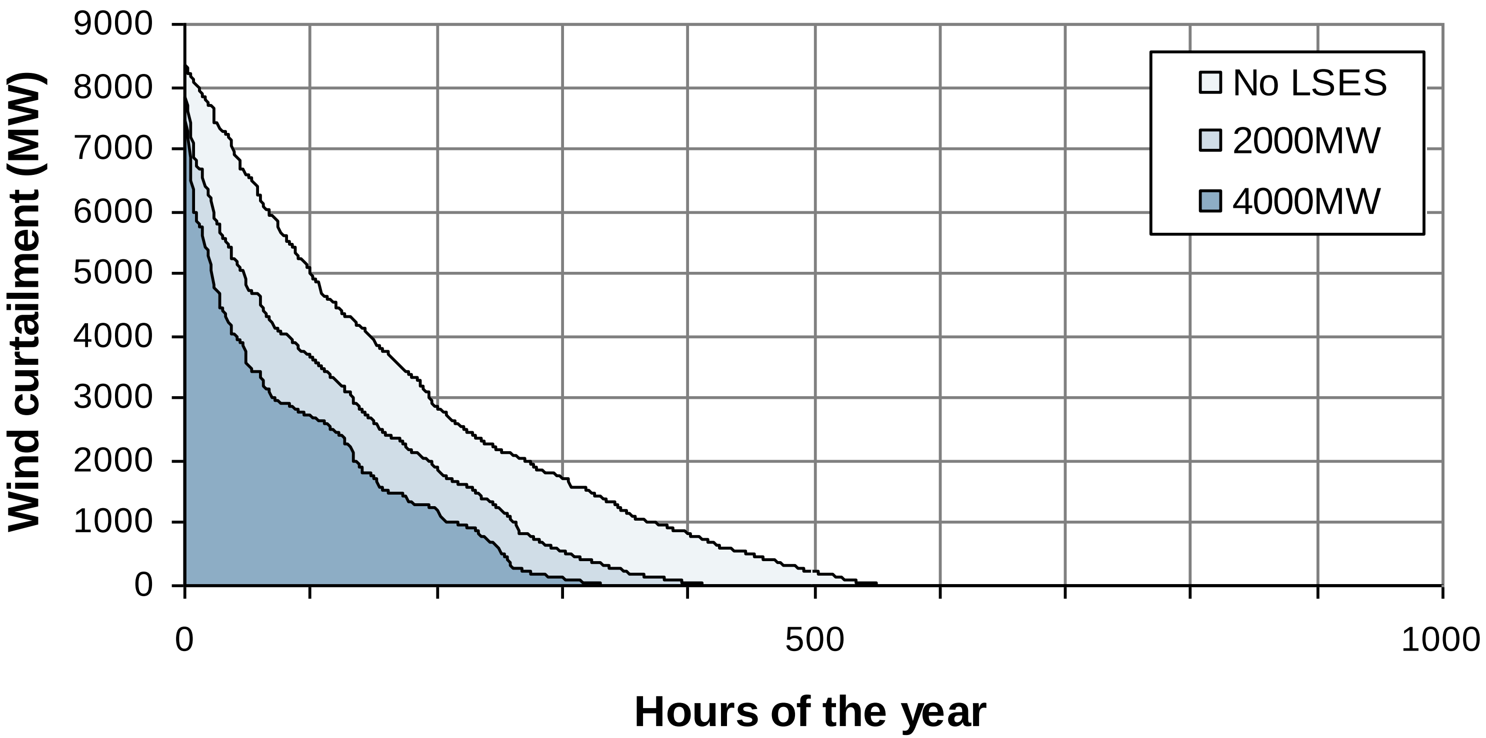
Topics - Influence energy storage

Roles of energy storage at transmission level:

- Balancing demand and supply
  - Seasonal and weekly variation
  - Strong variability of solar and wind energy
- Grid management
  - Participation in balancing market
  - Voltage and frequency regulation
- Energy efficiency
  - Arbitrage
  - Reduction of RE curtailment
  - Enabling base load plants (coal, nuclear)

Topics - Influence energy storage

- Influence of storage on wind curtailment (example NL)
- Storage helps but cannot prevent all curtailment in a cost effective way



Topics - Influence energy storage

General conclusions from several investigations for the Netherlands:

- Energy storage facility adds flexibility and available reserve capacity to the system. As a result:
  - Existing coal increases its generation (more hours at full load, so more efficient)
  - Less renewable energy curtailment
  - Lower total generation costs
- Benefit of storage facility is mostly analysed from a system perspective. Different operational strategy affects impact of storage:
  - Storage to compensate (RES) imbalance in own portfolio.
  - To increase company profits by applying arbitrage: storing energy during hours of low electricity price, and generating power at hours of a high electricity price. (profit maximization.)
  - A different operational strategy may change the observed benefit for the 'B.V. Nederland'.

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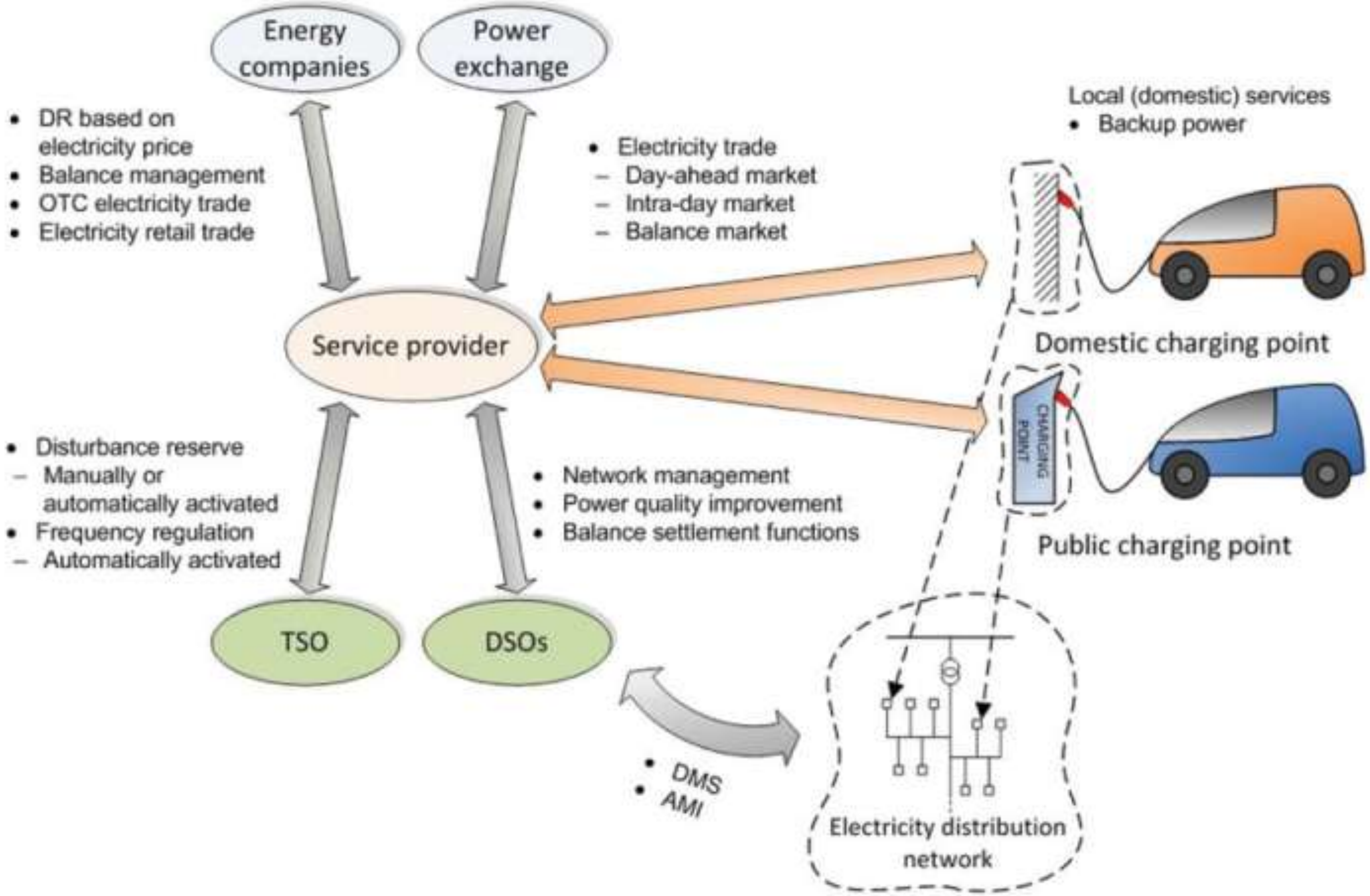
Topics - Influence of demand response

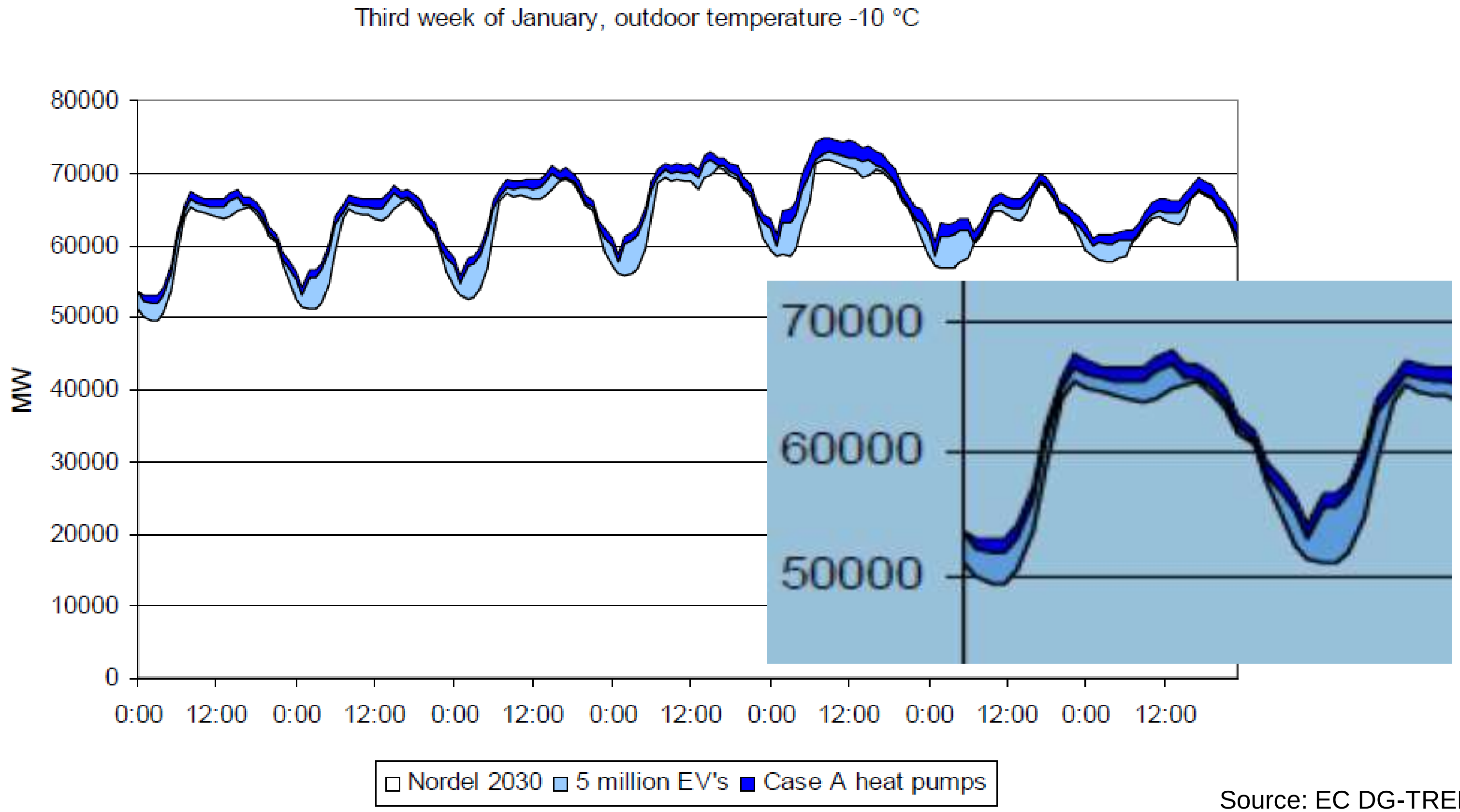
Demand Response: Complicated but necessary?



Source: IEA DSM 2012

Topics - Influence of demand response

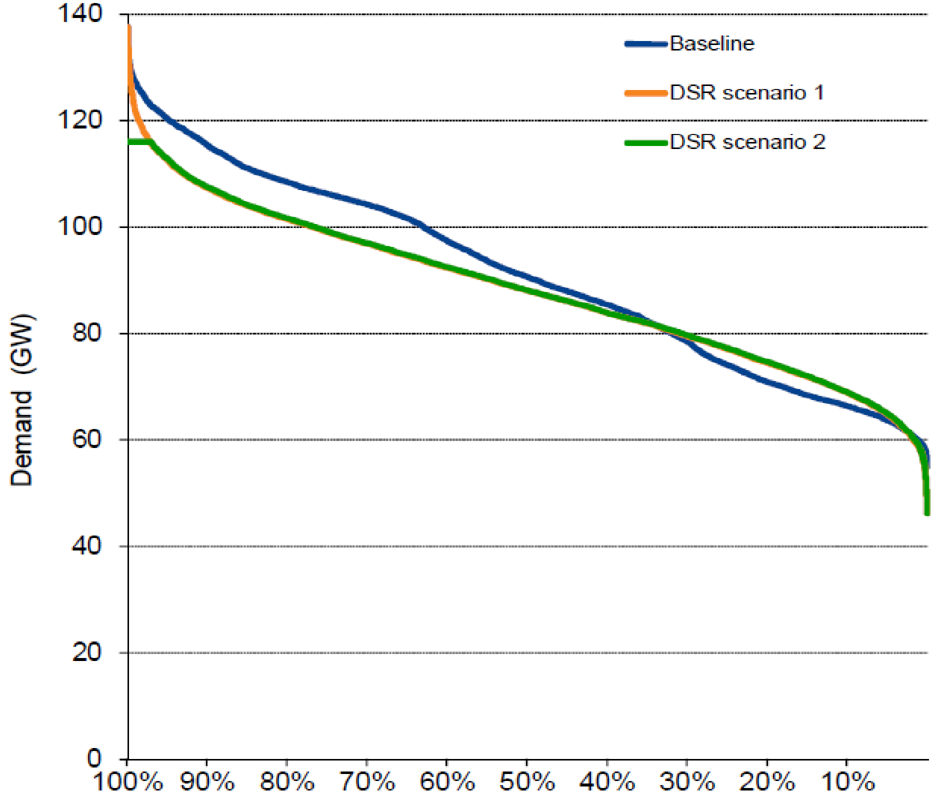
Example: Influence of Impact of integration of 5 million EVs and 400.000 heat pumps on the electricity demand curve of Nordel for the year 2030



Source: EC DG-TREN IRENE-40

Topics - Influence of demand response

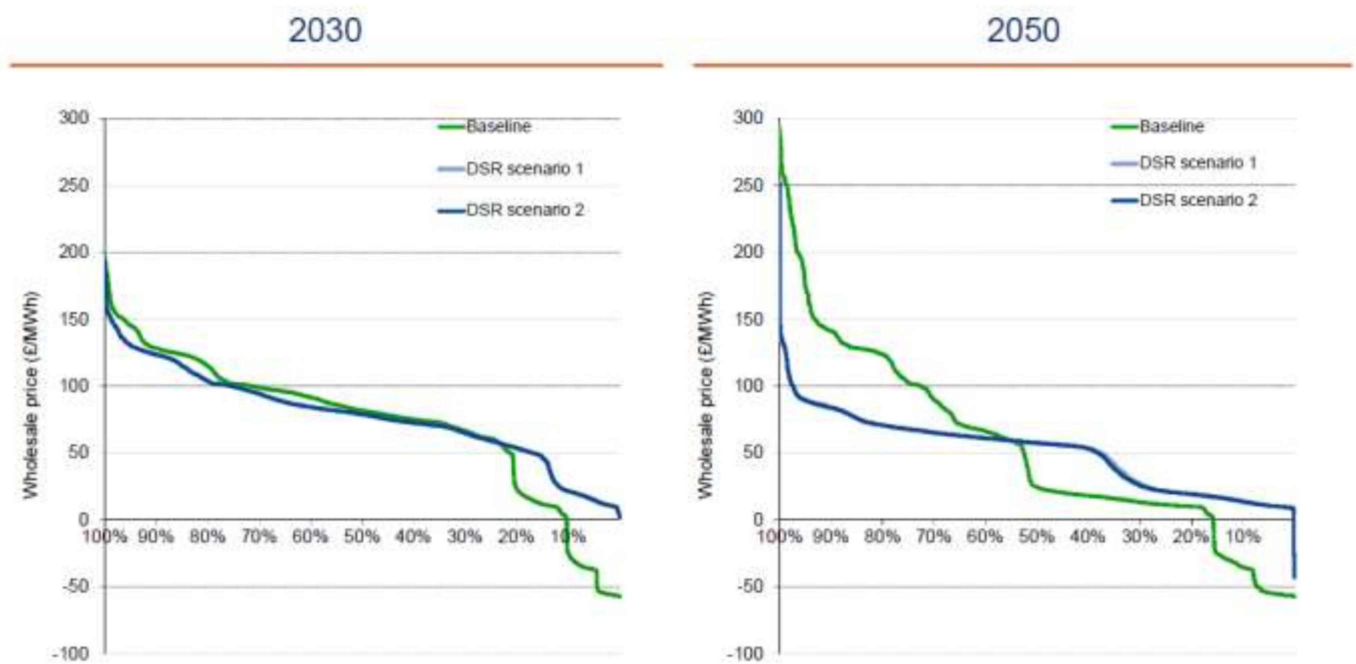
Example Germany: Possible influence of DR on demand



Source: Pöyry

Topics - Influence of demand response

- Influence of DR on wholesale prices
- Less volatile especially at high RE shares
- Competition with storage



Note: Due to the relatively small difference between prices in the two DSR scenarios, the price duration curves of DSR scenario 1 and DSR scenario 2 overlap

Source: Pöyry

Topics - Influence of demand response

- Influence of DR can be investigated using Market Models
- Cost of DR however is complicated and simultaneous optimisation is a high burden on run time
- Normally DR is examined by adjusting the load based on specific DR investigations
- DR seems indispensable for integration of large amounts of RE

Too much to investigate …..

What would we do without models?

Source: Rethinking

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