Coordinated Power Demand Forecasting & Procurement Planning – Enabler For 24x7 Power Supply

Global Experiences: Integrated Energy System Planning with ORDENA

May 2016

Contents

- Introduction to ÅF
- Demand forecast at a Glance
- Techniques for Demand Forecasting
- Practical Issues and Recommendations
- Recent International Forecasting Assignments
- Key Experts
- Ordena: Main Features

Introduction to ÅF
Facts at a glance

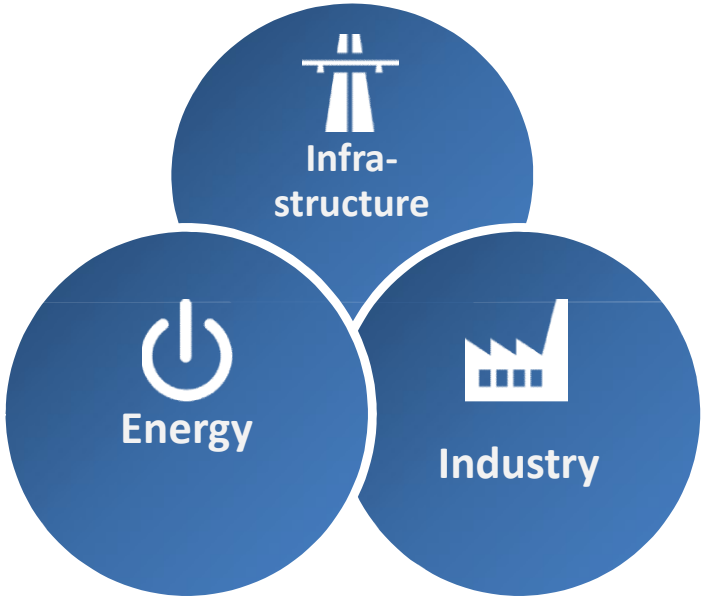
Global Presence: In 2015 ÅF performed projects in more than 100 countries worldwide

Headquarters: Stockholm, Sweden

Turnover: over 1.2 Billion USD

Number of ÅF offices: over 100 in more than 30 Countries

Number of employees: approx. 8,000



Energy

- Energy Markets
- Hydro Power
- Thermal Energy
- Nuclear Energy
- Renewables
- T&D

Infrastructure

- Buildings
- Tunnels
- Bridges
- Roads & Railways
- Urban Planning
- Environment

Industry

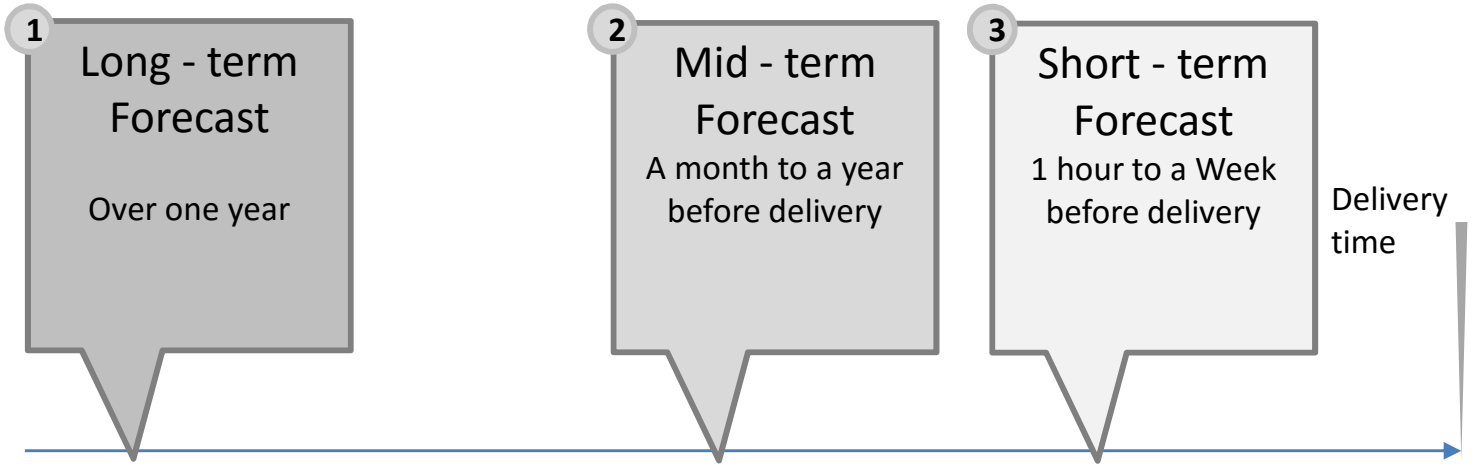
- Oil & Gas
- Chemistry
- Food & Pharma
- Forest Industry
- Steel & Mining
- Electric Power

Demand Forecast at a Glance

The Key issue for carrying out any type forecast is time. Depending on the time scope, there are 3 groups of forecast

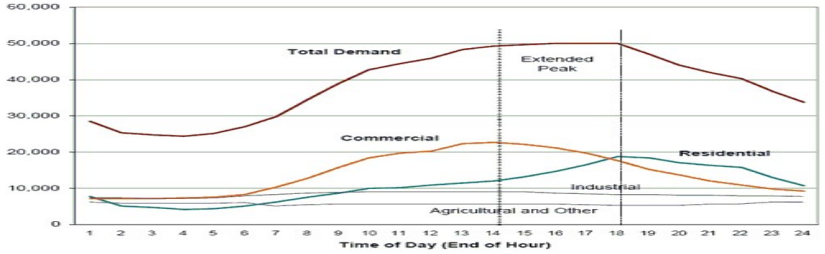
TIME SCOPE

- Depending on the **time in advance to delivery time**, **demand forecast** can be **classified in three groups**: Short-term, Medium-term and Long-term forecast
- Moreover, as it will be explained later, the **time scope** plays an **important role** on the decision of the **demand forecast technique** to be used.



Demand Forecast at a Glance

Once, the time scope is known the main parameters that influence demand must be taken into account in order to carry out Demand Forecasts

FACTORS THAT INFLUENCE DEMAND	
Weather	Electric load has an obvious correlation to weather. The most important variables responsible in load changes are: • Temperature • Humidity • Wind Speed/Wind Direction • Sky Cover • Sunshine
Time factors	In the forecasting model, we should also consider time factor such as: • The day of the week • The hour of they day • Holidays
Type of customer	Different kinds of customers have different load curves: 
Other factors	• GDP growth • Electricity price • Population Growth

Techniques for Demand Forecasting:

Demand Forecasting Techniques can be classified into two groups: Top-Down and Bottom-Up (1/5)

TOP-DOWN APPROACHES

Top-Down approaches can be classified in the following groups:

- **Traditional** Forecasting Techniques
- **Time Series**
- **Monte Carlo simulations**
- **Soft Computing** Techniques

Traditional Forecasting

The most used traditional forecasting methods are:

- Regression Methods
- Multiple Regression
- Exponential Smoothing

Regression Methods

Regression is **one of the most widely used** statistical techniques. This method assumes that the **load** can be **divided** in a **standard load trend** and a **trend linearly dependent on some factors influencing the load**. The mathematical model can be written as:

$$L(t) = Ln(t) + \sum ai \cdot xi(t) + e(t)$$

Where:
$L(t)$: is the load at time t
$Ln(t)$: is the normal or standard load at time t
ai: is the coefficient of each of the factors influencing the load
$xi(t)$:is the value at time t of the factors influencing the load
$e(t)$: is a white noise component

- The **parameters** in the formula can **be calculated from historical data**

Techniques for Demand Forecasting:

Demand Forecasting Techniques can be classified into two groups: Top-Down and Bottom-Up (2/5)

TOP-DOWN APPROACHES

Traditional Forecasting

Multiple Regression

Multiple Regressions is the **most popular method** and often **used to forecast the load affected by a number of factors** ranging from meteorological effects, per capital growth,... Multiple Regression analysis for load forecasting uses the **technique of least-square estimation.** The mathematical model can be written as:

$$Y(t) = V(t) \cdot a(t) + e(t)$$

Where:

$Y(t)$: is total measured load system

$V(t)$: vector of adapted variables such as temperature, day type,...

$a(t)$: is the transposed vector of regression coefficients

$e(t)$: is model error at time t

Historical data is used to **adjust** the formula

Exponential Smoothing

In this method, a **exponential smoothing model is used for doing the load forecast as follows**:

$$y(t) = \beta(t) \cdot T \cdot f(t) + e(t)$$

Where:

$y(t)$:load at time t

$\beta(t)$: Coefficient of vector

$f(t)$: Fitting function vector of the process

T: Transpose operator

$e(t)$: White noise

Techniques for Demand Forecasting:

Demand Forecasting Techniques can be classified into two groups: Top-Down and Bottom-Up (3/5)

TOP-DOWN APPROACHES

Time Series

Time series methods appear to be among the most popular approaches applied to short-term load forecast. Time series methods are **based on the assumption that the data have an internal structure, such as autocorrelation, trend or seasonal variation.** The **main motivation** of **the approach is to** accurately **assemble a pattern matching available data and then obtain the forecasted value with respect to time** using the established model. **Main time series models** are:

- Autoregressive (AR) Model
- Autoregressive Moving-Average (ARMA) Model
- Autoregressive Integrated Moving-Average (ARIMA) Model

Autoregressive (AR) Model

In autoregressive models, the load is assumed to be a linear combination of previous loads as follows:

$$L_k = \sum_{i=1}^{m} \alpha_{ik} \cdot L_{k-i} + e_k$$

Where:
L_k: is the predicted load at time k e_k: is a random load disturbance
α_{ik}: are unknown coefficients

Autoregressive Moving-Average (ARMA) Model

ARMA model represents the current value of the time series y(t) linearly in terms of its values at previous periods [y(t-1), y(t-2),...] and in terms of previous values of a white noise [a(t), a(t-1),...]

$$y(t) = \varphi 1 y(t-1) + \varphi p y(t-p) + a(t) - \varphi 1 a(t-1) - \ldots - \varphi q a(t-q)$$

Autoregressive Integrated Moving-Average (ARIMA) Model

These models represent stationary processes and require of a complex mathematical formulation.

Techniques for Demand Forecasting:

Demand Forecasting Techniques can be classified into two groups: Top-Down and Bottom-Up (4/5)

TOP-DOWN APPROACHES	
Montecarlo Models	**Montecarlo models have the following characteristics**: • **Probability distributions** are specified for each input variable • The **model uses samples from these input variables and calculates many realizations of the output variables which are then used to determine output variable probability distributions**
Soft Computing Techniques	• Soft computing constitutes a collection of disciplines that include fuzzy logic, **neural networks** or **evolutionary algorithms**. These disciplines are based on biological evolutionary processes • These **techniques** are mainly used for **short-term forecasts** where a **high level of precision is required**.

Techniques for Demand Forecasting:

Demand Forecasting Techniques can be classified into two groups: Top-Down and Bottom-Up (5/5)

BOTTOM-UP APPROACHES

Bottom-Up approaches are based on adding up the different components that make demand. Components of demand can be classified in mainly two groups depending on:

- **Type of growth**: horizontal and vertical growth
- **Type of customer:** residential, commercial, industrial,….

<table>
<tr><th></th><th>Horizontal</th><th>Vertical</th></tr>
<tr><td>Type of Growth</td><td>• New loads or disconnection of existing customers can have an important effect on the growth of electricity demand
• This is specially important for industrial and commercial loads</td><td>• Electricity demand can vary because of the growth or decrease in the demand of existing customers due to very different factors such as the weather, GDP variation, electricity price</td></tr>
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• Hence, it is important to differentiate types of loads in order to determine future loads based on horizontal and vertical demand growths</td></tr>
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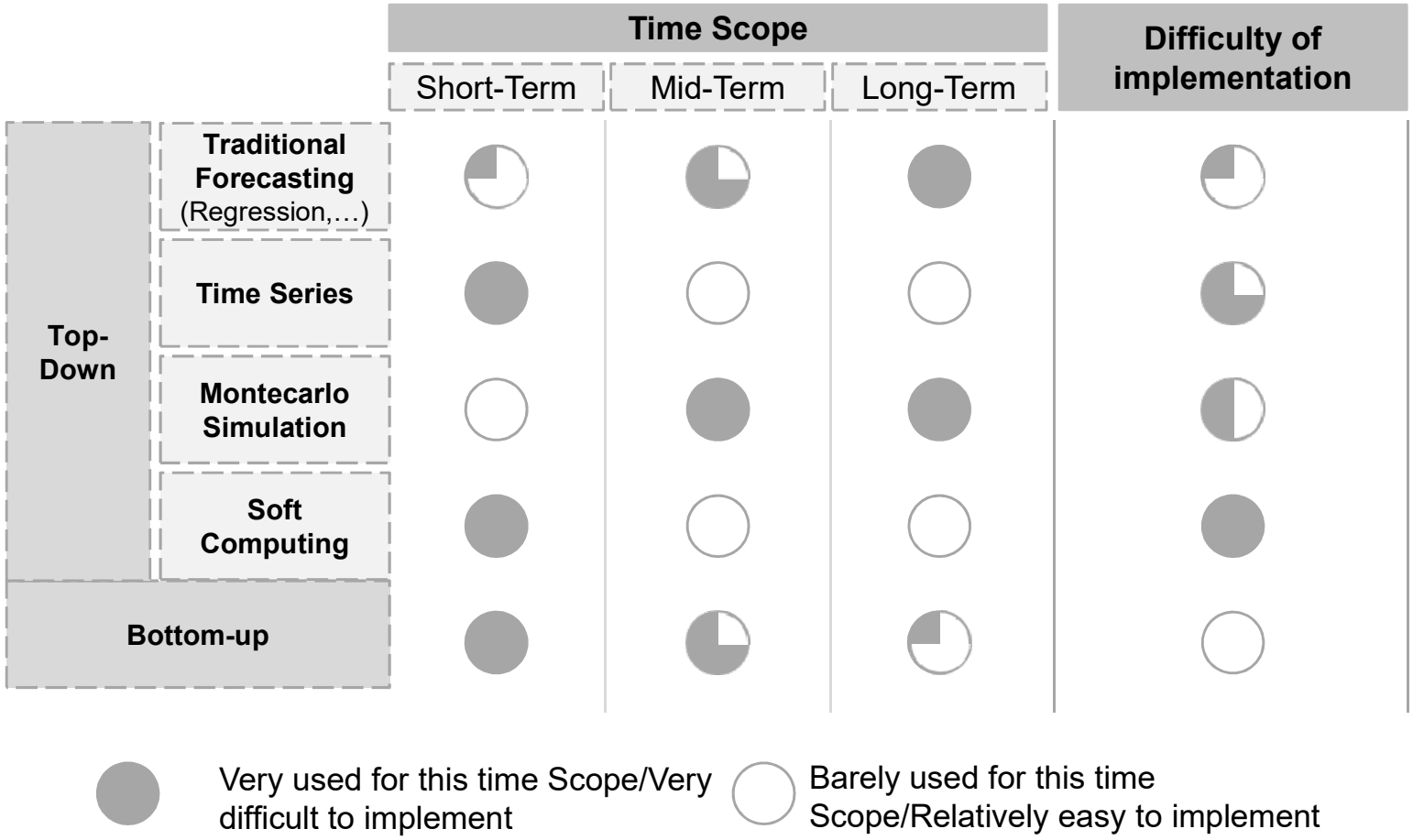
Techniques for Demand Forecasting:

Analysis of the different techniques: Time Scope and Difficulty of Implementation



Practical Issues and Recommendations

Recommendations for Medium-term forecasts

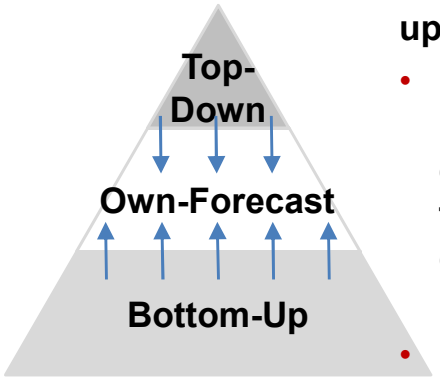
Medium-term Forecast

Medium-term forecast must be carried **using the following 3 steps process**

1 **Check External Forecast Methodologies & Results**

- **Check** the **methodology being used by National Grid, ECRA** and the **distribution unit within SEC** in order to choose the best methodology to be used
- **Take into account the results of the demand forecast** carried out by **these stakeholders** in order to **double check own demand forecasts**

2 **Own-Forecast**



Medium-term forecasts must be carried out by mixing **Top-Down** and **bottom-up** approaches:

- **Bottom-up** approaches, as the one mentioned before, **fit well** for carrying out **demand forecasts in the medium-term**, since **no big changes are expected on the main demand drivers**
- However, a **mixture of both bottom-up and top-down approaches is needed in order to check the strength of the bottom-up approach**

3 **Final Forecast**

Final Medium term forecasts must be taken into account:

1. **External Forecasts Results**
2. **Own-Forecast**

Practical Issues and Recommendations

Recommendations for Long-term forecasts

Long-term Forecast

The same 3 steps process as in Medium-term forecasts is recommended for carrying out long-term forecasts.

As uncertainty increases with distance to delivery time and demand patterns change over time a different approach is recommended for carrying out the own forecast (step 2)

1 Check External Forecast Methodologies & Results

- **Check** the **methodology being used by National Grid, ECRA** and the **distribution unit within SEC** in order to choose the best methodology to be used
- **Take into account the results of the demand forecast** carried out by **these stakeholders** in order to **double check own demand forecasts**

2 Own-Forecast

As mentioned, uncertainty increases with time and therefore **methodologies to carry out Long-term forecasts** must be able to **internalize** these **changes in the environment and accommodate to them. Based on this, the consultant thinks that the best solution for carrying out LT forecasts is:**

1. Use a methodology able to **internalize a changing environment and different possible scenarios.**
2. **Base simulations on macro parameters:** GDP, growth of population, electricity price (in case big changes in electricity prices are expected),…

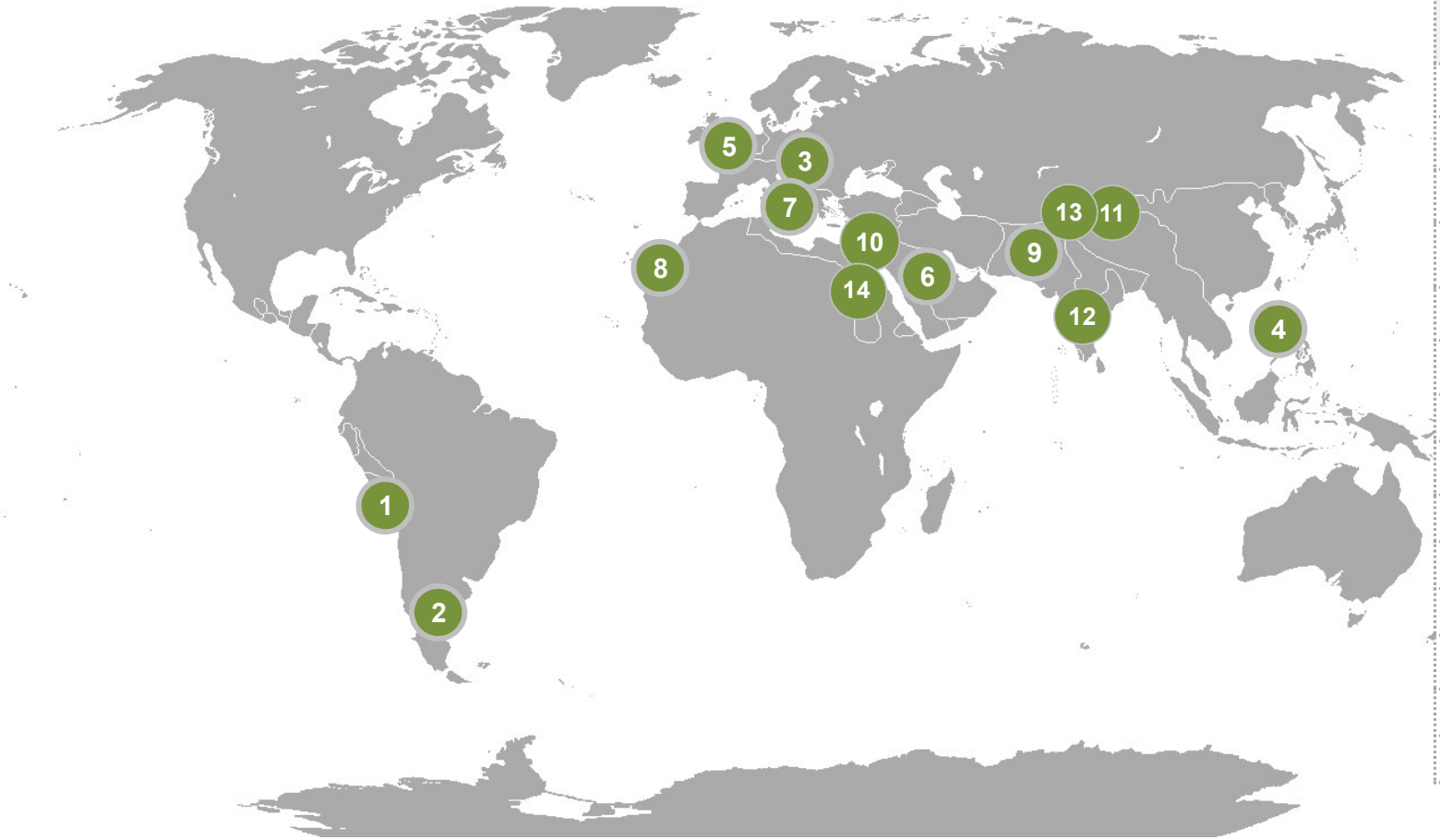
3 Final Forecast

Final Medium term forecasts must be taken into account:

1. **External Forecasts Results**
2. **Own-Forecast**

Recent International Forecasting Assignments

AF Mercados EMI: Project Delivery Footprint

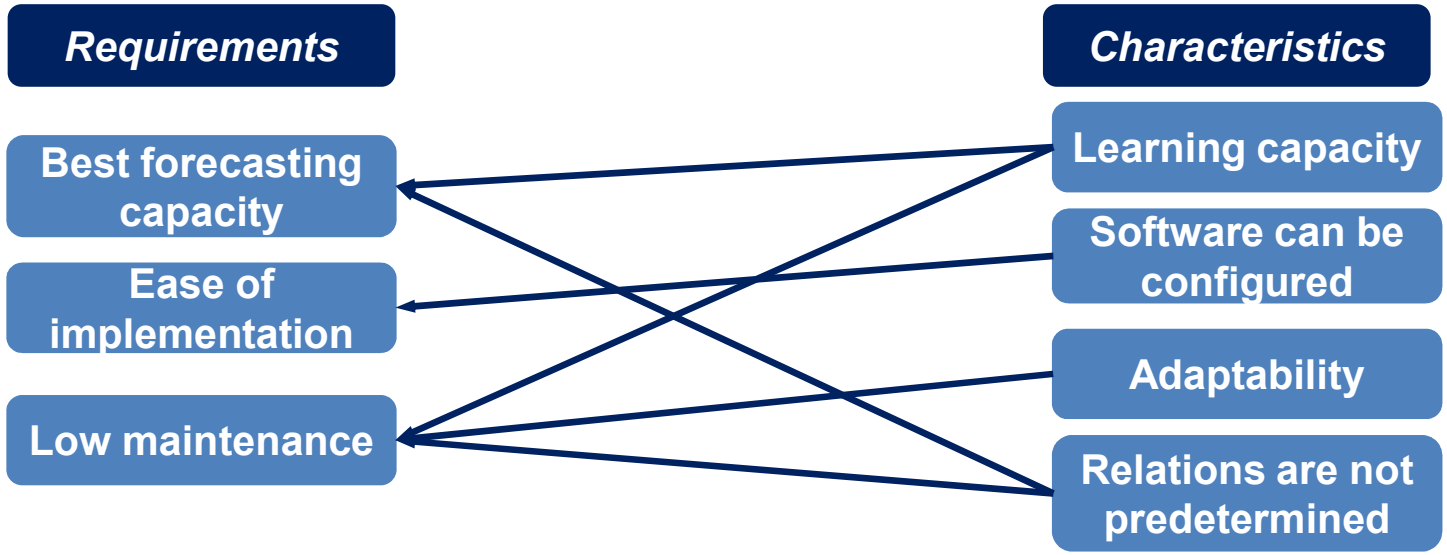


S. No.	Country
1	Bolivia
2	Argentina
3	European Union
4	Philippines
5	Scotland
6	Saudi Arabia
7	Serbia
8	Morocco
9	Pakistan
10	Turkey
11	Asia
12	India
13	Kyrgyzstan
14	Egypt

Recent International Forecasting Assignments
Spain

Spain: Short-term Price Forecasting

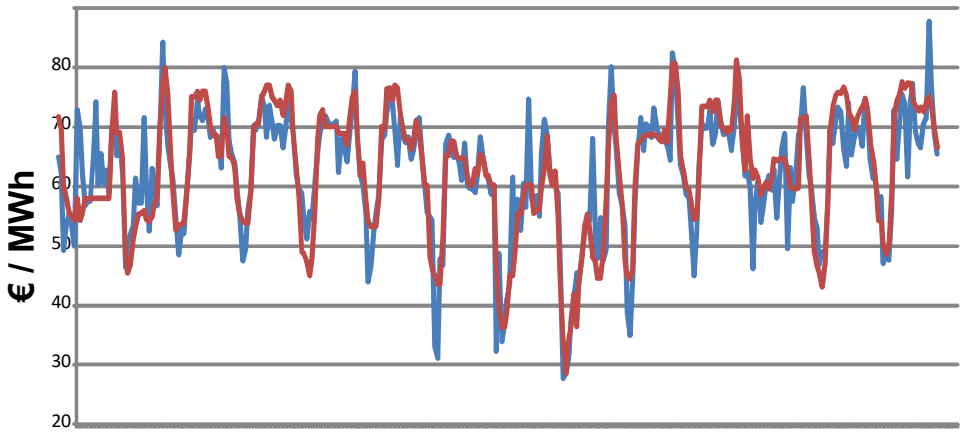
SHORT LIST	COMPARISON	SELECTION
Most common methods for short term forecasting (statistic - GARCH, VAR-, Neural Networks)	Comparison in terms of accuracy and other cualitative criteria	Neural networks were selected due to it higher accuracy



Recent International Forecasting Assignments
Spain

Spain: Short-term Price Forecasting

- The main criteria to select the method was forecasting capability, measured as *Mean Absolute Percentage Error* (MAPE)



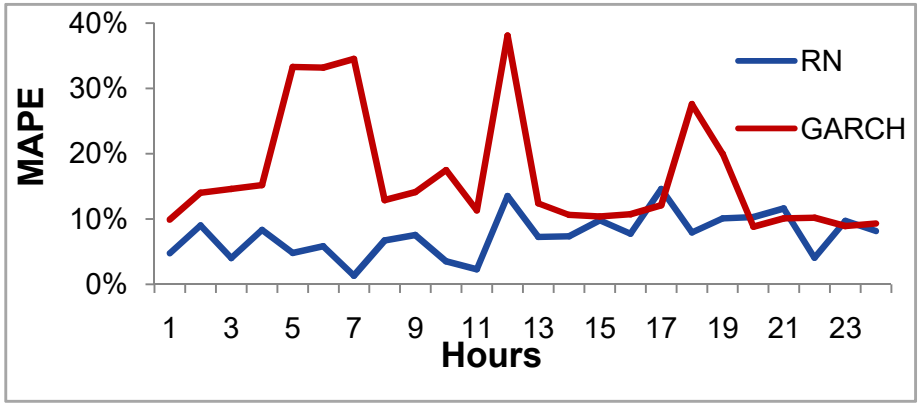
Electricity price forecast for two weeks

>> Real prices
>> Forecast

MAPE of the different models

Model	GARCH	VAR	NNs
Hourly price	12.54%	9,29%	11,3%
Price median	1,55%	1,86%	-
Base load price	6.45%	7,81%	-
Peak price	7.59%	7.72%	-
Prices for 24 hours	11.58%	-	7,51%

MAPE of the different models by hour



Recent International Forecasting Assignments
Egypt

Egypt: Energy Pricing and Fuel Switching Reform Strategy

The objective is to eliminate subsidies to fossil fuels for economic growth while protecting the poor. The following are the sub-objectives:

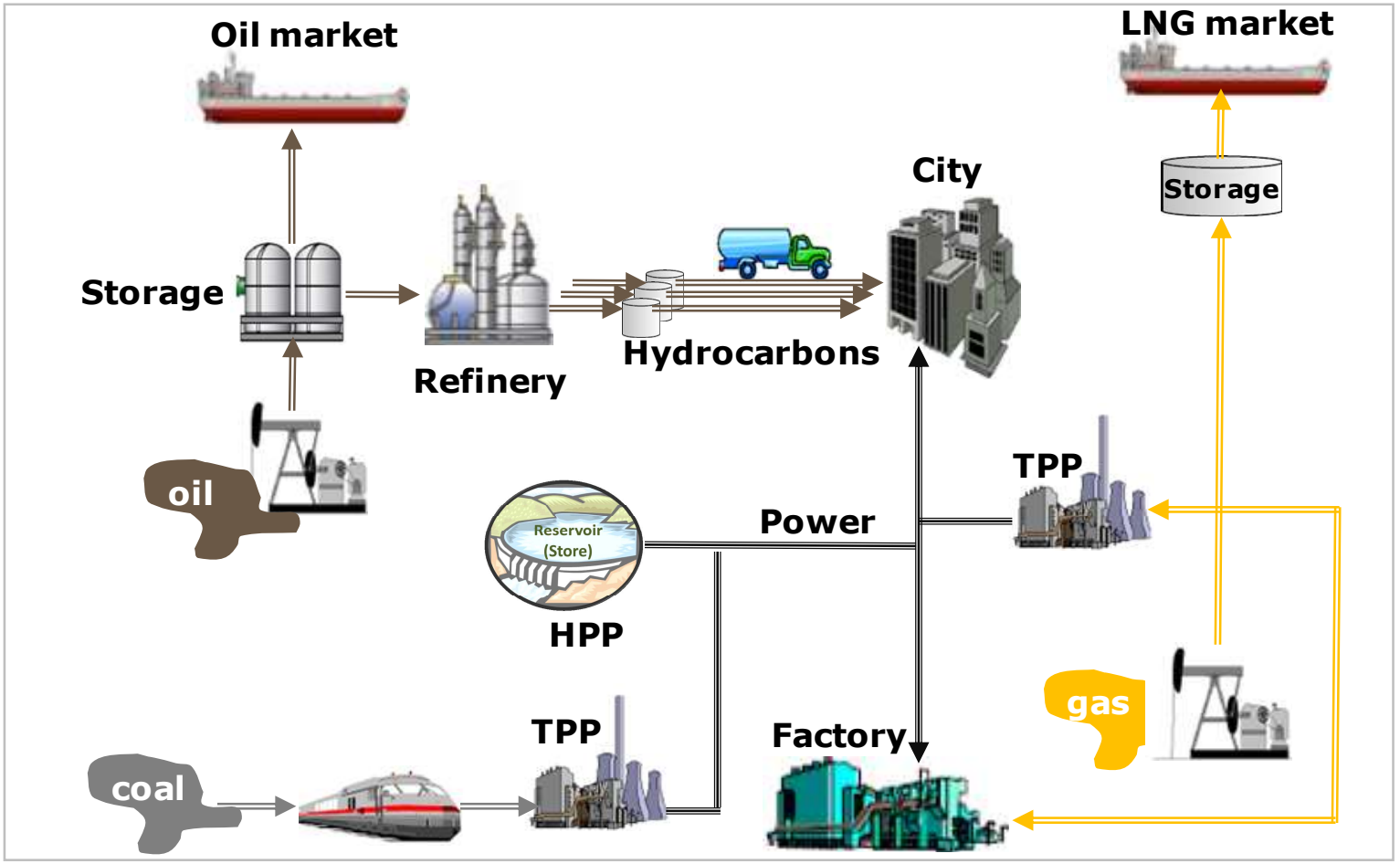
- Model the Egyptian energy system, including natural gas and oil
- Develop a Comprehensive Pricing Strategy
- Develop an Energy Subsidy Reform Roadmap
- Develop a Capacity Building Program

Background	• Increased need for energy imports, especially natural gas • The present system does not lead to an efficient use of resources • National utilities cannot recover costs with the present framework • Slowdown of investments compromising the future reliability of supply
Issues to be addressed	• Solutions require consideration of economic, social and political situation • The impact on consumers, especially on low income households • The macroeconomic impact in terms of fiscal position and forex • The impact on the financial sustainability of the sector • Implications of the different pricing mechanisms • Changes in the international prices • Impact on energy security

Recent International Forecasting Assignments
Egypt

Egypt: Energy Pricing and Fuel Switching Reform Strategy

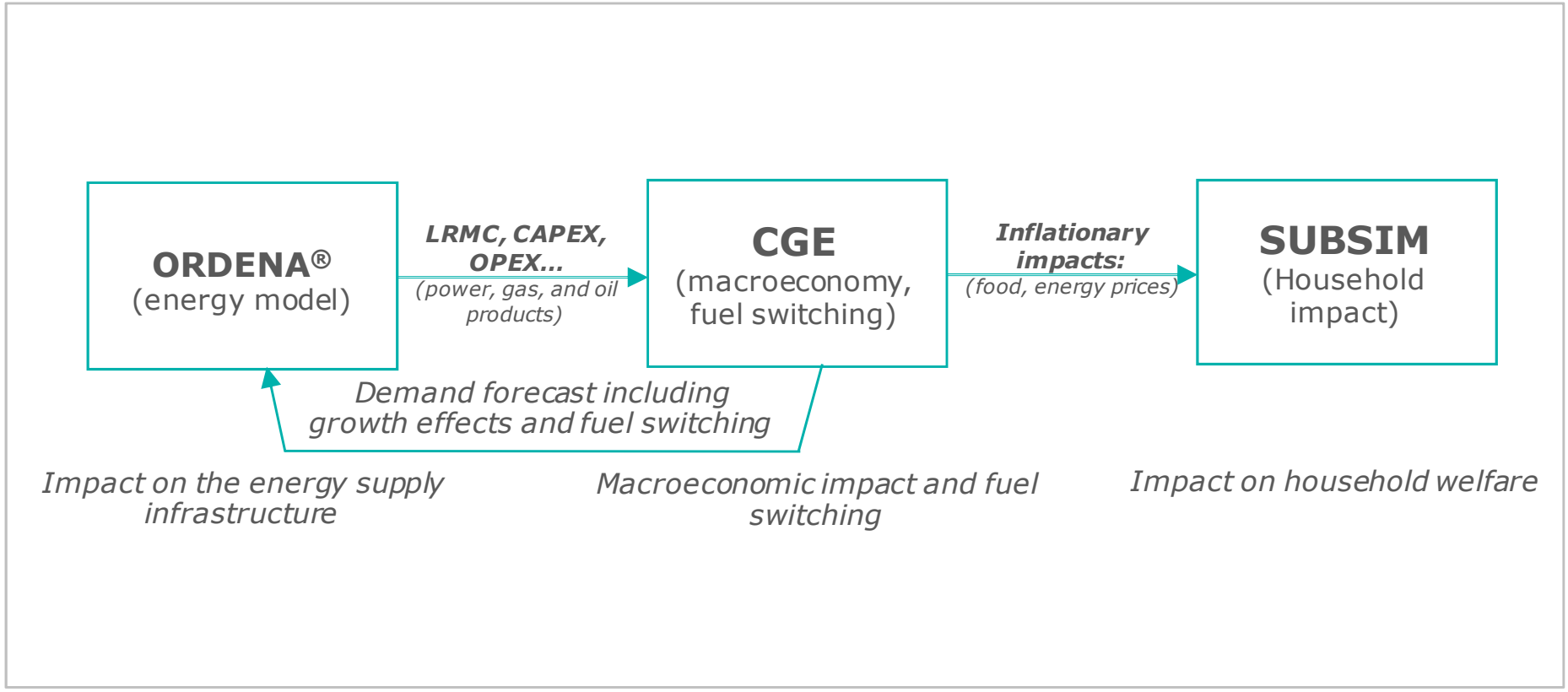
ORDENA® was preferable to the client than TIMES due to its ease of use



Recent International Forecasting Assignments
Egypt

Egypt: Energy Pricing and Fuel Switching Reform Strategy

This tailored approach was preferable for the client than the standard approach



Recent International Forecasting Assignments
Saudi Arabia

Saudi Arabia: Provision of Economic Dispatch Model for Unit Commitment

Background

The Saudi Electricity Company (SEC) has historically dispatched power based on a mix of administrative, technical and economic criteria. With the corporatization of the National Grid Company (comprising the transmission and system operator) within the SEC Hold Co structure, the company made a strategic decision to revise this methodology to focus on a strong economic dispatch process so as to improve overall power system efficiency. SEC / National Grid Company retained AF Mercados EMI to assist in the ***development of the economic dispatch methodology*** and to provide the software to implement it (AF Mercados' proprietary model ORDENA).

Scope of Work

1. Kick-off Mission and Methodology Structuring:
a) Final work plan and methodology / model refinement discussions with SEC.
b) Review of SEC data management and systems.
2. Provision of ORDENA Model.
3. Model Installation & Initialization:
a) Installation with full system database development. (System data and benchmark data in the event of incomplete data).
b) Model fine-tuning: base-case scenario simulation and verification of results validity. Adjustments made to make the model to converge to accurate results.
4. Training and Support:
a) Initial Training: one-week of training on-site at the Client premises.
b) Hands-on, on-the-job training for full model initialization/implementation.
c) Full set of operational manuals.
d) One-year of Post-Sales Support.

Ordena®
Key Experts

AF Mercados EMI: Key Profiles

Jeremy Hornby

- **2008-Present: AF-Mercados EMI Madrid (Spain) Executive Consultant, Economic Analysis and Regulation**
- Jeremy is an experienced economist with particular expertise in the economic regulation of energy businesses, the interaction of regulatory and commercial incentives and enabling organization achieve business objectives, he has been working in these areas since 1995. He has advised on regulatory issues in consulting and regulatory roles over the past 20 years in both industrialised advanced economies and emerging developing ones, in a variety of regulated sectors, such as energy, water and telecoms.
- **Qualifications**
  - **Master in the development of Neurocognitive Techniques in Business Organizations (Neuromanagement) - Universidad Rey Juan Carlos, Madrid.**
  - **MSc in Economics-London School of Economics**
  - MA in Economics (with First Class Honours) - Downing College, Cambridge

Ordena®
Key Experts

AF Mercados EMI: Key Profiles

Dr Wietze Lise

- **2012–present. Ankara/Turkey. AF-Mercados EMI Executive Consultant - Managing and developing consultancy on energy markets in Turkey and CIS countries**
- Dr Wietze Lise is a Senior Economist and Energy Markets expert. He has sound knowledge and experience in energy-economic modelling, economics of climate change, and resource management. During his nineteen years of research and consultancy experience, he worked in Holland at several research and consultancy companies who were leaders in the energy and environment field. In addition to that, he worked together with multidisciplinary teams both in Europe and Turkey, and acquired, produced and managed a myriad of projects.
- **Qualifications**
  - **Ph.D. in Economics**, PhD thesis: An Econometric & Game Theoretic Approach to Common Pool Resource Management: Case Studies in Rural India. Delhi School of Economics, Delhi University, India
  - M.Sc. in Applied Mathematics, MSc thesis: A Model of Participatory Development, with Applications to Rural India. Twente University, Enschede, the Netherlands
  - Technical Expertise:
    AIMMS, GAMS, MATLAB, SPSS, Eiews, EXCEL, WORD, POWERPOINT, ACCESS, LaTeX, Turbo Pascal

Ordena®
Main features of the model

- **ÅF's proprietary model for long, medium and short term analysis under uncertainty** (stochasticity of main variables, Monte Carlo etc.)
  - Generation and transmission system expansion model
  - Optimal medium term dispatch with optimal consideration of maintenance stops with simplified hydrothermal scheduling
  - Optimal unit commitment (ramps, non convex fuel cons., start-ups...)
- **Suitable for both centrally planned systems and a market environment**
  - **Impact of DSM on renewable power integration**
  - To establish efficient bidding strategies and optimal day ahead dispatch
  - Optimal investments, hedging strategies, fuel procurement, etc.
- **The ORDENA model allows forecasting the operation of an electricity market** for different scenarios, e.g. electricity prices, dispatch, revenues, fuel consumption, investments, flows in transmission lines etc.

Ordena®
Main features of the model

Demand Side Inputs:
- **Actual Demand in the Base Year**
- **Forecasted Demand**

Supply Side Inputs:
- Existing Generators
- Planned Generators
- Candidate Generators
- Operational Efficiency determining Parameters
- Cost Parameters (O&M charges, Capital expenditure and Fuel costs)
- Fuel Constraints
- Policy Constraints

WHAT MODEL DOES?

The model targets to find the combination of new investment and dispatch to meet the demand at the lowest cost over the year

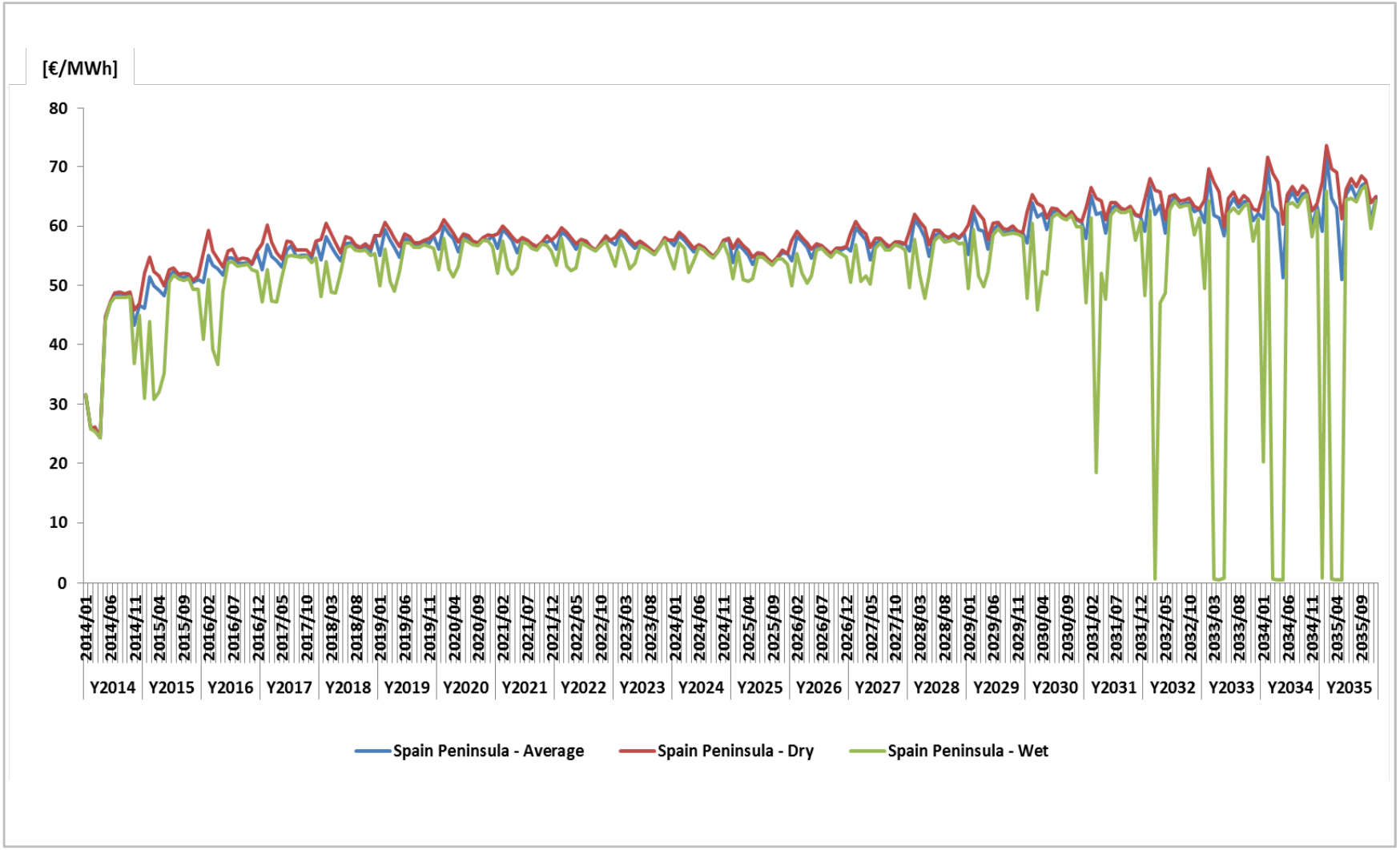
The Model Outputs provide forecasts for:

- Electricity prices (Medium to long term)
- Availability of electricity from various sources (considers transmission networks)
- Dispatch of all the generating units

This is a model at National level to assess prices and electricity availability for medium to long term

Evolution of the electricity price

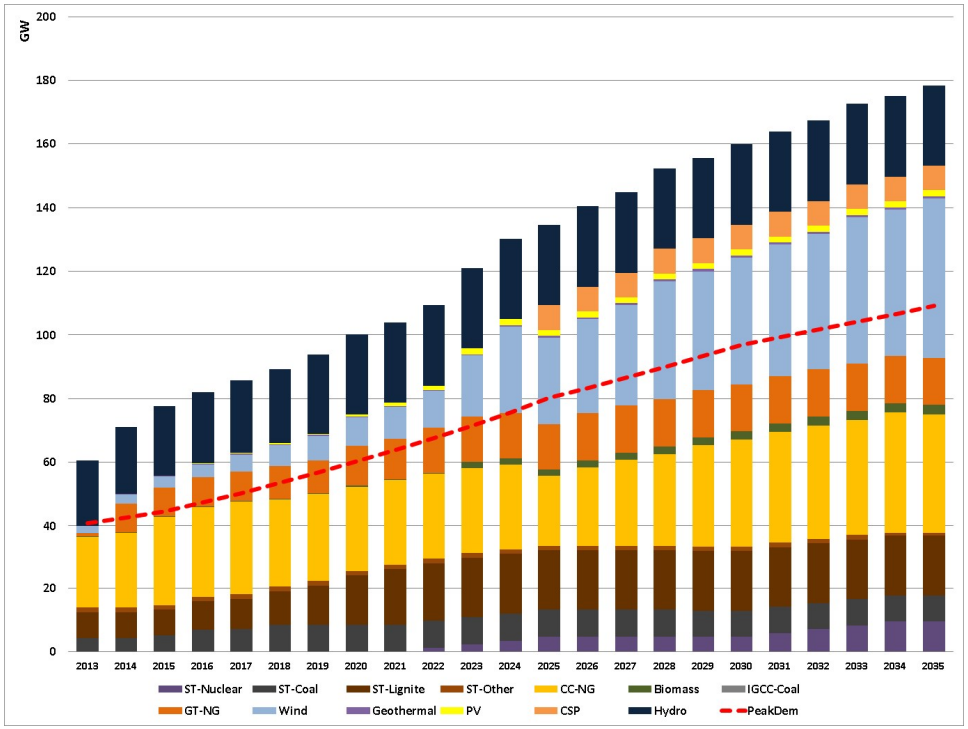
Future electricity price scenarios with ORDENA®



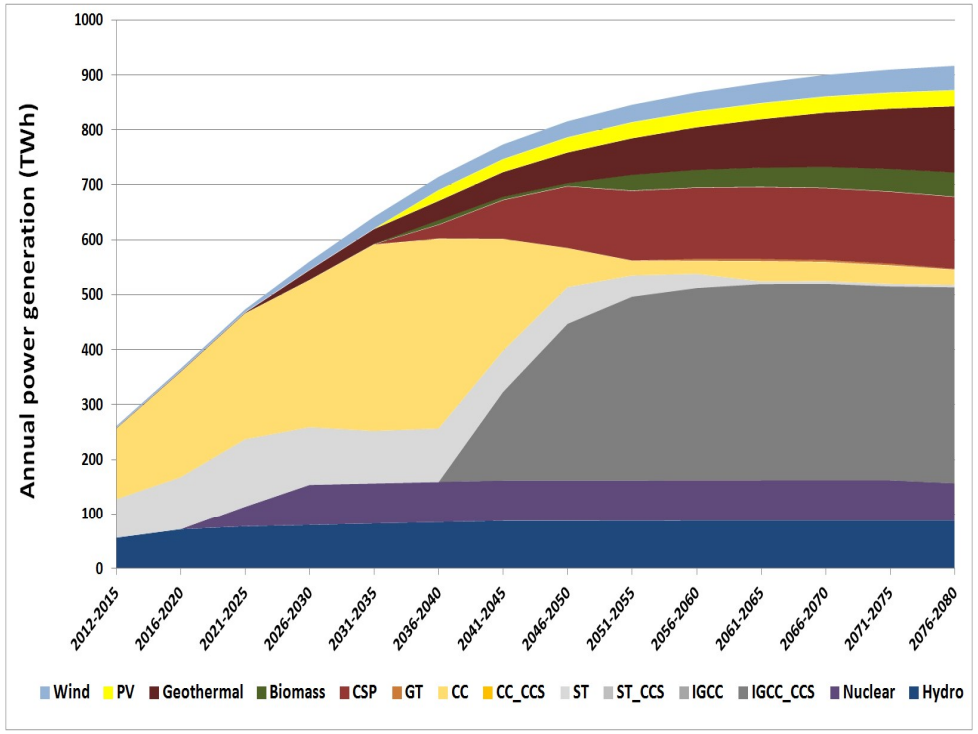
Ordena®
Main features of the model

System expansion with ORDENA®
Long term planning with new tech. CCS, IGCC etc.

Generation expansion scenario



Power system dispatch



Ordena®
Main features of the model

Module for oil products and natural gas
To enable ORDENA® perform an integrated energy system plan

It was **expanded from natural gas module** and presents the following elements:

- Processes: Used to represent complex processes, such as:
  - Distillation, blending
  - Hydrocracking, desulfuration, coker etc.
- Transport: Used to represent simpler processes, such as:
  - Transport, imports, exports etc.
- Storage: to represent the storage of oil derivates, natural gas etc.
- Energy balance: fuel sources (imports/fields) and sinks (exports), penalties for unserved fuel etc.

It **returns**:

- Investments, energy flows, processed fuel, consumption, LRMC, SRMC, emissions, costs etc.
- Warnings in case the data is not consistent

Thank you