European Network of
Transmission System Operators
for Electricity

entsoe

Demand forecasting methodology

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1. Introduction

For the creation of hourly load profiles for all European countries, ENTSO- uses a temperature regression and load projection model that incorporates with uncertainty analysis under various climate conditions. The model comes in a new software application developed by an external provider.

It allows to easily perform electric load prediction starting from data analysis of historical time series (electric load, temperature, climatic variables and other). Its overarching goal is to introduce an advanced forecasting tool which eventually will lead to a stronger harmonization of forecasting activities and comparability of their outcomes provided by ENTSO-E members.

The forecasting model incorporates the decomposition of time series into basic functions using Singular Value Decomposition (SVD), which reduces the computational burden and required data fed into the forecast model.

In a second phase, it adjusts load time series using TSOs bottom-up scenarios that reflect future evolution of the market (e.g., penetration of heat pump, electric vehicles, batteries). The forecast model reads a diverse set of data sources (historical load profiles, temperature time series, heat pumps, electric vehicles, etc.) and can provide multi-year demand forecasts in hourly resolution.

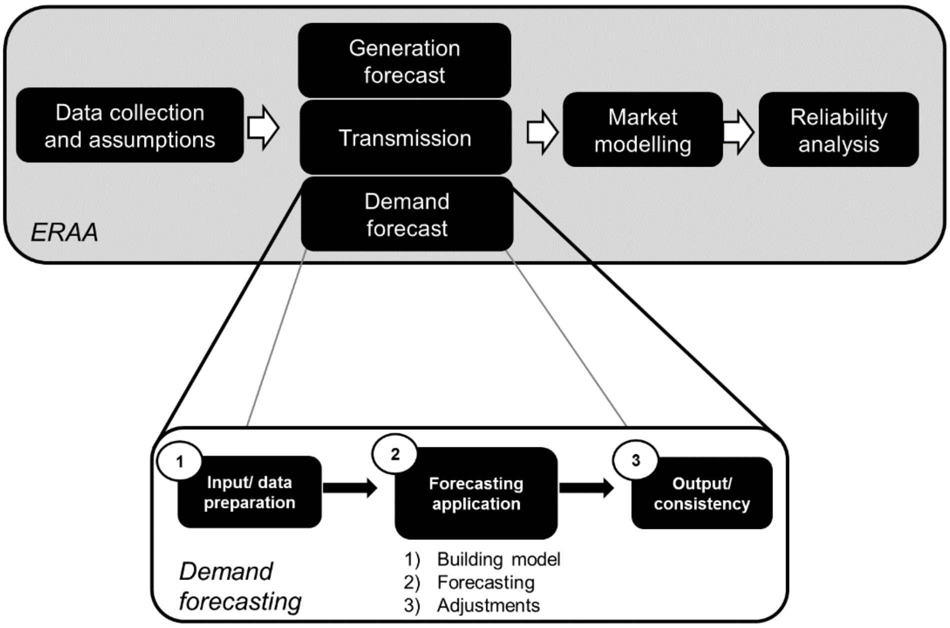

Figure 1: The embedding of demand forecasting in European resource adequacy assessment

Figure 1 shows the position of demand forecasting within the European resource adequacy assessment (ERAA). As can be seen, it provides together with generation capacity forecasts and transmission capacity information fundamental input to market modelling. A more detailed description of its functionalities and required input datasets are provided in the following.

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2. Demand forecasting methodology

The presented demand forecasting model relies on several data inputs and parameters, both for the model fitting (i) and adjustment phase (ii).

Data inputs used for the model fitting phase are:

- **Model parameters** – a set of parameters that determine for example the number of basis function number used in the SVD of time series, number of (virtual) cities considered, number of day groups considered (holidays/ special days), regression order, p-value (threshold for elimination of regressors) among others.
- **Pan-European Market Modelling Data Base** (PEMMDB) – a database that contains information on the network model and generation capacity stocks (Net transfer capacities, RES-based and fossil fuel-based generation capacities and their predicted evolution over time, maintenance and mothballing predictions, reserve requirements, and DSR potentials).

  The PEMMDB database further includes historical data on hydro conditions as well as the Pan-European Climate Database (PECD), consisting of time series for 35 climate years on temperature, irradiance, humidity, wind speed among others.

  From this database, the demand load forecasting methodology principally relies on historical load, wind speed, irradiance and temperature time series that are used to establish a link between load and the remaining variables.
- **Holiday/special days** are days that are characterized by different electrical load behavior, related to the load pattern deviations experienced during holiday days or special days. Currently, the software allows users to cluster special days into several groups that are separately treated during the forecasting process.

Following the model fitting phase, forecasted load time series are adjusted for additional factors that affect electricity consumption.

- **Load adjustments** – these take into account parameters that relate to electricity use (e.g. heat pumps (HP), electric vehicles (EV), temperature-dependent load growth). In particular, the forecasted load time series will be adjusted for:
  - Electric vehicles,
  - sanitary water,
  - air conditioning fraction,
  - air conditioning load,
  - heating heat pumps load,
  - batteries impact,
  - additional base loads and
  - increases in energy demand.

A typical forecast process with ENTSO E’s demand forecasting methodology passes the two phases explained earlier. A more detailed overview of the process is shown in Figure 2.

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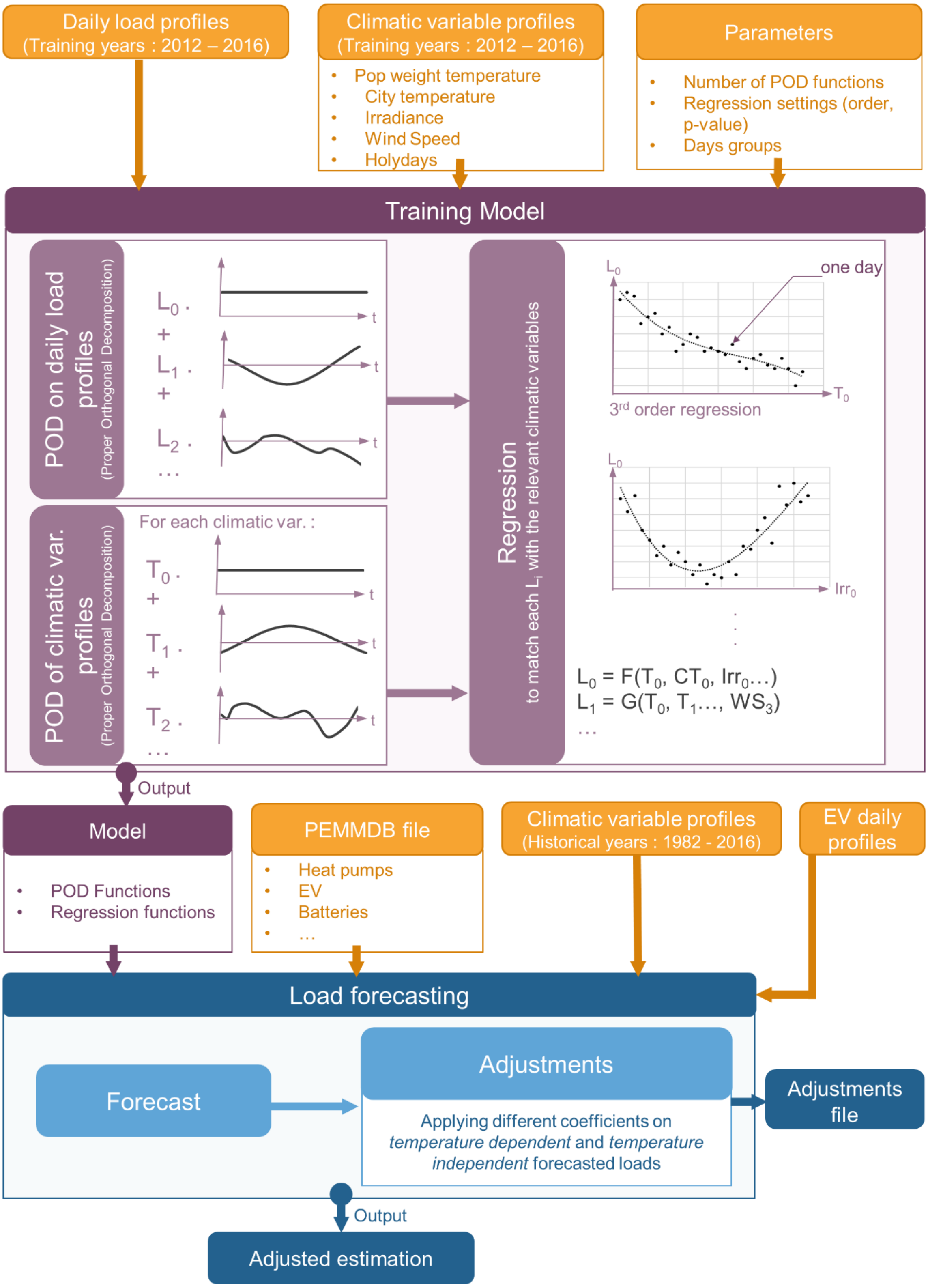

Figure 2: Demand forecasting methodology

After decomposing load and weather data time series into single building blocks (basis functions), used for time series reconstruction, a regression of load and weather data basis functions coefficients is conducted.

An as increasing number of regression variables and the variables' potential collinearity might adversely affect model accuracy, a stepwise removal of regressors is undertaken. The selection of variables is guided by a Sum Squared Error (SSE) criterion, where the change in SSE after removing a variable is assessed using an F-Test. A final model forecasting accuracy assessment lists the number of parameters eventually included in the regression, Root-Mean-Square Error (RMSE) and R^2 adjusted among others.

3. Evolution of demand forecasting methodology

Demand is a fundamental input to European resource adequacy studies performed by ENTSO-E. With regard to the past modelling approach, the utilization of the current, improved model brings several advantages to its user group (non-exhaustive list):

- Multiple historical climate and load time series are used to derive forecasted load profiles for each market node. In the previous methodology, only one reference year was used during the forecasting process;
- Increased granularity with
- Automatic identification of different climate variables needed for the forecasting process (temperature, irradiance, wind speed, etc);
- Better treatment of historical profiles used in the forecasting process (correction of holiday periods, exceptional events, etc.);
- The load forecast is decomposed into temperature-dependent and temperature-independent components. That way, final load profiles are adjusted, taking into account added consumption from heat pumps and electric vehicle charging. This way, the forecasts also consider the interdependencies of historical temperatures of each climate year and historical load patterns.

Further development of demand forecasting methodologies is currently coordinated under a taskforce dedicated to demand modelling. Such improvements may include:

- Guarantee model accessibility. As the model is currently implemented in MATLAB, a move towards open access software code (e.g. Python) is foreseen;
- Enable member-wide sharing of forecasting models, input data and output files through a web-application to be developed;
- Optimized auto-selection of model parameters (e.g. basis functions, regression orders, etc.) as a function of error metrics and a performance comparison of various model types;
- Review of metrics to quantitatively compare models with different regressor subsets selected by stepwise regressor elimination.

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