C3S Energy Webinar

Global Hydro Power and Electricity Demand Indicators

"Electricity Demand Modelling: the Generalized Additive Models"

Henri Upton (EDF) - 10 July 2024

Climate Change

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Goal of the projects

- Produce national-wise **aggregated electricity demand forecasts** …
- … for a list of **33 european countries** …
- … Using past **historical** national **electricity load** and **meteorological variables** (wind speed, solar irradiance, temperature) …
- … and a machine learning model based on the methodology of **Generatized Additive Models**

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Use case: seasonal forecasts

Three input streams (meteorological data) for the use case of seasonal forecasts:

- **ECMWF** (European Center for Medium-Range Weather Forecasts):
  - ***Hindcasts***: 1 forecast per month and for 25 members from 1993 to 2016 => 25 (members) x 12 (months) x 24 (years) = 7200 forecasts
  - ***Forecasts***: 1 forecast per month and for 51 members from January to September 2023 = 51 (members) x 9 (months) x 1 (year) = 459 forecasts

- **CMCC** (Euro-Mediterranean Center on Climate Change):
  - ***Hindcasts***: 1forecast for each month for 40 members from 1993 to 2016 => 24 (years) x 12 (months) x 40 (members) = 11520 forecasts
  - ***Forecasts***: 1 forecast for each month for 50 members from 2021 to 2023 => 3 (years) x 12 (months) x 50 (members) = 1800 forecasts

- **DWD** (Deutscher Wetterdienst):
  - ***Hindcasts***: 1 forecast for each month for 30 members from 1993 to 2016 => 24 (years) x 12 (months) x 30 (members) = 8640 forecasts
  - ***Forecasts***: 1 forecast for each month for 50 members from 2021 to 2023 => 3 (years) x 12 (months) x 50 (members) = 1800 forecasts

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Meteorological data

provenance

variable

Start date

End date

S_SY51_ECMW_T319_GHI_0000m_Glob_ADM0_S202309020000_E202404030000_INS_TIM_01d_07m_qbc_org_50_NA---_NA---_NA---.csv

time step

horizon

Member number

1 country = 1 column

Date,GB,TZ,RS,PT,TH,...
2023-09-02,123.4,201.5,154.2,158,1,244.1,...
2023-09-03,124.4,208.5,157.2,153,1,249.1,...
2023-09-04,128.4,209.5,157.2,154,1,247.1,...
2023-09-05,121.4,201.5,159.2,155,1,243.1,...
...
2024-04-03,121.4,201.5,159.2,155,1,243.1,...

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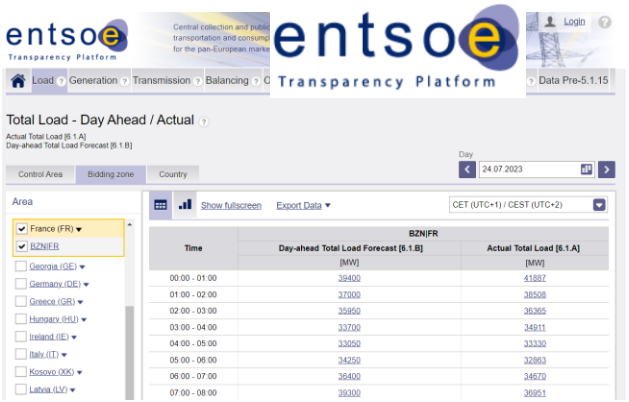
Consumption data

Actual Total Load [6.1.A]



Raw data

Store raw data in a database to simplify the request for historical data.

Raw data

CSV

Subset of raw data filtered by date and area

Raw data downloaded directly from Transparency Platform – Several ways :

- Export from Data Portal :
  - https://transparency.entsoe.eu/load-domain/r2/totalLoadR2/show
- RESTful API :
  - https://documenter.getpostman.com/view/7009892/2s93JtP3F6
- SFTP :
  - sftp://sftp-transparency.entsoe.eu

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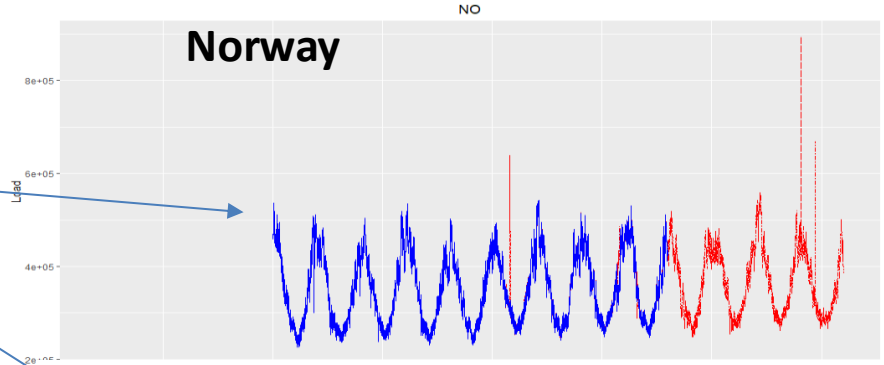
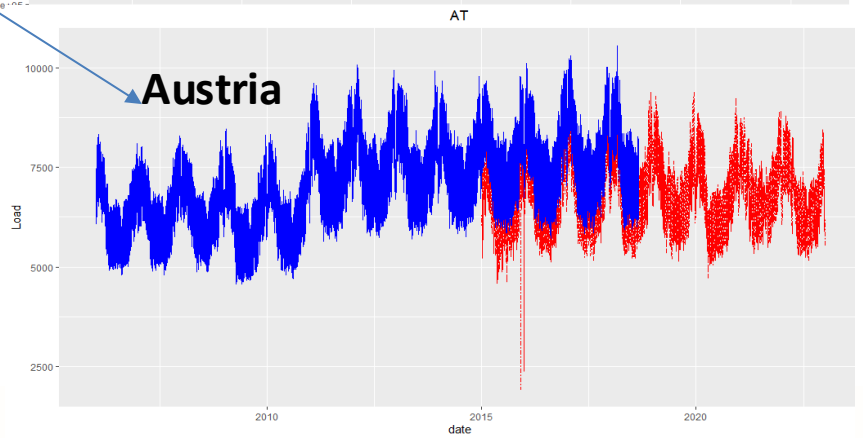
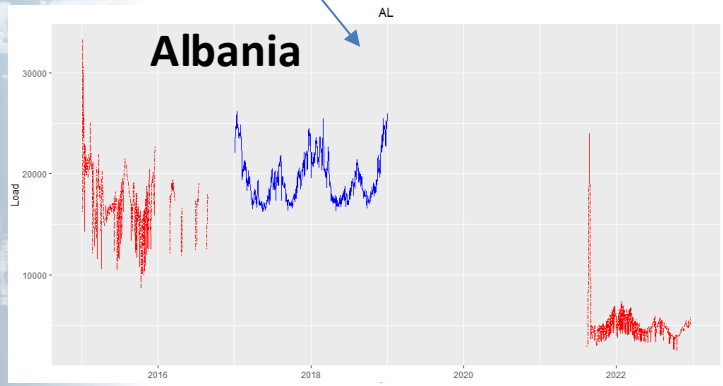
Consumption data

Hourly consumption data for 39 countries

- 24 are quite correct
- 10 are really different and it will be complicated to use oldest models.
- 5 are unusable







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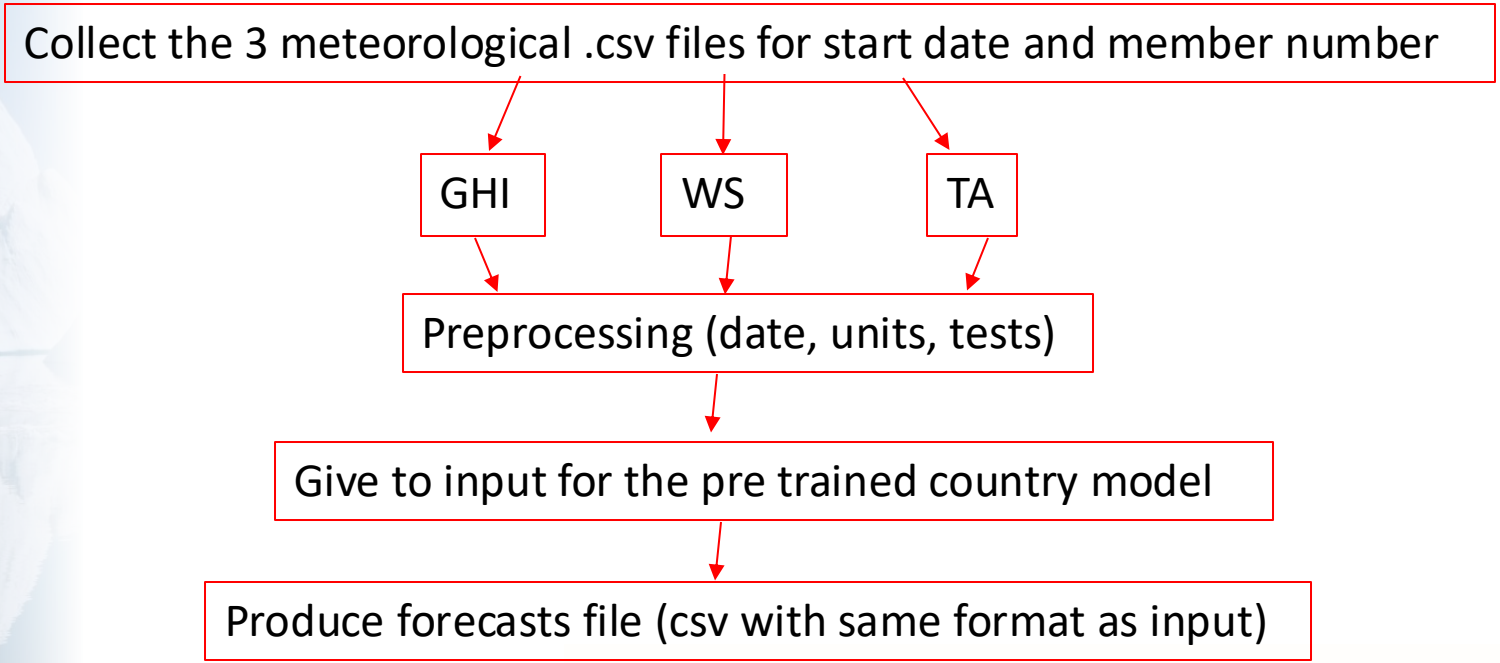
Overall pipeline

For a given **data stream**, **country**, **start forecast date**, and **member number** :



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GAM models

For each country, we use **G**eneralized **A**dditive **M**odels models, which are additive models : it's a semi-parametric approach that can carry out non-linear effects and produce relatively parsimonious and interpretable models at the same time.

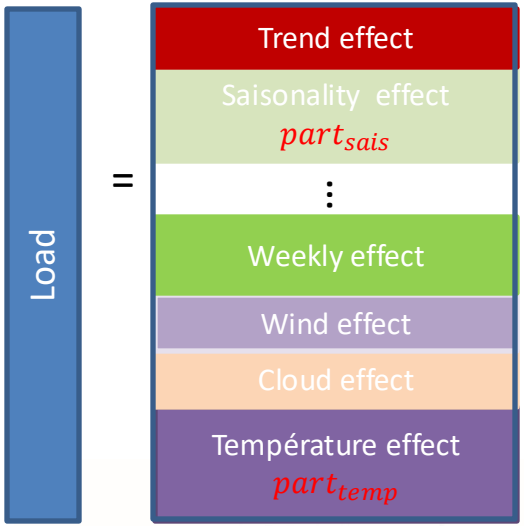
Electricity consumption is a time series with a trend, an annual, weekly and daily saisonality, which depends on :

Economic activity

trend

climate

Calendar events



For most countries, we estimate the model from 2013 to 2018 and validate on 2019

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GAM models

A Generalized Additive Model or GAM is a class of predictors that aims to predict a target variable $y \in \mathcal{M}_{N,1}$ from a vector of explanatory variables $\mathbf{x} = (x_1, \ldots, x_P) \in \mathcal{M}_{N,P}$, based on a sum of an *intercept* coefficient, a sum of functions of each explanatory variable, and a noise distributed according to a given distribution :

$$\forall i \in (1, \ldots, N), y_i = \beta_0 + \sum_{j=1}^{P} s_j(x_{ij}) + \epsilon_i \tag{1}$$

The explanatory functions $(s_1, \ldots, s_p)$ are more commonly called *splines* and are themselves compositions of the whole numbers $(K_1, \ldots, K_P)$ base functions, or *basis functions* :

$$\forall j \in (1, \ldots, P), s_j(x) = \sum_{k=1}^{K_j} \beta_{kj} b_{kj}(x) \tag{2}$$

GAM models

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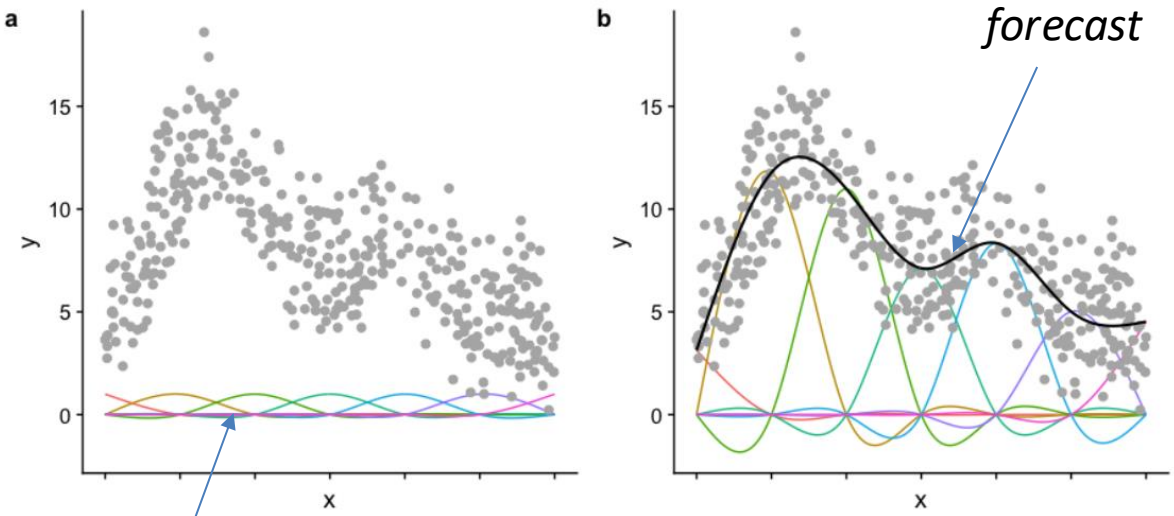

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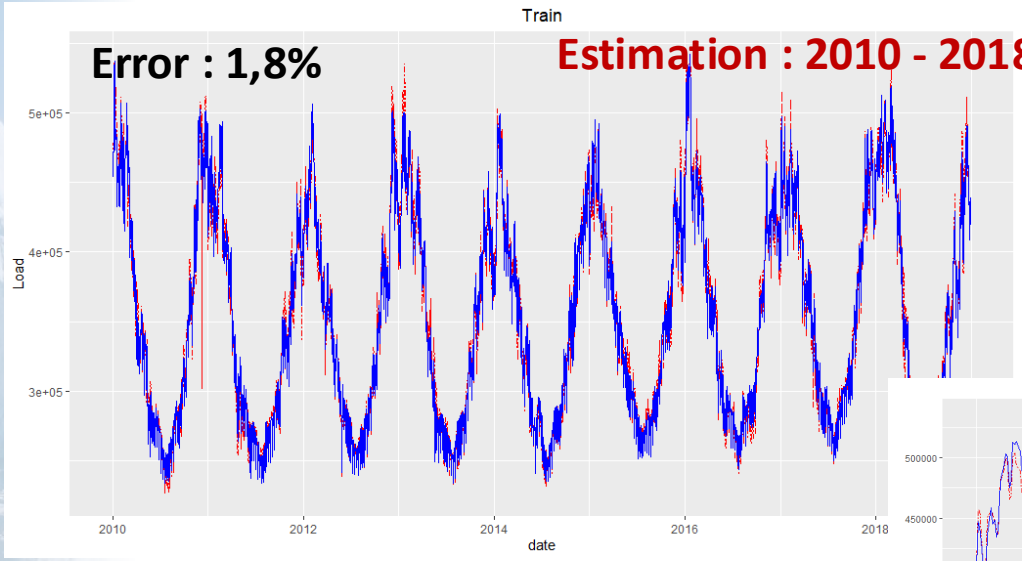
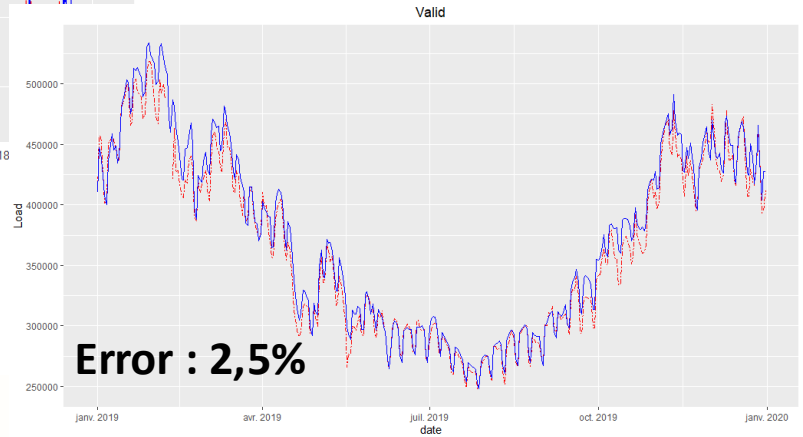
Example : Norway



Validation : 2019



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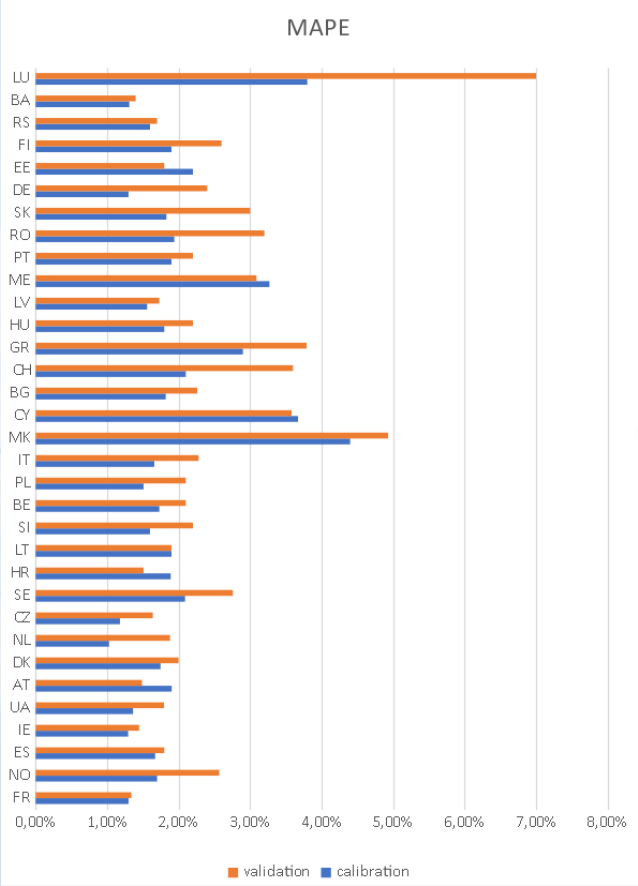
FIRST RESULT BY COUNTRY



33 countries have been done with 4 countries added recently : DE (Germany), EE (Estonia), FI (Finland) and RS (Serbia)

Mean Absolute Percentage Error :

$$MAPE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{Y_i - \hat{Y}_i}{Y_i} \right|$$

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Perspectives

- Update models with training / validate with more recent data (post covid structure, other calendar effects, meteorological trends over time)

- Develop models from R programming language to C++ for executable for sharing purposes