

# Documentation

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## Preface

Welcome to the [short-term-forecasting](#) wiki!

Short-term forecasting of electricity generation, demand and prices using machine learning.

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## Background

The transition towards a future low-carbon economy is driven globally by the Paris Agreement [par2015], which recognises the need for sustainable development worldwide to counter the threats of climate change. The European Union (EU) is committed to reduce greenhouse gas (GHG) emissions by 2050 to 80-90 % below 1990 levels [ene2012]. As the energy industry is responsible for the highest share of anthropogenic GHG emissions, importance is placed on how changes in energy systems can help achieve these GHG emission reduction targets [ene2012].

A number of opportunities exist for the decarbonisation of the energy industry. The International Renewable Energy Agency (IRENA), in their renewable energy roadmap study, has identified renewable energy as having the highest potential in reducing energy-related carbon dioxide (CO<sub>2</sub>) emissions globally, which is closely followed by energy efficiency and electrification with renewable energy [glo0000]. In a 2018 political agreement, the EU member states agreed upon a target of at least 32 % of the demand being met with renewables by 2030, through national targets of the individual member states [ren0000]. The electricity demand in the transport sector is also expected to increase due to expected petrol and diesel engine bans and subsequently the electrification of road transport [wor2017].

According to the EU reference scenario 2016 [ene0000], wind and solar energy resources are expected to generate a total of 35 % of EU’s electricity by 2050. This is a significant increase (23 %) from 2015 levels.

Type[f1]	Variable	Fuel type	Flexibility	Low carbon	CAPEX[f2]	OPEX[f2]	LCOE[f2]
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**Table 1:** Characteristics of the main energy generation technologies, adapted from Erbach 2016 [erb2016] and Tidball, et al. 2010 [tid2010].

Type[f1]	Variable	Fuel type	Flexibility	Low carbon	CAPEX[f2]	OPEX[f2]	LCOE[f2]
Coal	no	fossil	medium	no	low	high	very low
Natural gas	no	fossil	high	no	very low	very high	low
Biomass	no	renewable	medium	yes[f3]	low	very high	very high
Nuclear	no	nuclear	low	zero-emission	medium	medium	medium
Hydro	no	renewable	very high	zero-emission			
Solar	yes	renewable	very low	zero-emission	very high	very low	very high
Wind	yes	renewable	very low	zero-emission			
Onshore wind					high	very low	very low
Offshore wind					very high	low	high
Geothermal	no	renewable	high	zero-emission	high	medium	high

[f1] Costs for natural gas, biomass, solar and geothermal are that of advanced combustion turbine, biomass gasification plant, utility-scale photovoltaic and hydrothermal plant respectively

[f2] CAPEX - capital costs; OPEX - operational expenditure (includes fuel and fixed O&M costs); LCOE - levelised cost of electricity

[f3] regrowth of biomass compensates emissions

## Regions

### North Sea countries

As per the definition provided by the European MSP Platform [nor2000] and the CPMR North Sea Commission [mem2015], the North Sea region consists of eight countries: Belgium, Denmark, France, Germany, Netherlands, Norway, Sweden and United Kingdom.

### NUTS (Nomenclature of territorial units for statistics)

See the Jupyter notebook.

## Bidding zones

### Definition

According to [bid2014]:

- The largest geographical area within which market participants are able to exchange energy without capacity allocation.
- The majority of bidding zones in Europe are defined by national borders (e.g., France or the Netherlands).
- Some are larger than national borders (e.g., Austria, Germany and Luxembourg or the Single Electricity Market for the island of Ireland)
- Some are smaller zones within individual countries (e.g., Italy, Norway or Sweden).

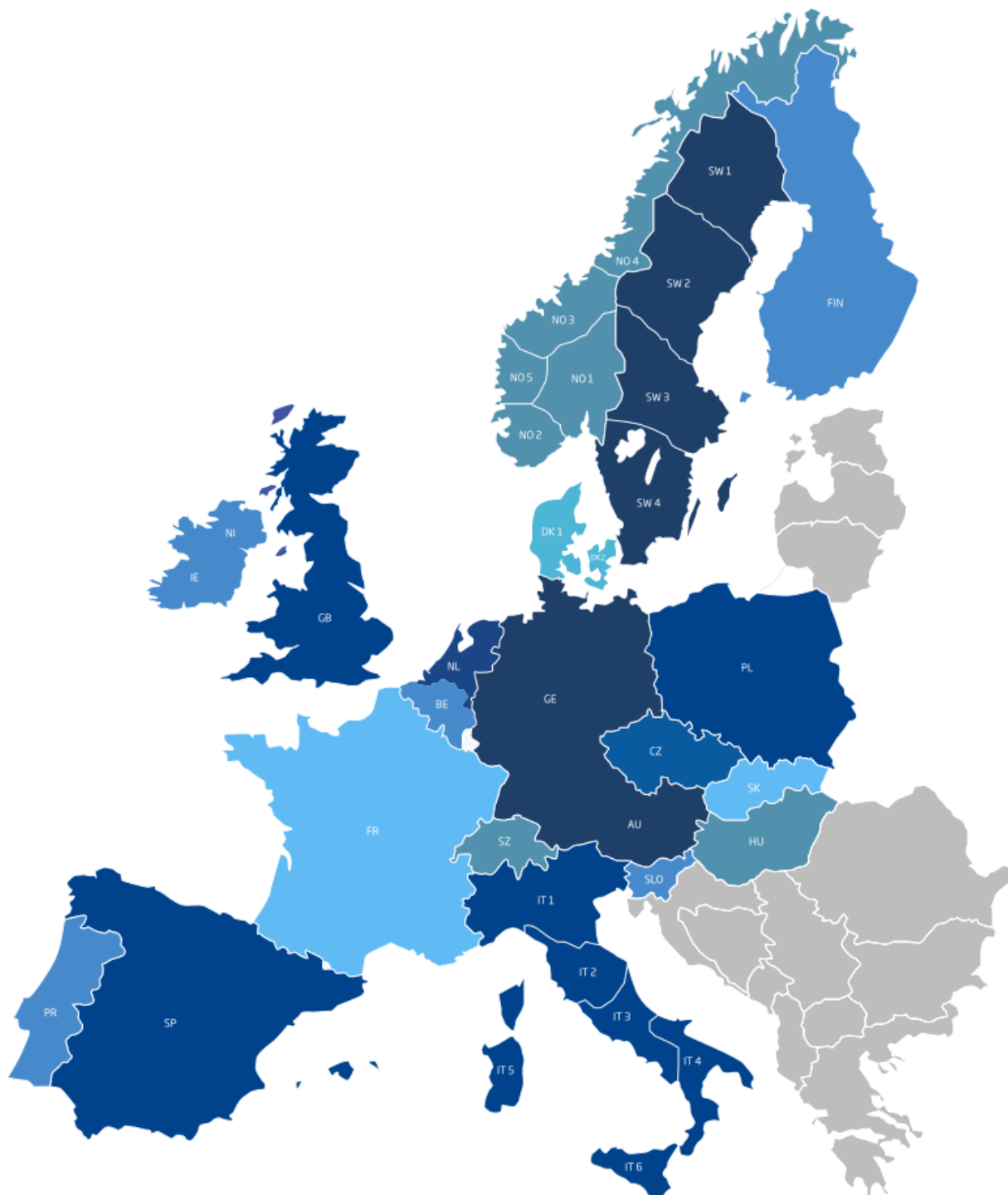
## Bidding zones in the North Sea region

The bidding zones in the European electricity market are illustrated in the map below [\[tre2017\]](#).

**Table 2:** Bidding zones in the North Sea region.

Country	Market(s)	Zone(s)
Belgium (BE)	EPEX SPOT	BE
Germany (DE / GE)	EPEX SPOT	DE-AT-LU <a href="#">[f4]</a>
Denmark (DK)	Nord Pool	DK1, DK2
France (FR)	EPEX SPOT	FR
Netherlands (NL)	EPEX SPOT	NL
Norway (NO)	Nord Pool	NO1, NO2, NO3, NO4, NO5
Sweden (SE / SW)	Nord Pool	SE1, SE2, SE3, SE4
United Kingdom (UK)	EPEX SPOT, Nord Pool	GB, I-SEM <a href="#">[f4]</a>

[\[f4\]](#) *Austria (AT / AU); Luxembourg (LU); Great Britain (GB); Irish single electricity market (I-SEM), which includes Republic of Ireland (IE) and UK's Northern Ireland (NI)*



**Figure 1:** Bidding zones in the European electricity market. Source: [Polskie Sieci Elektroenergetyczne](#).

## Data

### Data folder navigation

- ENTSO-E
  - generation and load data for each bidding zone in the North Sea region, grouped by country
- Meteo - meteorological data, grouped by country
- Market - market data for the North Sea region
- NUTS - territorial units
- output - output or modified data from this project

### Met data

#### Deutscher Wetterdienst

- CDC (Climate Data Center) portal
- CDC OpenData
- Terms of use for data on the CDC ftp server
- Data set descriptions
  - Hourly station observations of air temperature at 2 m above ground in °C for Germany
  - Hourly station observations of relative humidity in % for Germany
  - Hourly station observations of precipitation amount in mm for Germany
  - Hourly station observations of form of precipitation (WR code) for Germany
  - Hourly station observations of index whether precipitation has fallen for Germany
  - Hourly mean of station observations of wind speed ca. 10 m above ground in m/s for Germany
  - Hourly mean of station observations of wind direction at ca. 10 m above ground in degree for Germany
  - Hourly station observations of air pressure at station level in hpa for Germany
  - Hourly station observations of air pressure at mean sea level in hpa for Germany
  - Hourly station observations of cloud coverage in eighths for Germany
- Hourly wind data

#### Royal Netherlands Meteorological Institute

#### Met Office

#### Norwegian Meteorological Institute

#### Swedish Meteorological and Hydrological Institute

#### Danish Meteorological Institute

#### Météo-France

#### The Royal Meteorological Institute of Belgium

## Generation and demand data

### ENTSO-E Transparency Platform

- GENERAL TERMS AND CONDITIONS FOR THE USE OF THE ENTSO-E TRANSPARENCY PLATFORM
- LIST OF DATA AVAILABLE FOR FREE RE-USE
- Downloaded data:
  - Actual Generation per Production Type
  - Total Load - Day Ahead / Actual

## Market data

### Nord Pool

- Membership list - Nord Pool
- Terms and conditions for use

### EPEX Spot

- EPEX SPOT Exchange Members

## Other data

### NUTS (Nomenclature of territorial units for statistics)

## Methodology

### Modelling framework

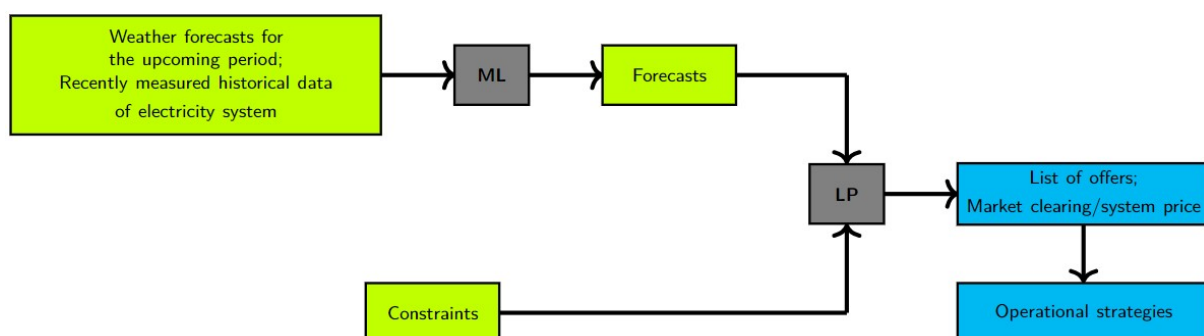


Figure 2: Modelling framework.

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