Renewable Energy Production Forecast

PROJ0016 - Big Data Project

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February 27, 2020

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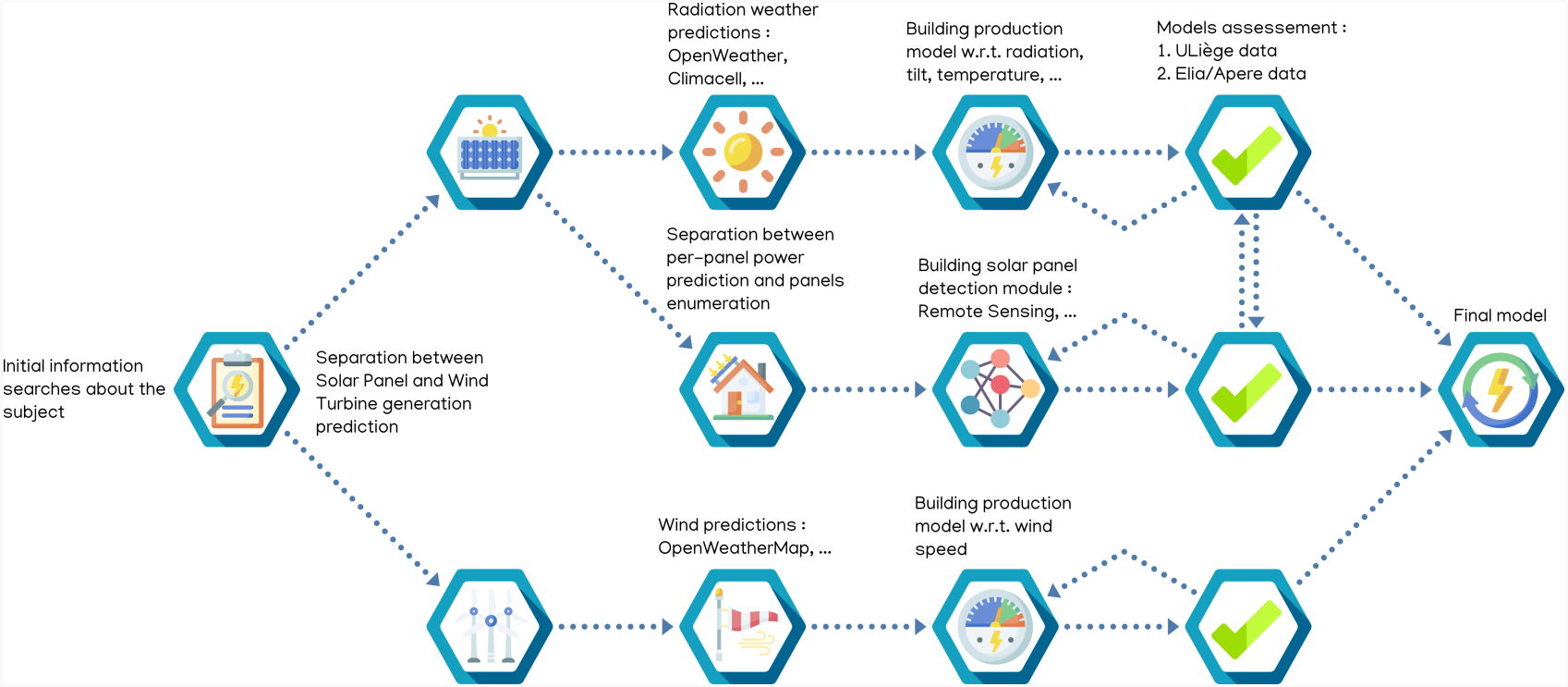
Road Map


Initial information searches about the subject
Separation between Solar Panel and Wind Turbine generation prediction
Radiation weather predictions : OpenWeather, Climacell, ...
Separation between per-panel power prediction and panels enumeration
Wind predictions : OpenWeatherMap, ...
Building production model w.r.t. radiation, tilt, temperature, ...
Building solar panel detection module : Remote Sensing, ...
Building production model w.r.t. wind speed
Models assessement : 1. ULiège data 2. Elia/Apere data
Final model

Photovoltaic Production

Influencing Parameters

- Tilt β of the panel
- Surface azimuth A_s of the panel
- Module efficiency η
- Module area A

Influencing Parameters

- Temperature T
- Irradiance received by the panel I
- Incidence angle θ between the sun rays and the normal to the panel

Resulting Model

Combining these parameters yielded the following model:

$$P_{out} = \eta I \cos(\theta) A$$

which gives the output power of the photovoltaic panel in Watts (bounded by P_{max}, the maximum output power of the panel).

Incidence Angle

The cosine of the incidence angle can be expressed as[1]:

$$\begin{aligned}\cos(\theta) = &\sin(\delta)\sin(\phi)\cos(\beta) + \sin(\delta)\cos(\phi)\sin(\beta)\cos(A_s) \\ &+ \cos(\delta)\cos(\phi)\cos(\beta)\cos(\omega) \\ &- \cos(\delta)\sin(\phi)\sin(\beta)\cos(A_s)\cos(\omega) \\ &- \cos(\delta)\sin(\beta)\sin(A_s)\sin(\omega)\end{aligned}$$

where solar angles can be computed using pvlib.

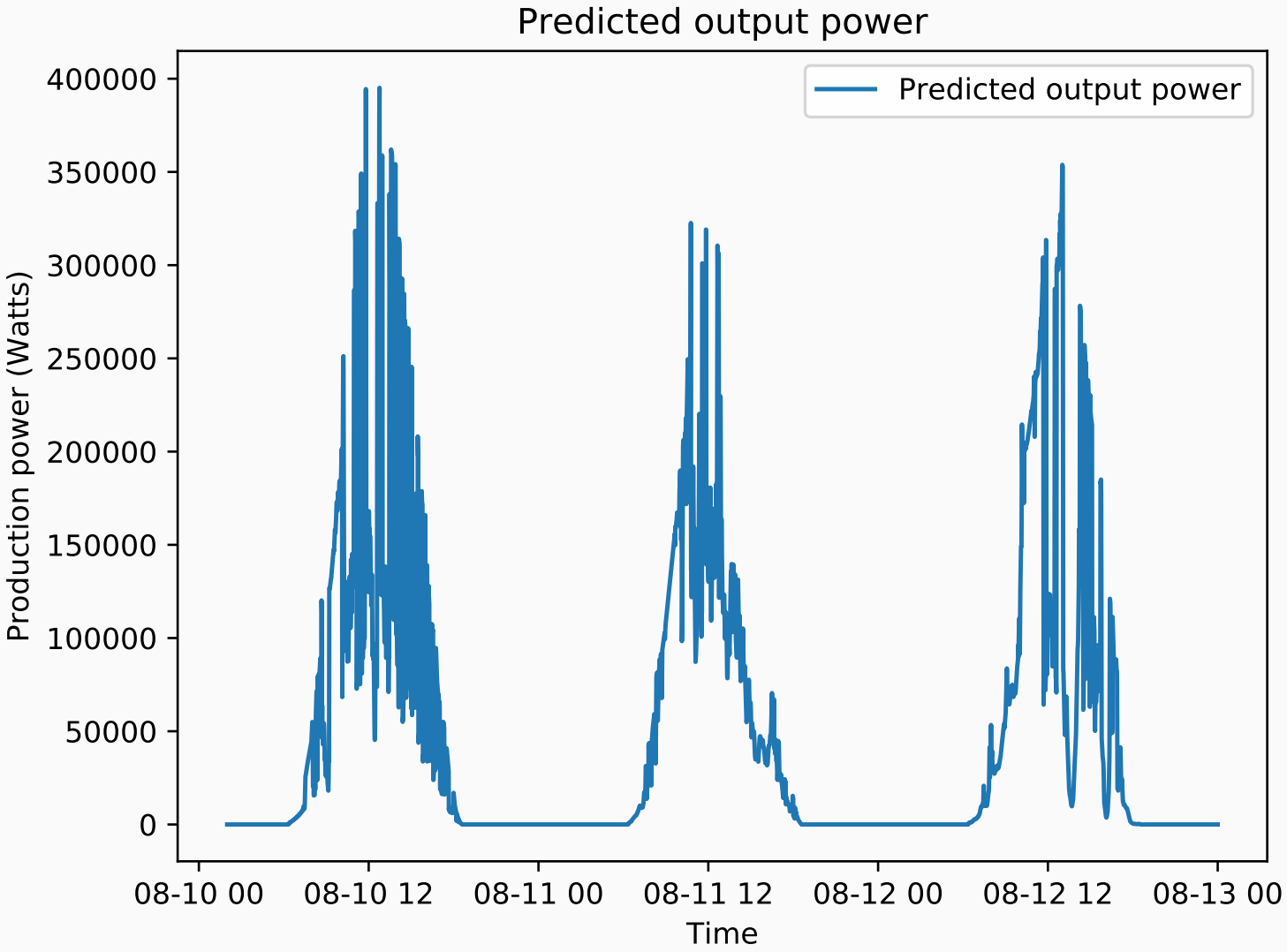
Challenges

- Panel type evaluation
- Module efficiency evaluation
- Module maximum power P_{max} evaluation
- Panel tilt evaluation
- Finding irradiance forecast data

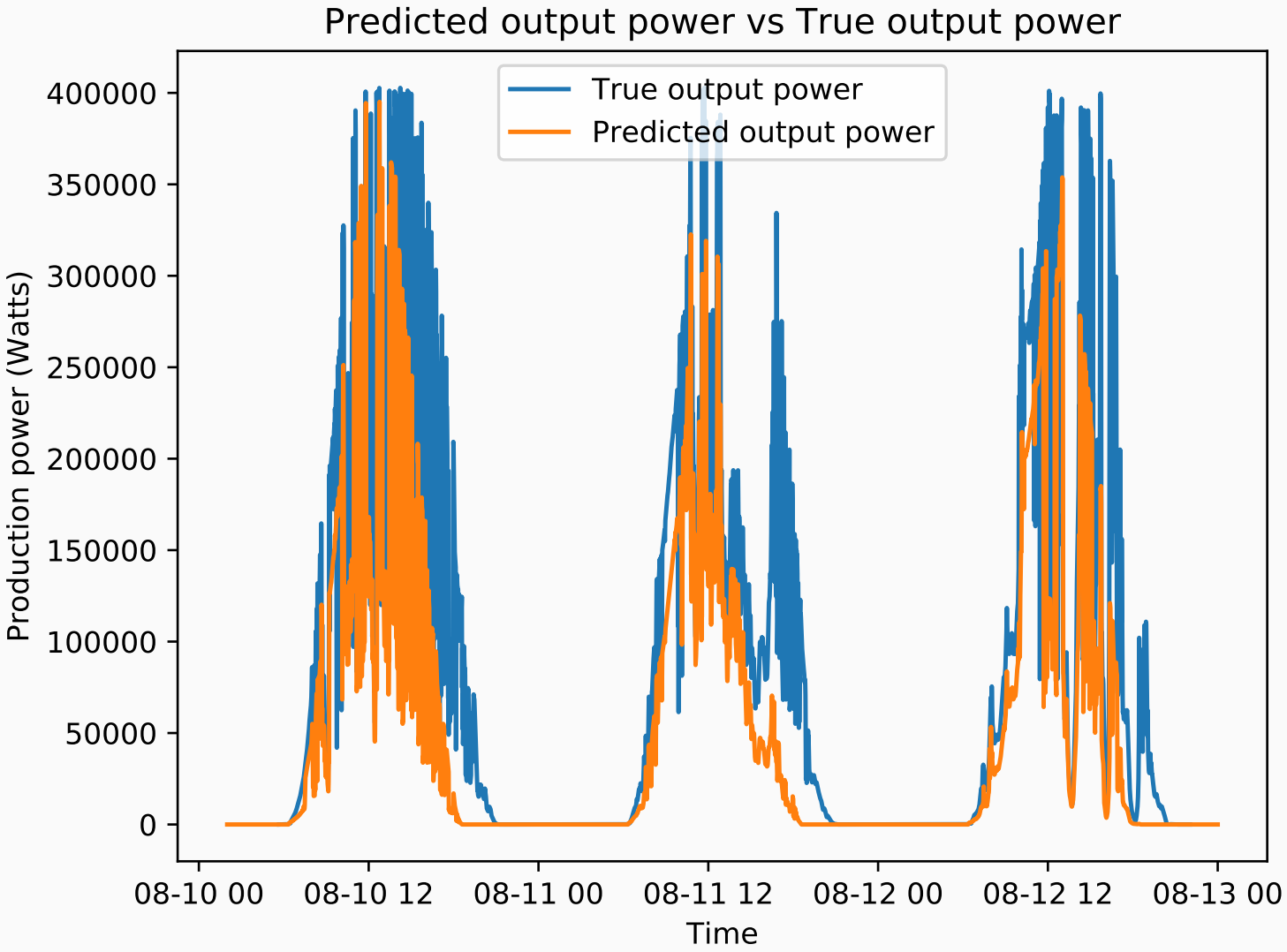
Example Model

An example model has been implemented on the Sart-Tilman data (using the thermodynamics laboratory data).

Example Model



Example Model



Next objectives

- Maximum power bounding
- Temperature influence
- Potential scaling of the irradiance

Photovoltaic panels enumeration

Test set – WalOnMap

Wallonia possesses a `WebMapService` : WalOnMap.

It gives access to high quality (1 px per 25 cm) georeferenced images of the region[1].

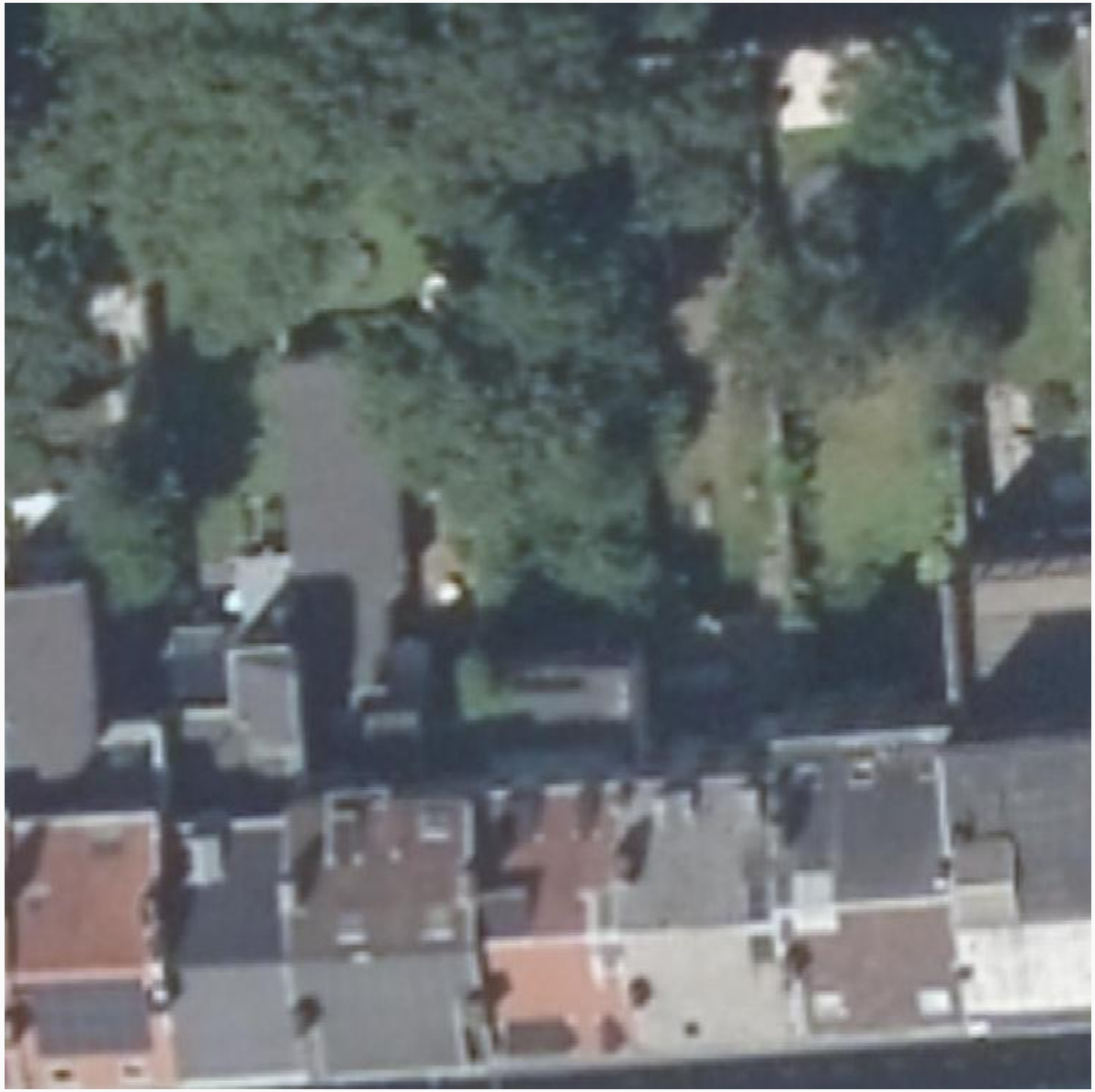
[1] The satellite pictures were taken in 2018.

Test set – WalOnMap

Based on WalOnMap API, we have produced a prototype python program to retrieve an image w.r.t. some geo-localisation.

```
$ python3 wms.py 50.637082 5.564001 50
```

Test set – WalOnMap



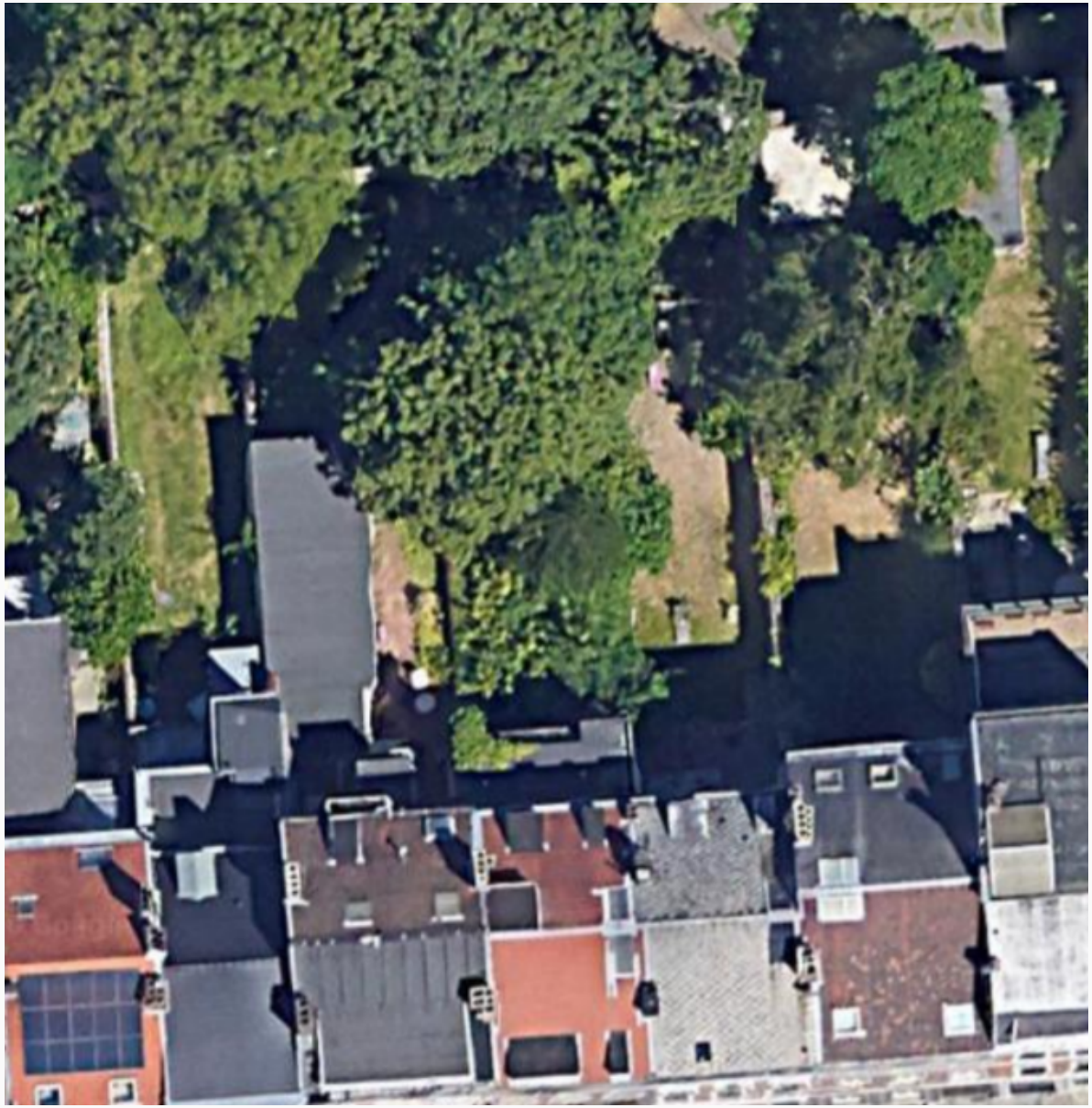
Test set – GoogleMaps

There is also an API for GoogleMaps.

Google Maps has an even finer resolution and more recent satellite pictures.

We will try to obtain an API key.

Test set – GoogleMaps



Detection model – DeepSolar

- The network isn't provided pre-trained
- The learning set isn't publicly available
- Written in `Python 2.7` (Deprecated)

We need another solution.

Detection model

We found some alternatives :

- DeepSolaris (BISS Institute, Heerlen)
- Solar Panel Detection (Alan Turing Institute)
- Automatic solar photovoltaic panel detection in satellite imagery (Duke University)
- ...

Interesting methods but no trained model or training data.

We need training data.

Training data

Two ideas :

1. Annotating (by hand) satellite pictures with/without solar panels[2]. Total control but dummy work. Also, we still need to know *some* panel coordinates.
2. Finding (or asking for) a solar panel coordinates dataset. We have one for England (OpenStreetMap), but it is very imprecise and only gives a position. Problem : we need a surface for training a segmentation network.

[2] For example using Cytomine.

Training data

Next objectives

Short term

- Find quickly a suitable training set.
- Maybe build a simple computer vision detection model.

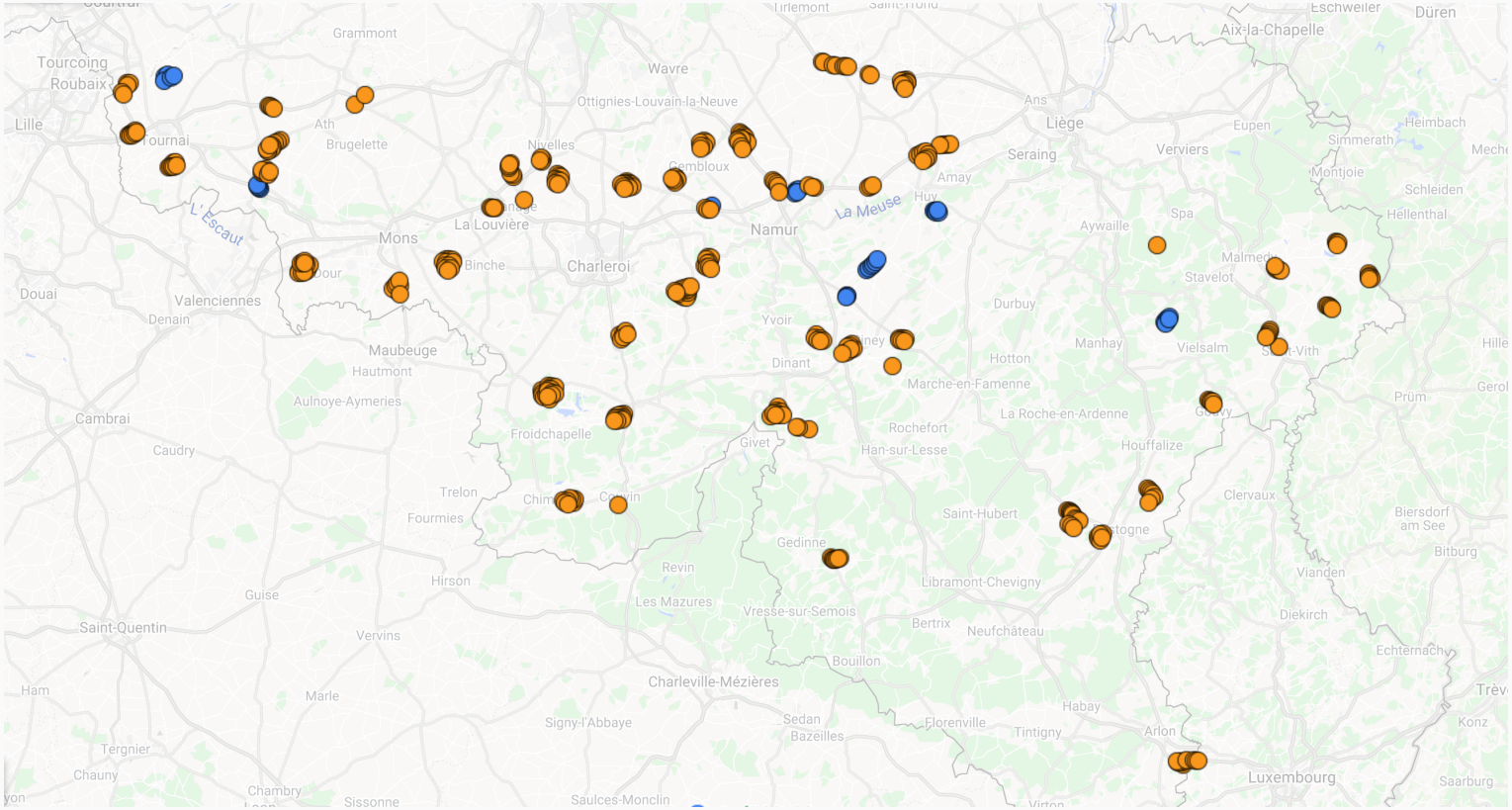
Long term

- Surface, orientation and (maybe) tilt detection.

Wind Power Production

Wind turbines enumeration

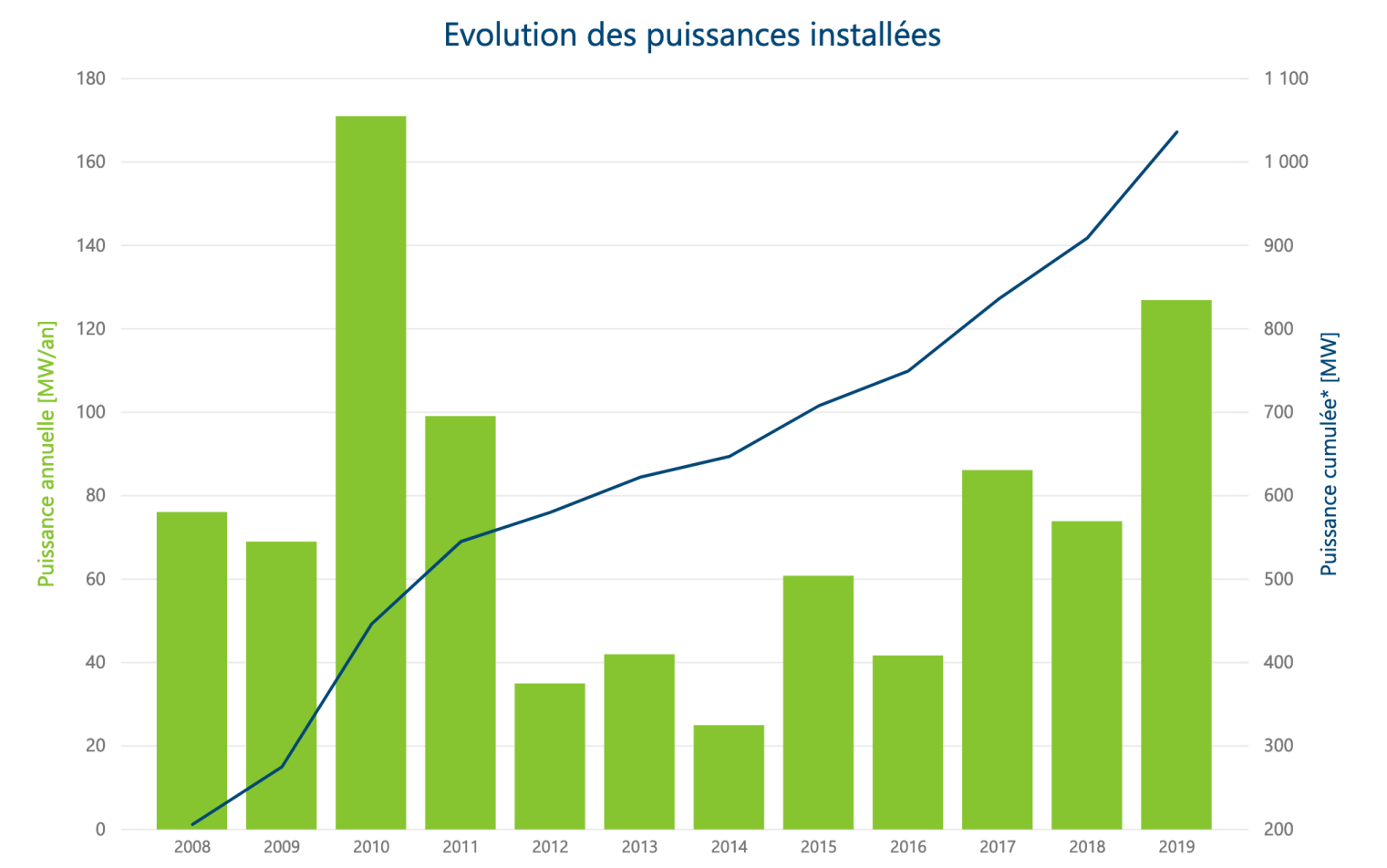
- SPW Energie data (2018)



SPW Energie - Wind turbines map [2]

Wind turbines enumeration

- Outdated (+13.97% MWp in 2019 in Wallonia: 127MW)



APERe - Wind power in Wallonia [3]

Wind turbines characteristics

- Metadata of the KML Google Maps file from the SPW Energie (one row for each unique wind turbine in Wallonia):

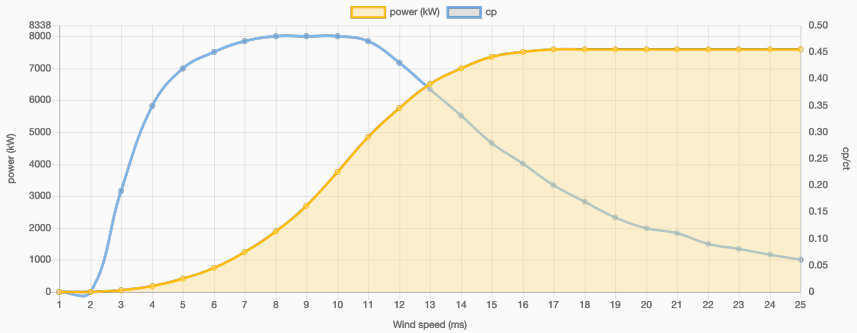
Id	CodeCWaPE	Exploitant	Localisation	Puissance	Lat	Long	Marque	Type	Etat

- Each unique `(Marque, Type, Puissance)` is extracted.
- Model of power production w.r.t the wind for each of these unique tuple.
- Need of power curve data for each of these models

Wind turbines characteristics - Power curves

Data from website *Wind Turbines Models* [4] includes:

- Cut-in, cut-out, rated wind speed
- Hub height
- (Most of the time) a 20-50 data-points discrete power curve



Enercon E-126 Power Curve

Wind turbines characteristics - Models

According to the availability of the power curve, the model built for a certain `(Marque, Type, Puissance)` is :

- a cubic spline interpolation of the power curve data between the cut-in and cut-out wind speed, or
- a naive theoretical model where the power:
  - is 0 between 0 and the cut-in wind speed
  - is 0 above the cut-out wind speed
  - is the peak power of the wind turbine between the rated and the cut-out wind speed
  - is proportional to the cubed wind speed between the cut-in and rated wind speed, as the theoretical wind power is $\frac{1}{2}\eta\rho A v^3$.

Weather

For now, we use free weather API that provides limited information:

API	Live	Nowcast	Forecast	Solar Radiation	History
OpenWeatherMap	x	-	3h (5d)	-	-
Climacell	x	5min (5h)	1h (5d)	x	- (?)
Darksky	x	1min (1h)	1h (1d)	-	x

Aggregated Wind Power Production

Whereas the final model should only focus on the Liege province, here we consider all wind turbines of Wallonia, in order to compare with Elia's mmeasures

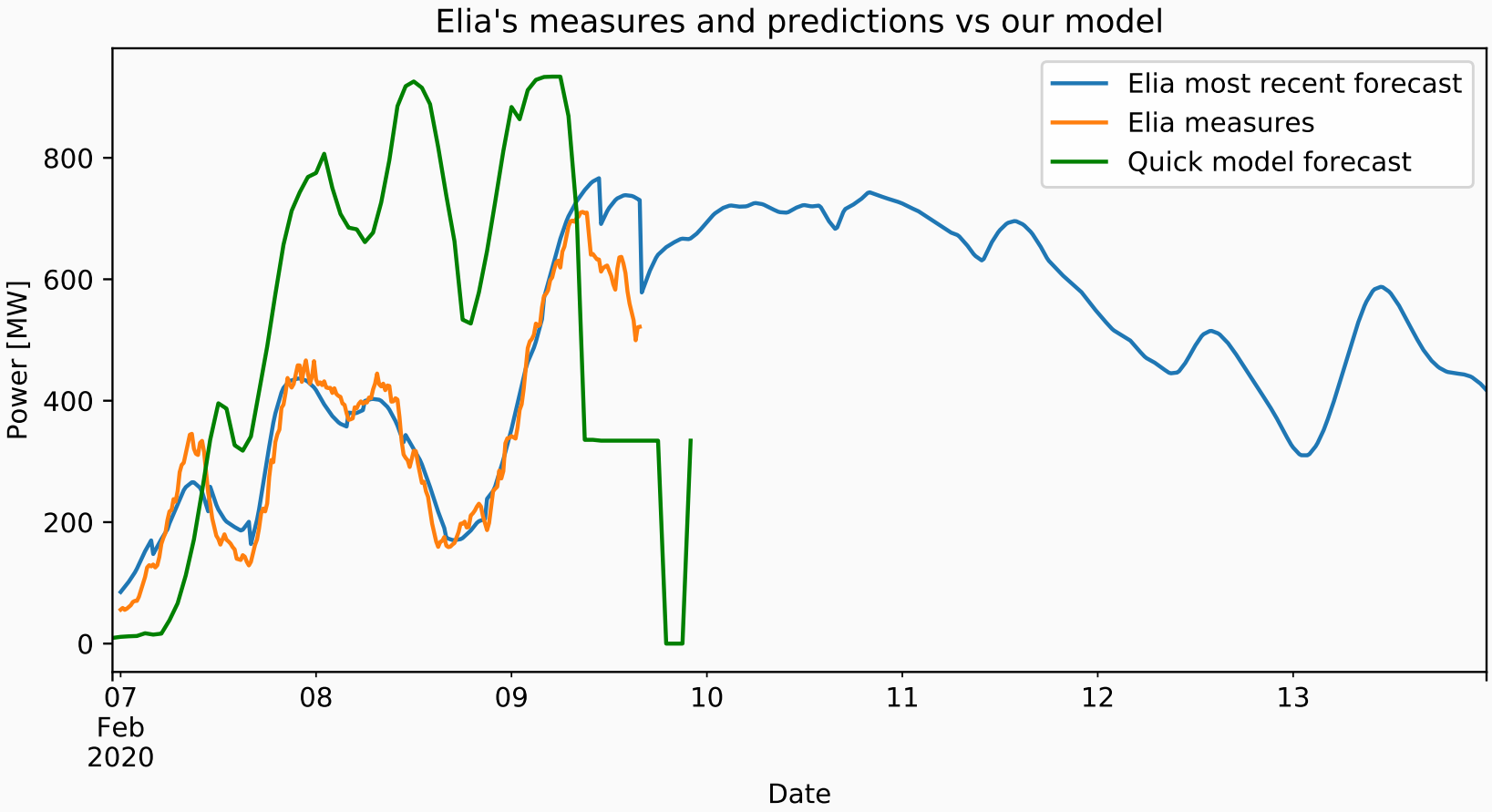
For each wind turbines,

- Weather API query in order to get the wind speed at this location (lat, lon)
- Power production estimated thanks to the wind and the `(Marque, Type, Puissance)` model.

Then, all individual powers are summed up.

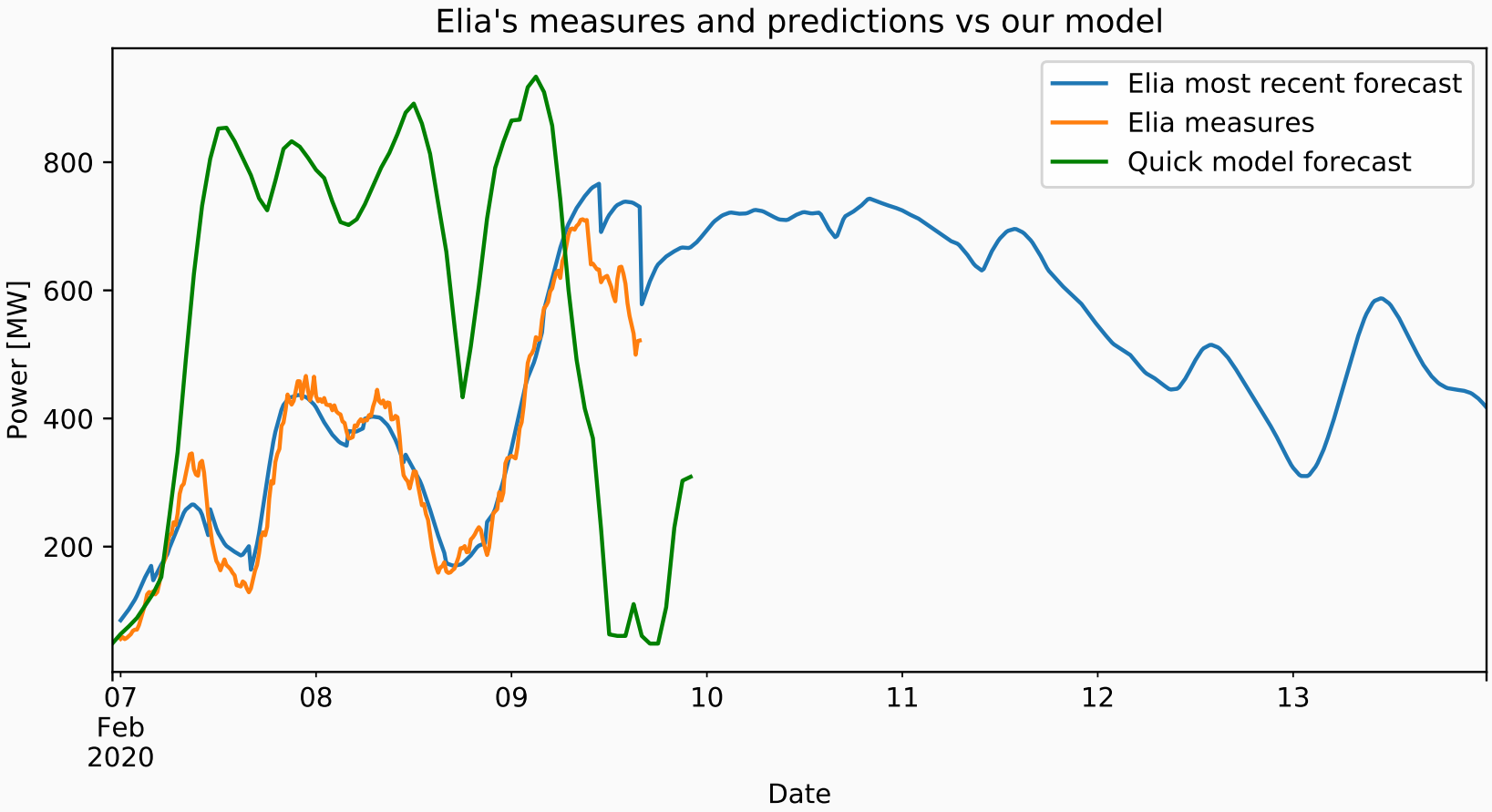
Results

Running a quick model using only the wind speed at Liege yielded the following results for the last three days:



Results

Running a quick model using the wind speed at each power plant yielded the following results for the last three days:



Next objectives

- Getting a more recent list of wind turbines
- Getting a power curve for each existing type of wind turbine in Wallonia
- Using the hub height to get a more precise wind speed at rotor height
- Understanding the gap between Elia's prediction and ours
- Getting hourly power production data from some wind turbines to identify where the differences come from.

References

- *Part 3: Calculating Solar Angles*. URL: https://www.itacanet.org/the-sun-as-a-source-of-energy/part-3-calculating-solar-angles/.
- *Situation Eolien Wallonie 2018*. URL: https://energie.wallonie.be/fr/le-vent-pour-produire-de-l-electricite.html?IDC=6170&IDD=11276.
- *Données de production éolienne*. URL: http://www.apere.org/fr/observatoire-eolien/.

 Silvio Matysik and Lucas Bauer. *Wind turbine models*.
URL: https://en.wind-turbine-models.com/.