

Mapping the Invisible: A Remote Sensing Audit of Rooftop PV Data in France



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Background and Motivation

Transmission system operators (TSOs) must **balance real-time electricity production and consumption**.

Rooftop PV has created an invisible [1] capacity escaping direct observation by the transmission system operator.

Rooftop PV increases net load estimation uncertainties mainly through **uncertainties regarding the reported installed capacity** [2].

In France, invisible PV amounts to **5 GWc of capacity** and **has grown by 24% between 2024 and 2025**.

Related Works

Remote sensing of (rooftop) PV systems emerged as a viable solution to quickly map systems at scale from overhead imagery [3].

These registries can help fill the gap in existing registries [4]

Methods

1. PV mapping algorithm (DeepPVMapper)

Based on earlier works [5], **reports the precise location** and the **technical characteristics of the PV systems**.

Applied to France, enabled to **detect 500,000 systems**.

2. Case study: underreporting in French PV data

More than 100 DSOs in France, practices may differ from one to another. We **assess whether there are inconsistencies in French PV data**.

We evaluate whether DeepPVMapper enables to detect cases of possible underreporting.

We then **quantify underreporting at the scale of France**.



WEBSITE



INTERACTIVE MAP

Data

Training data : BDAPPV [5], a crowdsourced dataset with more than 8,000 identified systems.

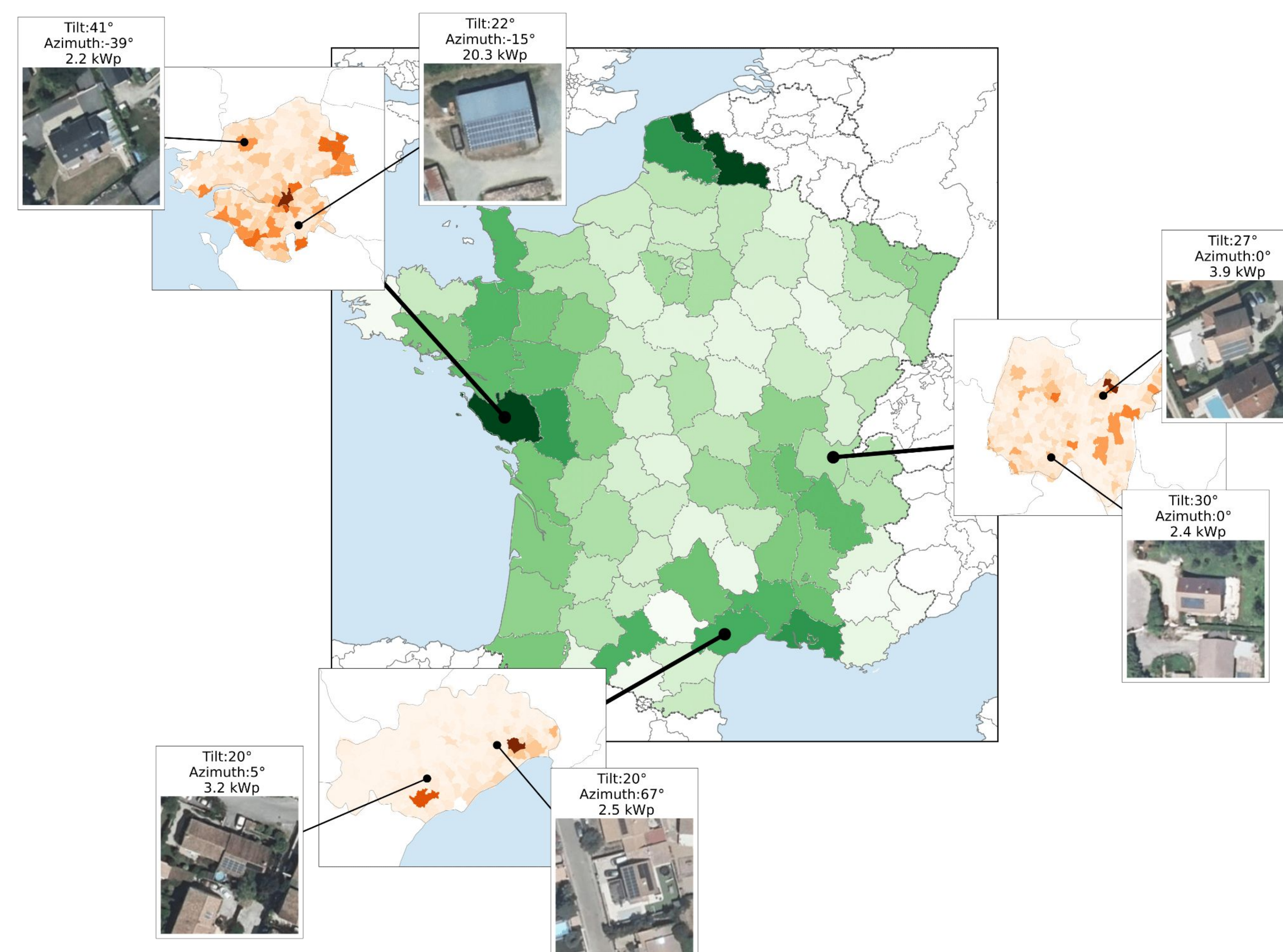
Aerial imagery : IGN BDORTHO (20 cm/pixel)

Ground truth data: manual annotation of IGN images for sampled cities.

Official registries

- Registre national d'installations : the official source, consolidated by RTE
 - RTE's internal data the internal data of the TSO that serves as ground truth data regarding connected systems.
- The dates are matched with the image dates.*

PV Mapping results



Nearly **500,000 systems** mapped (image dates : 2017-2023)

Pointwise location and characterization of the systems: **tilt, azimuth angle, installed capacity**.

Overall systems' **distribution follows the observed patterns** in official registries.

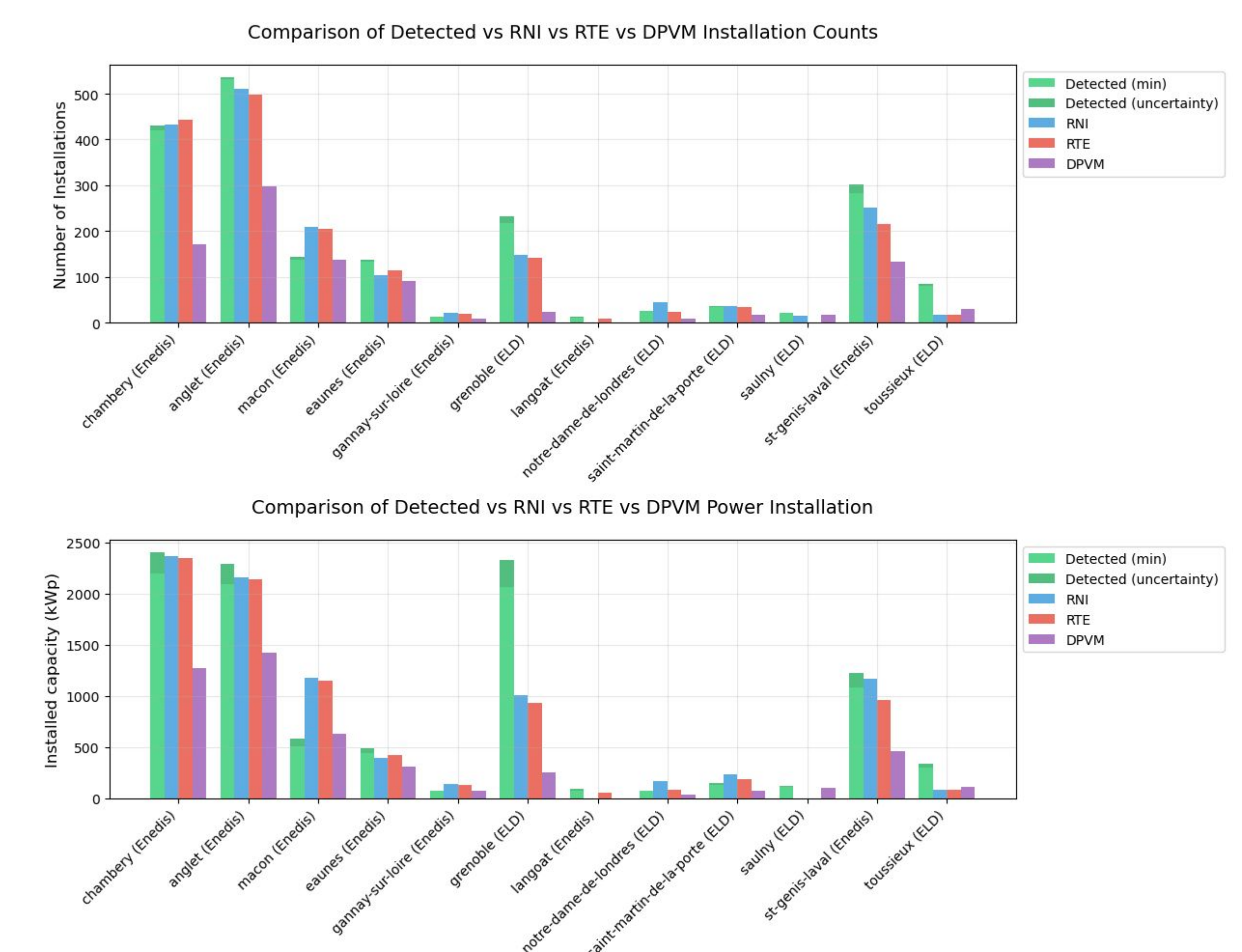
- [1] Shaker, H., Zareipour, H., & Wood, D. (2015). A data-driven approach for estimating the power generation of invisible solar sites. *IEEE Transactions on Smart Grid*, 7(5), 2466-2476.
- [2] Kasmi, G., Touron, A., DUBUS, L., Saint-Drenan, Y. M., & Blanc, P. Balancing Robustness and Accuracy in Rooftop Pv Estimation: Benchmarking the French Tso's Approach and Physics-Based Models. *Available at SSRN 5385856*.
- [3] Yu, J., Wang, Z., Majumdar, A., & Rajagopal, R. (2018). DeepSolar: A machine learning framework to efficiently construct a solar deployment database in the United States. *Joule*, 2(12), 2605-2617.
- [4] Kausika, B. B., Nijmeijer, D., Reimerink, I., Brouwer, P., & Liem, V. (2021). GeoAI for detection of solar photovoltaic installations in the Netherlands. *Energy and AI*, 6, 100111.
- [5] Kasmi, G., Saint-Drenan, Y. M., Trebosc, D., Jolivet, R., Leloux, J., Sarr, B., & Dubus, L. (2023). A crowdsourced dataset of aerial images with annotated solar photovoltaic arrays and installation metadata. *Scientific Data*, 10(1), 59.

Registry Audit Results

Gathering ground truth data to **assess the accuracy of the official registries** (both public (RNI) and internal to the TSO (RTE))

PV registries (both public and RTE) show relatively **good correlation with ground truth data** ($r \sim 0.97/0.98$) but **strong geographical variability**.

DeepPVMapper data enables to **identify false negatives in official registries**.



Perspectives and future works

Outlook from on the current ground truth dataset (12 cities, 233 km2, 331 000 inhabitants):

- There might be *few* missing kWp (~hundreds at most)
- Effect of the DSO should be further investigated

Future work : continue the survey to estimated the missing installed capacity in France and **estimate how much missing kWp DeepPVMapper enables to retrieve**.