Facade Segmentation for Solar Photovoltaic Suitability

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Motivation and Objectives

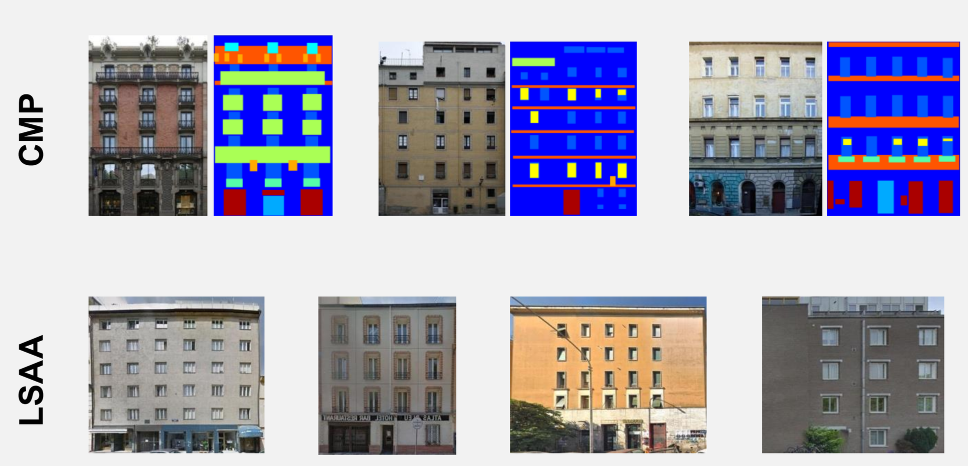
Buildings contribute almost 40% of global CO_2 emissions. Building-integrated photovoltaics (BIPV) on facades are underused, especially where roof space is limited. Existing tools for PV potential oversimplify facades and their architectural details. Therefore, this study develops an automated pipeline to

- Segment facade elements from street-level imagery.
- Create PV-suitability masks excluding semantically and geometrically unsuitable surfaces.
- Generate practical PV panel layouts and estimate energy yield.

Datasets

CMP Facades[1]: 606 annotated images with 13 classes of architectural elements (training, validation, test).

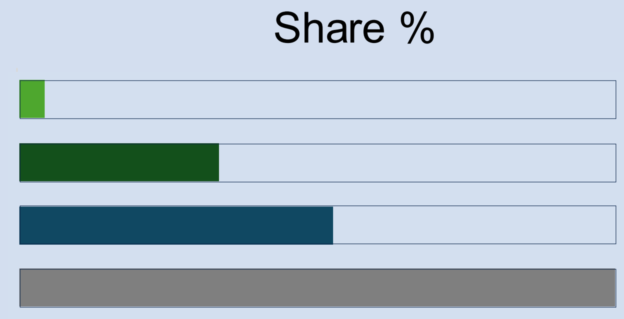
LSAA[2]: 373 rectified images of facades with known facade area and orientation from 10 cities (application).



Data samples from CMP and LSAA dataset

Key Findings

- An automated workflow integrating semantic segmentation into practical PV layout design.
- Facade articulation and obstructions can reduce deployable PV potential significantly.
- Relying solely on theoretical availability can overestimate installable capacity, particularly for highly articulated facades, as observed in the application dataset representing the old building stock in different cities.



Shares of wall, theoretical and practical surfaces for PV application in the LSAA subset

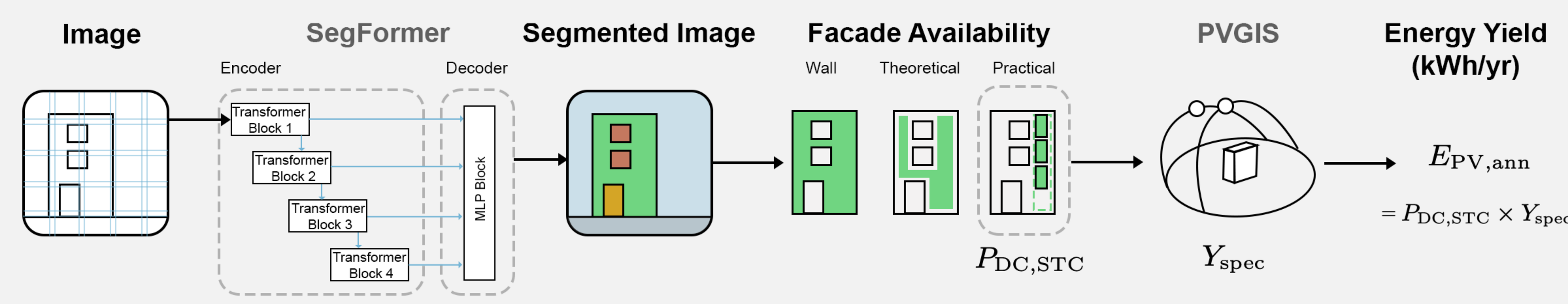
- Scalable to city-wide screening using ortho rectified street-level imagery.

Method

We propose a 4-step methodology:

1. **Segmentation:** fine-tune SegFormer-B5 (ADE20k)[3] on the CMP Facades dataset.
2. **PV mask generation:** select wall class and apply buffers and thresholds.
3. **PV layout:** fit PV modules* using maximal rectangle search. **large* = 935 × 1300 mm, *small* = 720 × 875 mm
4. **Energy yield estimation:** PVGIS[4], annual specific yield based on location and orientation.

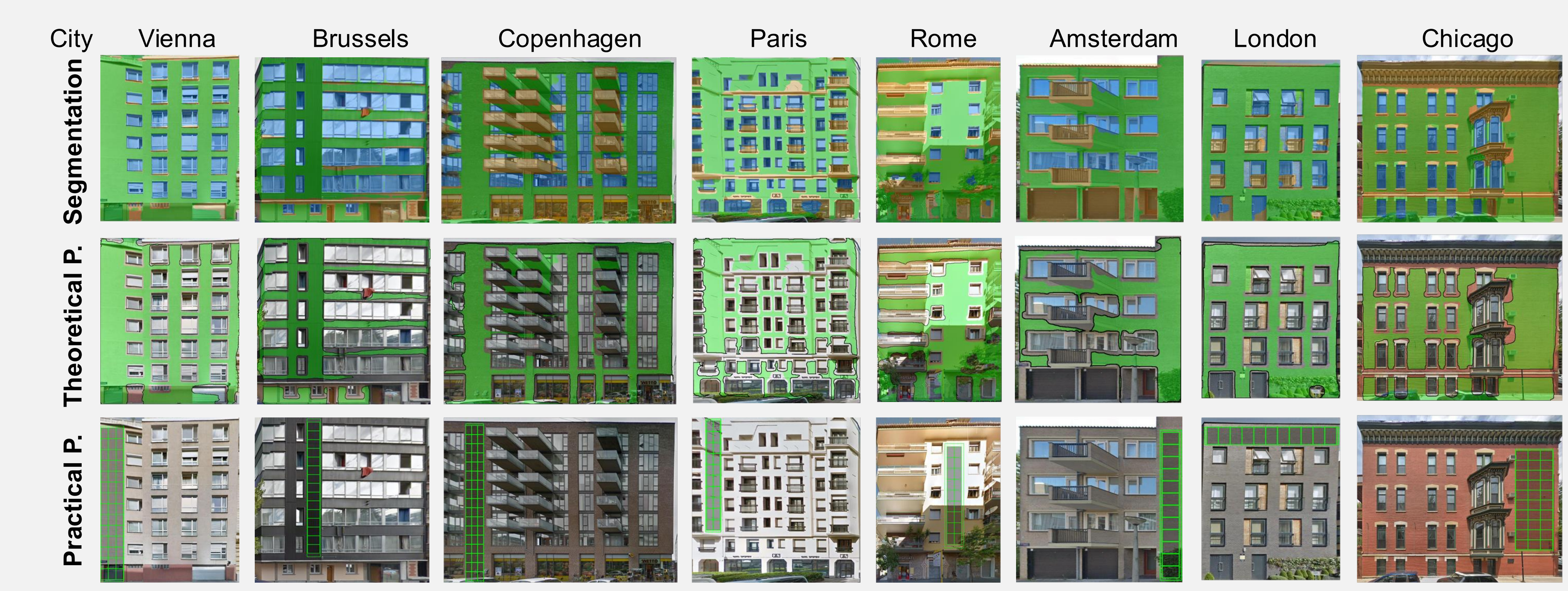
GitHub



Method diagram. Y_{Spec} refers to the site and orientation specific yield as acquired from PVGIS, $P_{\mathrm{SDC\ STC}}$ is the installed peak DC capacity and $E_{\mathrm{PV\ ann}}$ is annual energy yield.

Results

PV fraction (f_{PV}) and PV-suitable area (A_{PV}) per facade is estimated for LSAA dataset. The results show an average PV-suitable fraction of about 39% of the facade area (A_{Facade}) after applying clearance buffers and component cleaning. After performing the maximal rectangle search, the total number of panels (N_{Panels}) that fit on the facade surface is reduced to about 5% of A_{Facade}. N_{Panels}, as well as facade location, dimensions, and orientation are used to calculate the annual PV energy output ($E_{PV\ ann}$). Figure below illustrates the results of each step in the proposed workflow for eight example facades from different cities.



	Vienna	Brussels	Copenhagen	Paris	Rome	Amsterdam	London	Chicago
γ	–38°	146°	–80°	–25°	–66°	–91°	13°	–1°
$P_{\mathrm{DC,STC}}$	9.45 kWp	3.52 kWp	11.48 kWp	4.5 kWp	4.05 kWp	2.7 kWp	2.48 kWp	6.75 kWp
$E_{\mathrm{PV,ann}}$	**8,182.66** kWh	**1014.66** kWh	**7122.42** kWh	**3945.15** kWh	**3740.82** kWh	**1509.49** kWh	**2300.41** kWh	**7235.39** kWh

Example applications (with panel size *large*) from the LSAA subset (N = 373).

Fine-tuned SegFormer-B5 offers a dataset-level mIoU of 0.52, with macro precision, recall, and F1 scores of 0.68, 0.68, and 0.68, respectively.

Method	Bg	Fac	Win	Door	Corn	Sill	Balc	Blind	Mold	Deco	Pill	Shop
Ours	0.74	0.62	0.69	0.46	0.51	0.48	0.50	0.56	0.37	0.52	0.33	0.43

Per-class IoU on CMP Facades dataset

Future Work

- Improve segmentation for occluded and complex facades.
- Generate alternative layout options with multi-region packing.
- Integrate more detailed solar irradiation and shading analysis.

References

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