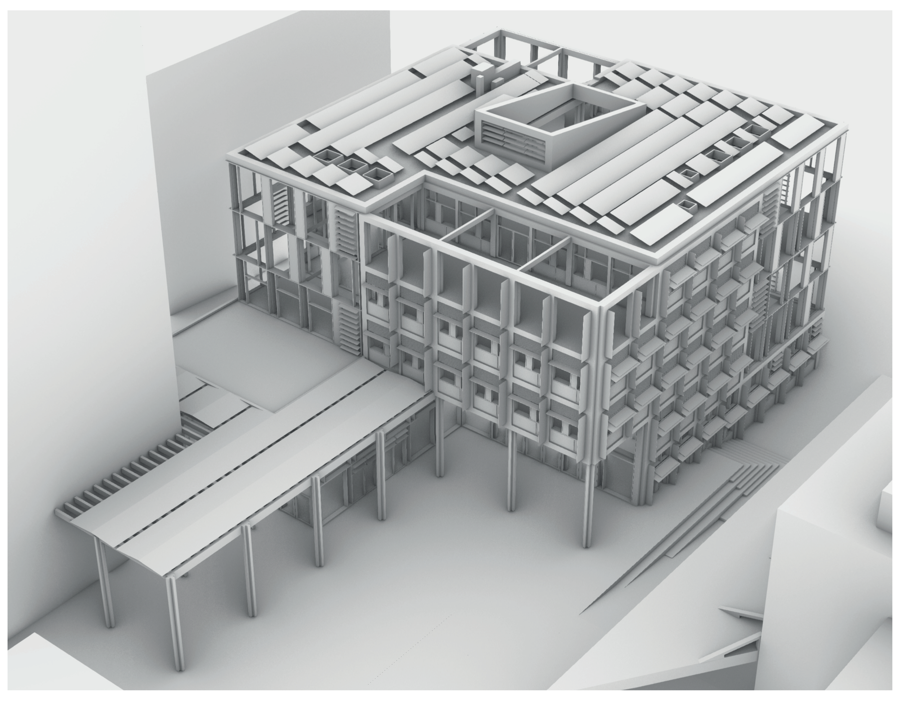
Building-Integrated Photovoltaics in time & space

Building photovoltaics "in time" presents a multi-criteria performance-based method for sizing a BIPV installation considering different time horizons from 2030 to 2100. Each scenario is based on weather files, representing historical data (TMY; typical meteorological year) and prospective data (three alternative future climate change scenarios (RCP2.6, 4.5 and 8.5)). Through a solar and energy simulation process using the Smart Living Lab building as case-study, electricity consumption and production values are computed along with various performance parameters such as self-sufficiency and carbon content of the electricity produced for each simulated weather scenario. Results show that characteristics (i.e., size, etc.) of the BIPV installation that represent the best trade-off solution are slightly different according to the weather file considered. Given the warming climate, the global performance of a given BIPV installation can be expected to increase over time.

The scientific methodology involves four main phases: 1) Developing solar and energy models, 2) Generating artificial weather files for TMY and CC scenarios, 3) Conducting an iterative simulation process based on the self-sufficiency (SS) and self-consumption (SC) rates achieved and 4) Analysing and comparing the results to identify the most optimal installation.

By optimizing the embodied energy used for the manufacturing of the components and considering the future climate, the building industry can work towards achieving carbon neutrality by 2050. The results of this study can assist architects in conducting project-specific analyses and contribute to the development of new simulation methods for building design.



Smart Living Lab Building, Project (SIA 3.32), Fribourg, CH
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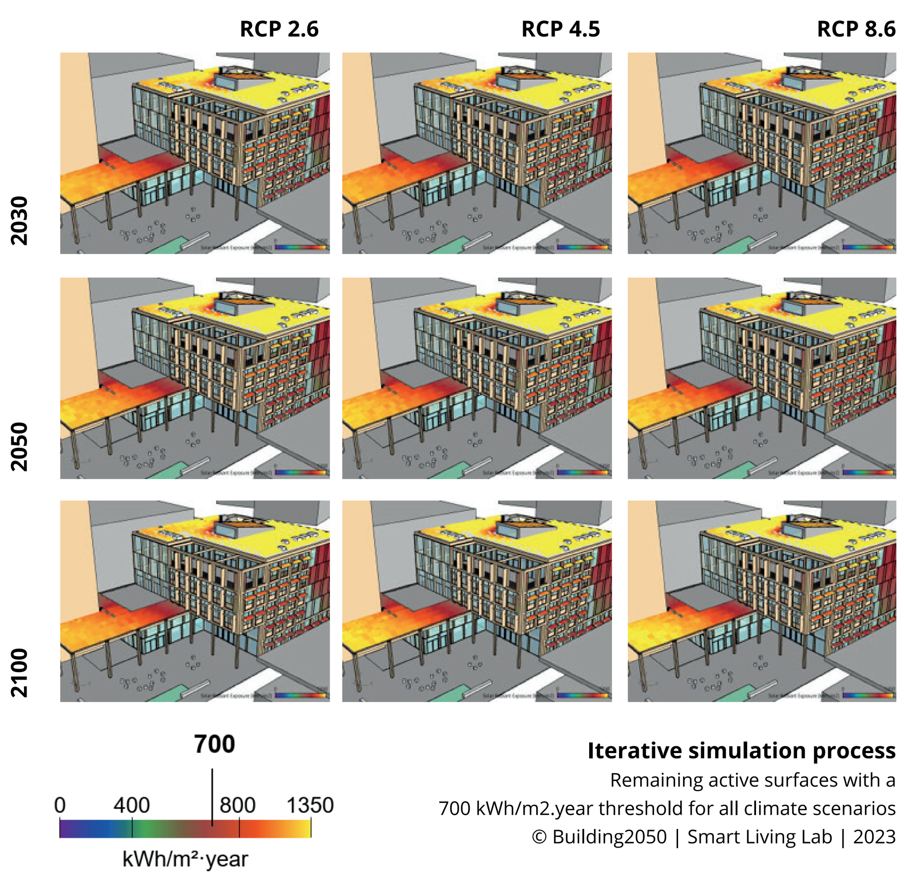

Iterative simulation process
Remaining active surfaces with a 700 kWh/m2.year threshold for all climate scenarios
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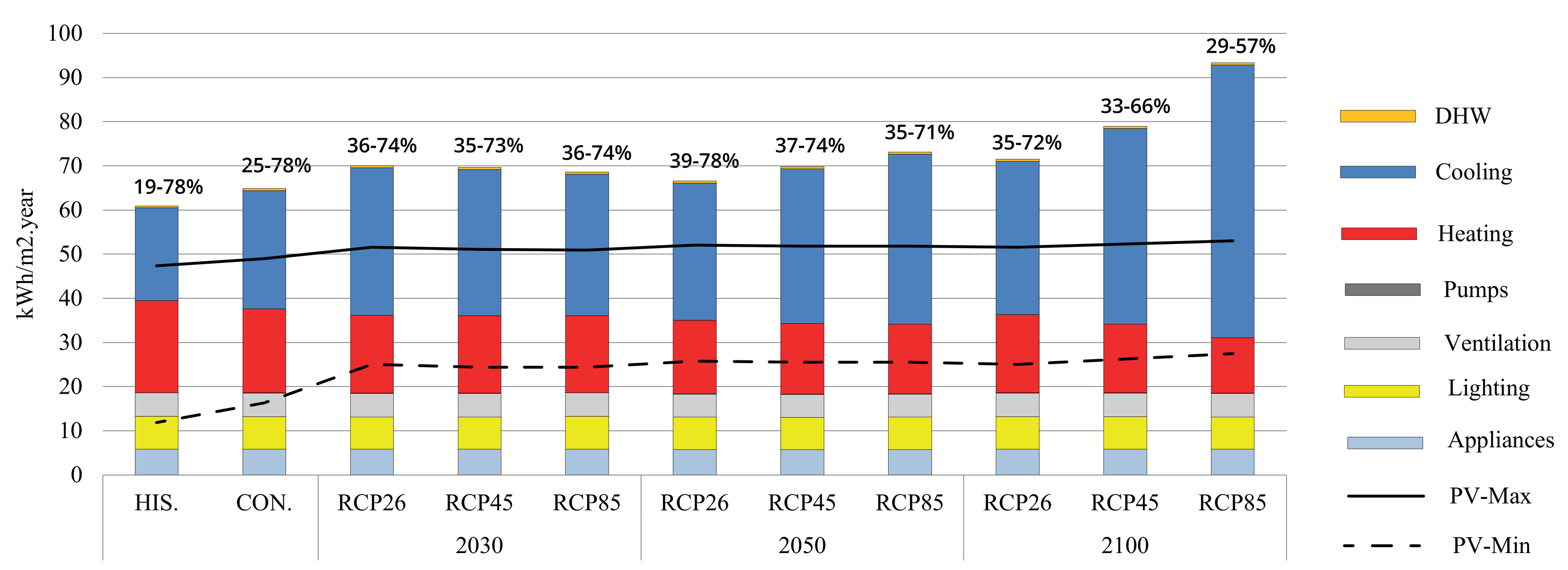

Annual comparison of electricity demand, production and coverage ratio for all scenarios
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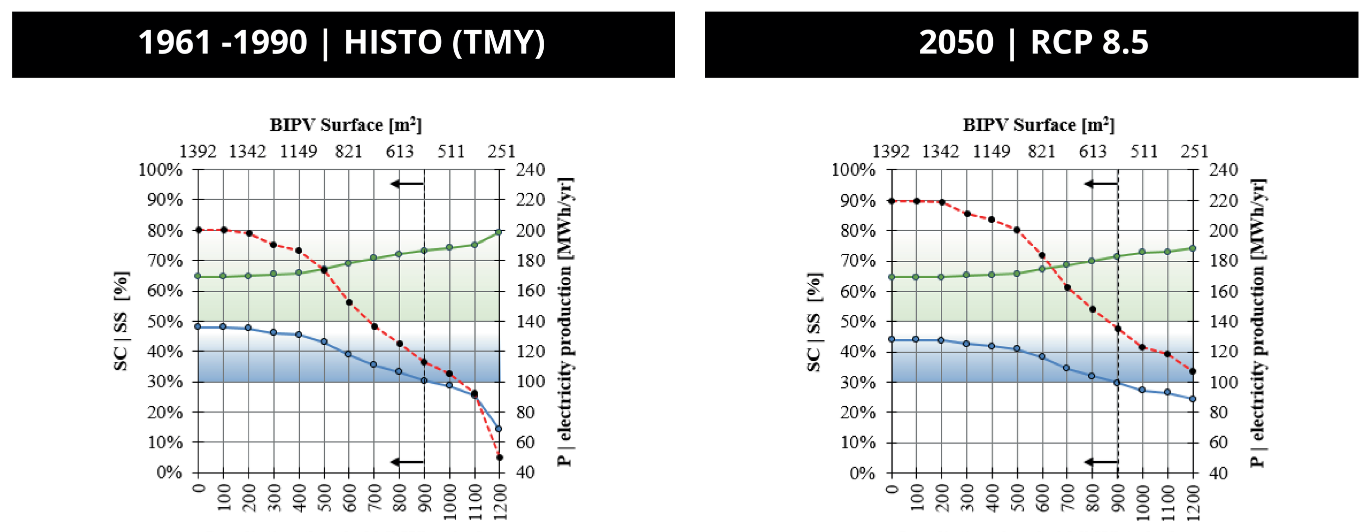
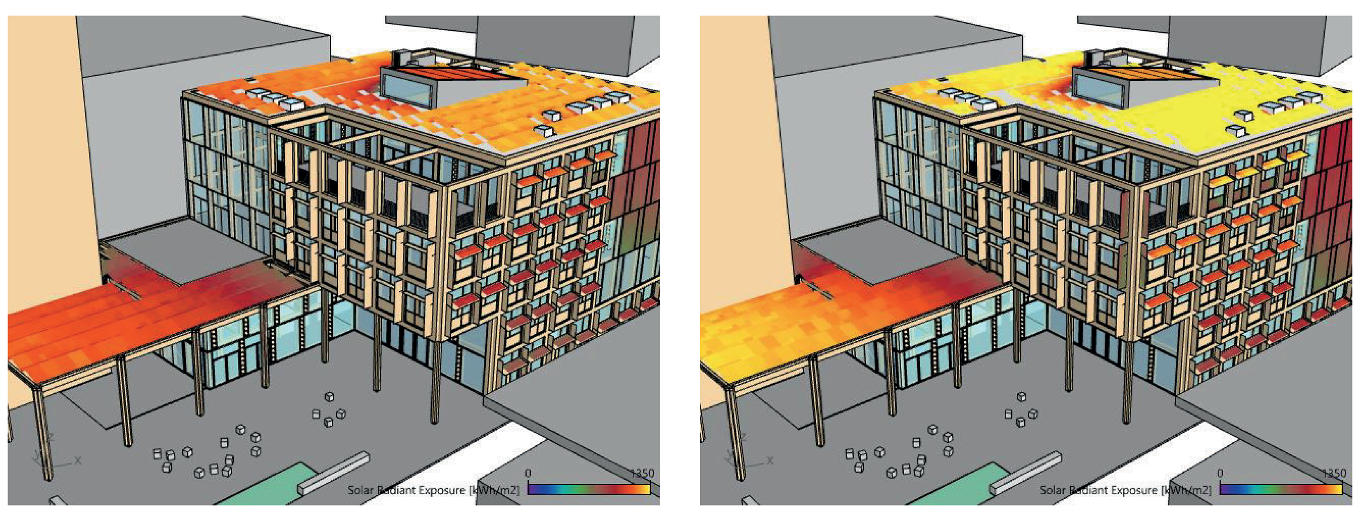


Optimization analysis

Annual production / Resulting. Irr.Thr. limit / Self-consumption (SC) / SC requirement (≥30%) / Self-sufficiency (SS) / SS requirement (≥50%)



Cumulative annual irradiation
filtering at 700 kWh/m²·year threshold
South-West façades
© Building2050 | Smart Living Lab | 2023

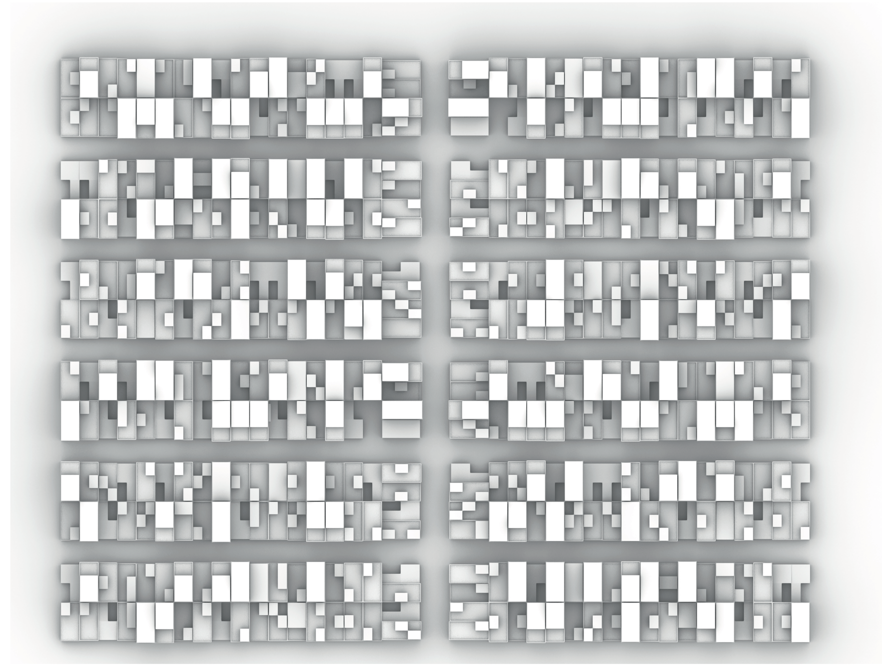
0 400 800 1350
kWh/m²·year

Discover the building! ▶ Web page of the Smart Living Lab Building

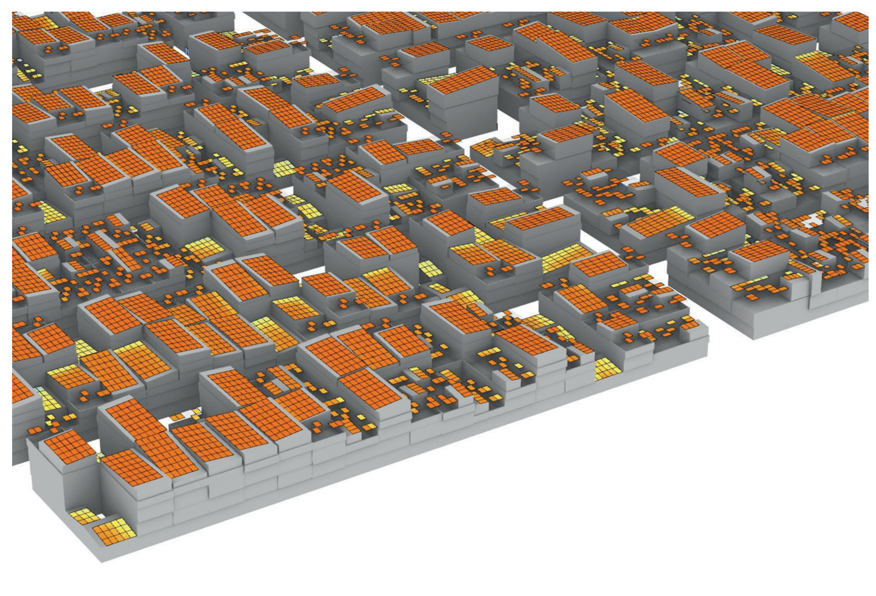
◀ Explore the data! DesignExplorer interactive parallel coordinate plot for all simulations

Building photovoltaics "in space" introduces a process to estimate the PV solar harvesting potential of rapid changing metropolitan areas like the pirate-origin neighbourhoods in Bogota. Incremental auto-construction is a common process in many metropoles in Latin America, Africa, and Asia, where low-income families achieve housing through self-managed construction. This process not only provides urban housing ownership but also an essential source of income generation for most households. As a result, multiple individual initiatives produce buildings that form extensive housing areas with increasing demands for supplies, particularly electric power. In spite of a growing need, the increasing energetic crisis, the favourable latitudes for annual solar irradiation, or the existence of legislation seeking to foster renewable energies, photovoltaic technologies are not yet applied in these areas.

Our project aims to define an open-source digital tool allowing stakeholders to evaluate urban-integrated photovoltaics (UIPV), including smart grid management at a neighbourhood scale based on a digital model capable to integrate the actual shapes of buildings. As a case study, we model auto-constructed housing in pirate urbanizations in Bogotá (Colombia), along 3 modules: (1) Generation of urban form; (2) Distribution of PV panels; (3) Simulation of solar irradiation at the Building and the neighbourhood scale. The tool may provide in the future the necessary elements to individuals and communities to take informed decisions in regard to the application (or integration) of PV technologies to their assets.



Barrio San Pedro, Bogota
Random generation of a mixed-stage buildings based on existing urban grid
Building2050 | Smart Living Lab | 2021



Cumulative annual irradiation on Neighbourhood level, sample 4
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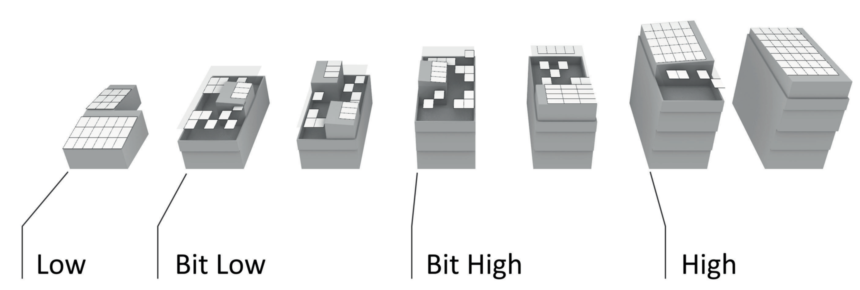

Samples of building's four incremental stages,
showing "pergola" and "roof" panel types
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Street view of Barrio San Pedro, Bogota.
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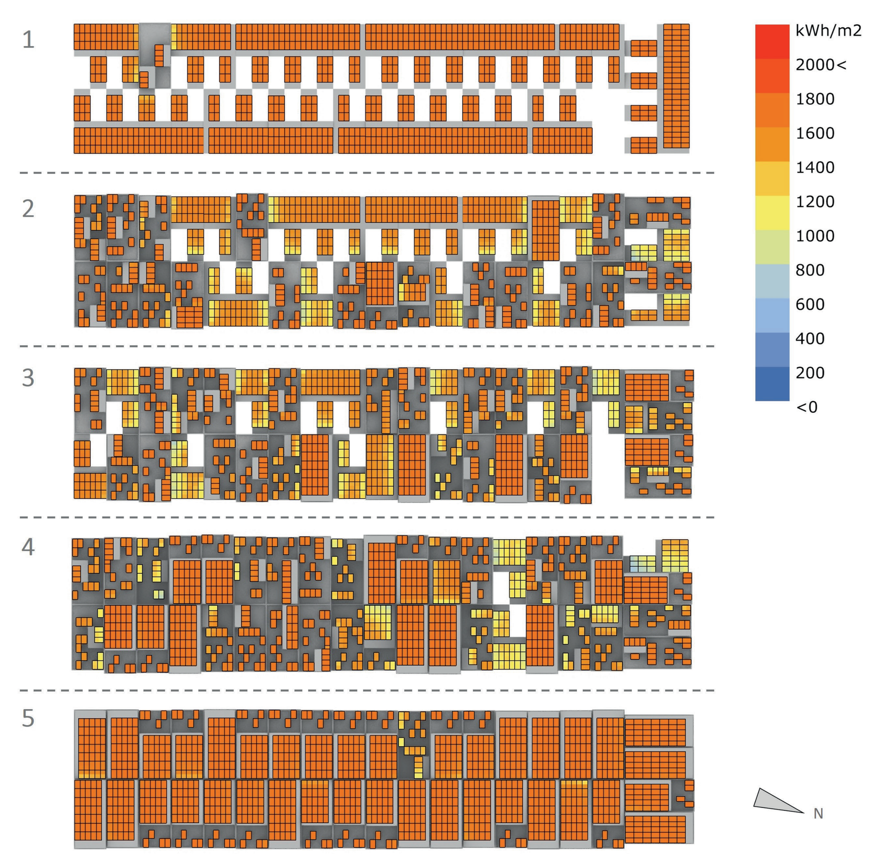

Samples of Cumulative annual irradiation on NEIGHBOURHOOD LEVEL
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Scenario	Ratio Panel/Plot	Total P* (MWh/Year)	P/m2** (kWh/Y)
1. 100_1_1_1	0.55	3870	224.2
2. 75_60_40_25	0.57	4019	226.4
3. 50_50_50_50	0.61	4307	226.5
4. 25_40_60_75	0.60	4209	226.4
5. 1_1_1_100	0.87	6143	226.7

PV-production (MWh/Year) for NEIGHBOURHOOD LEVEL
(representative samples)
Scenarios named according to the weight values (1 to 100) for Low_BitLow_BitHigh_High
*P: Production / **Production per m² of Panel
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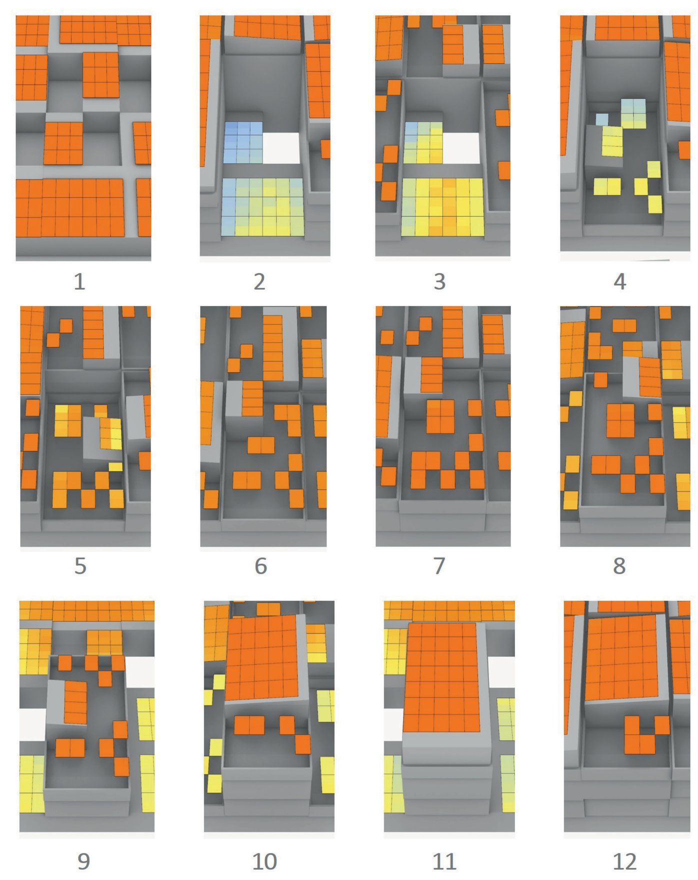

Samples of cumulative annual irradiation on BUILDING LEVEL
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Scenario†	Ratio Panel/Plot	Total P* (MWh/Y)	P/m2** (kWh/Y)
1 BLow/CLow	0.60	9.76	225.9
2 BLow/CHigh	0.60	9.75	225.7
3 BLow/CBitHigh	0.60	9.75	225.7
4 BBitLow/CHigh	0.29	4.72	226.9
5 BBitLow/CBitHigh	0.33	5.45	227.1
6 BBitLow/CBitLow	0.31	5.08	226.8
7 BBitHigh/CBitHigh	0.36	5.81	227.0
8 BBitHigh/CBitLow	0.36	5.82	227.3
9 BBitHigh/CLow	0.29	4.73	227.4
10 BHigh/CBitLow	0.64	10.48	225.9
11 BHigh/C Low	0.78	12.70	226.8
12 BHigh/CHigh	0.64	10.48	225.9

PV-production (MWh/Year) for BUILDING LEVEL
(representative samples)
†B: Building analysed; C: adjacent buildings (Cluster) *P: Production / ** Production per m² of Panel
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