QUYOSH ROOFSCAPE

MASTER PROJECT HS21
ETH ZURICH

ABU BAKR SHOSHIJ MAHALLA
TASHKENT - UZBEKISTAN

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In the year 2064, the today's energy self-sufficient country of Uzbekistan will run out of its proven gas reserves. Current primary energy source for heating and electricity generation is natural gas, while the changing lifestyles and increasing population are increasing the demand projections. In the city of Tashkent more than 80% of the energy is consumed by the residential sector, and an update to this node may contribute to the energy transformation.

The climate of Tashkent is hot and arid with continental characteristics. The wind speed is mainly below 4 m/s, under the viable speed for electricity generation through wind turbines. In winter there are heating days which contribute to the natural gas demand along with the electricity need. In summer conventional HVAC installations which are spread around the town increase the overall electricity demand.

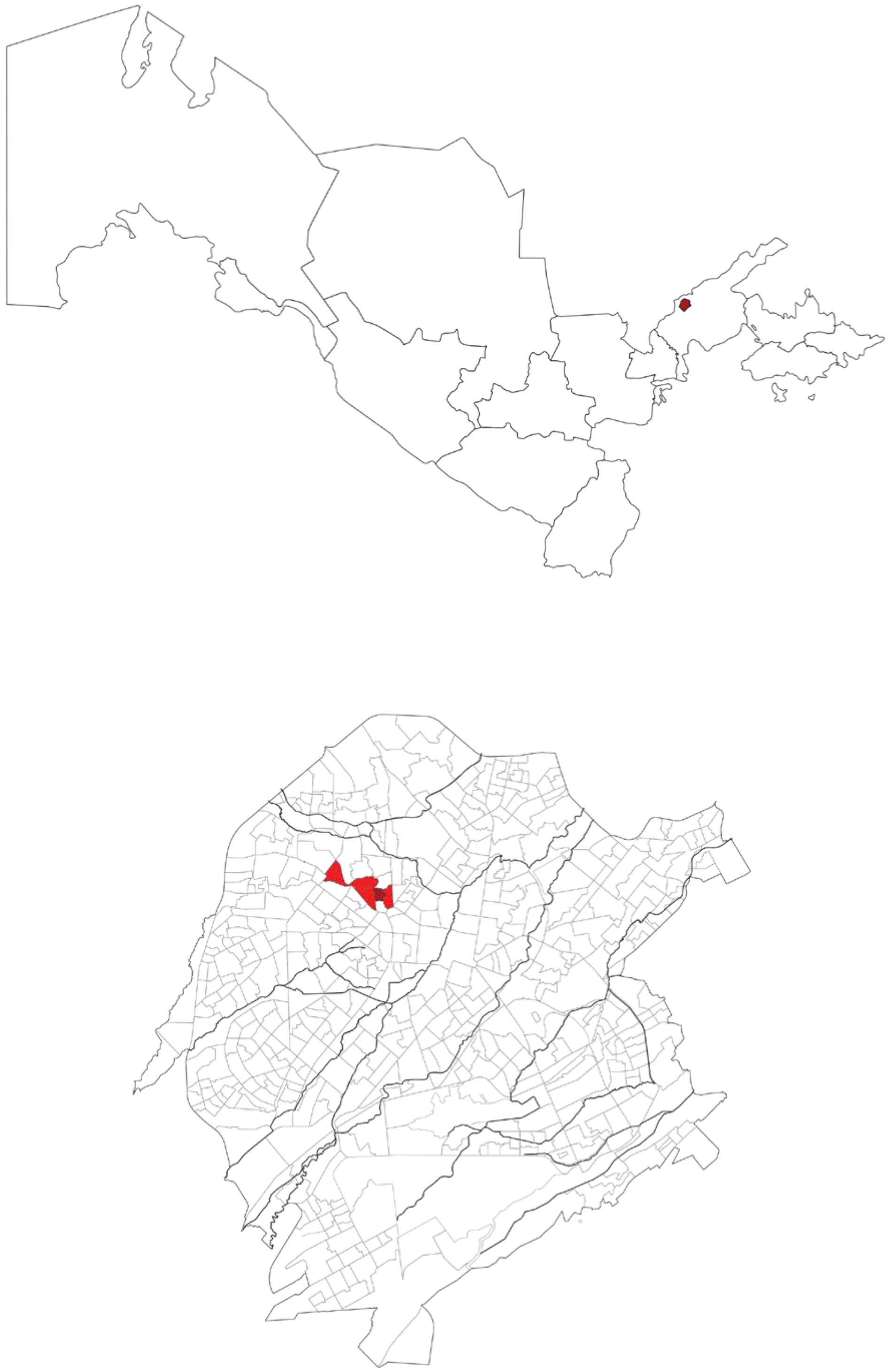
The mahallas are constituted of low rise high density courtyard houses with vascular circulation networks. This porous disposition provide an extensive roofscape across the mahalla, that is suitable for local harvesting of the solar energy. Regarding the design of their evolution, the existing residential mahallas with their seemingly ever-expandable cellular morphology allow for a principle approach in various scales.

In the largest scale, encompassing the mahalla territory, the project proposes a formally single roof that is constituted of roofscapes of individual houses. The aim is to reach the calculated coverage threshold for the energy self-sustainment. The approach is to promote decentralized means of energy production, which is solar energy generation in connection with the grid. In parallel to the findings in the research phase, a standardized module will be used to parametrically demonstrate the implementation.

In the medium scale, close to the perimeter of the house envelope, the proposed superstructure will take its place in terms of a conversion project. The dimensioning will engage in an interplay with the existing structure, depending on the orientation of the main structure. In the mahallas, the majority of the houses have ventillated roofs, therefore a replacement of the existing bulk roofscape with a tectonic superstructure is possible without depreciating the thermal and structural properties of the structures.

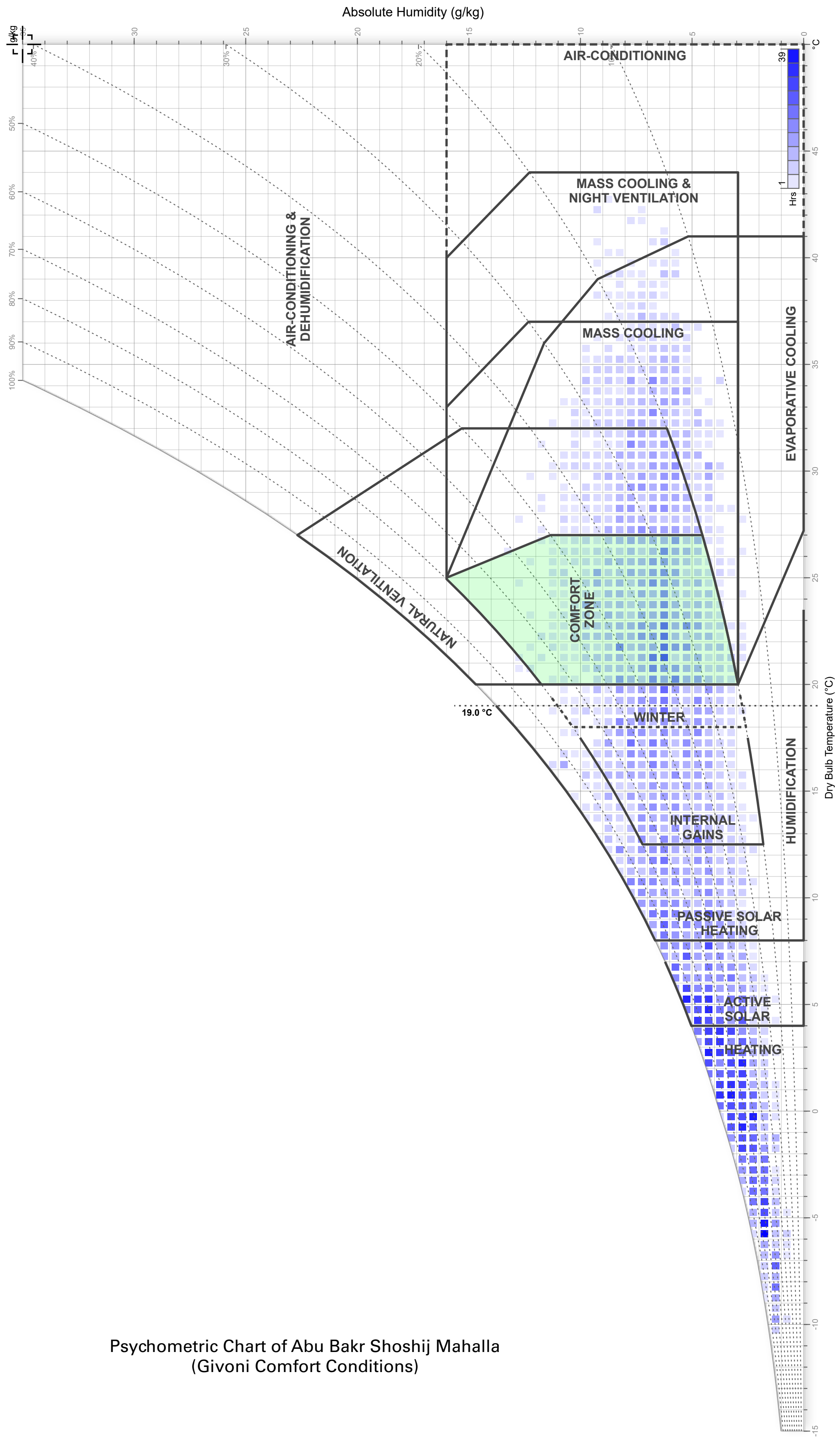
The traditional structures in the mahalla are timber frame with mud infill ("synch"). This is a type of double frame timber construction, where the gap between the layers are filled with dried mud and smeared with wet mud. The facades may be further covered with plaster. The studs of the frames are not standardized, and placed according to the expertise of the constructors. Connections between the studs and beams are mortise and tenon, and there are cross bracings between the studs in the proximity of the corners.

In the smallest scale, the proposed roof super-structure is solved from top to bottom. Starting from the theoretical canopy that houses the modules, the supporting truss network follows the module dimensions. The joists on which the truss network resides distribute the load evenly on to the load bearing walls through the intermediary beam. The differentiated corner heights of the individual modules, which give the shape of the curved canopy in the bigger picture, are captured in the dimensioning of the truss elements.



Top: Location of Tashkent City in Uzbekistan
Bottom: Location of the Mahallas within Tashkent City

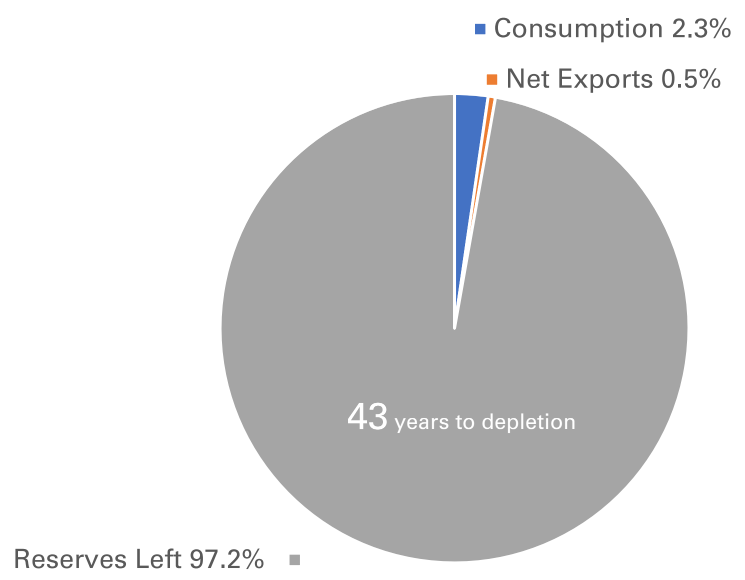
Studio Christ & Gantenbein



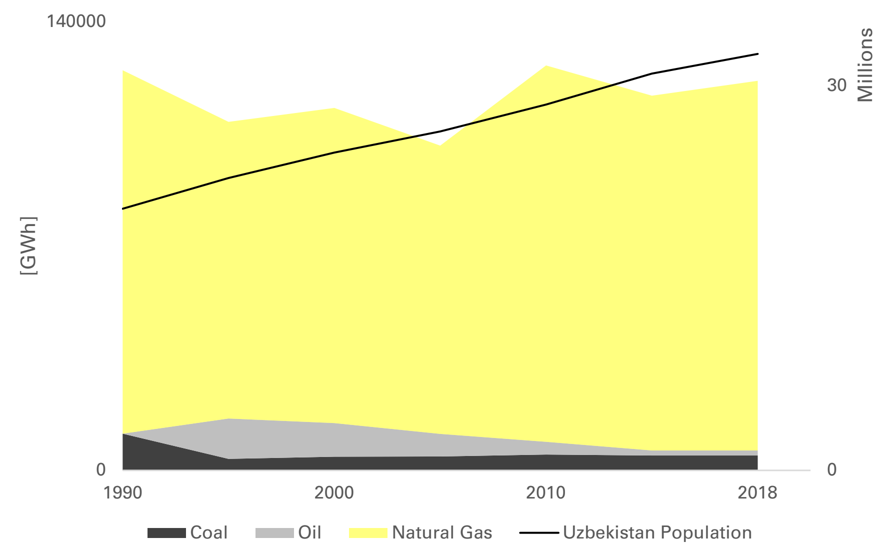
Psychometric Chart of Abu Bakr Shoshij Mahalla
(Givoni Comfort Conditions)

Studio Christ & Gantenbein
drajmarsh.bitbucket.io

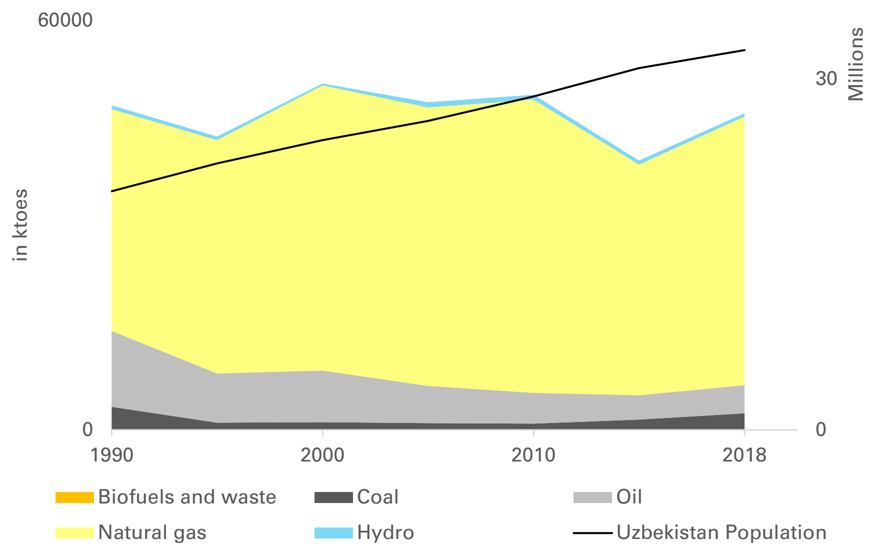
CLIMATIC SITUATION



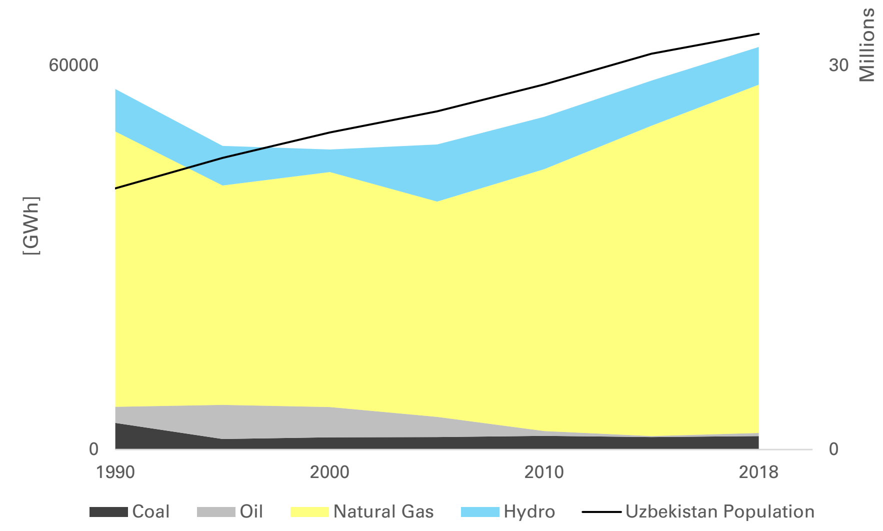
Uzbekistan Proven Reserves and Extraction Rate



Heat Generation by Source in Uzbekistan



Total Energy Consumption by Source in Uzbekistan



Elecricity Generation by Source in Uzbekistan

U.S. Energy Information Administration
UN World Urbanization Prospects
International Energy Agency

DEPENDANCE ON NON-RENEWABLE ENERGY SOURCES

Latitude/Longitude: 41.336, 69.236
PV type: CIGS
Installed: 8kWp
System loss: 14%
Optimal slope angle: 33°
Optimal azimuth angle: -1°
Yearly production: 11658 kWh
Year-to-year variability: 301 kWh
Yearly in-plane radition: 1928 kWh/m²

Household consumption:	4500 kWh/year
Heating:	3000 kWh/year
Total:	7500 kWh/year

Electricity production on roof

Available area:	108 m² (south facing)
	560 m² (total)

Solar modules

Dimensions:	1700mm x 1050mm (1.6sqm)
Peak performance:	250Wp (15% solar & 60% thermal efficiency)

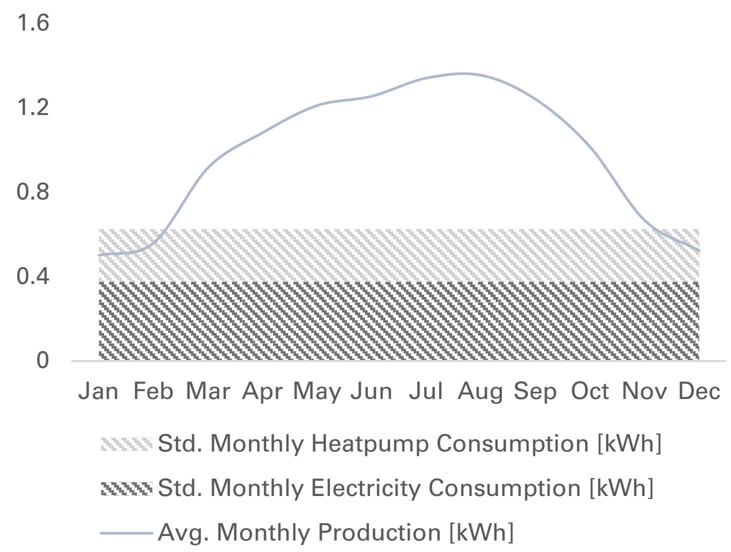
Solar field

Constellation:	32 modules each 250Wp
	8kWp total from 51.2 m²

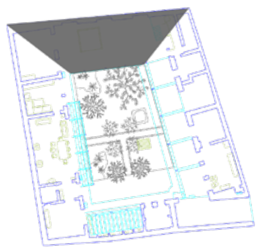
Production per kWp:	1030 kWh
Total generation:	11658 kWh/year
Handover to grid:	4158 kWh/year

System costs:	(est.) 16000 USD - 20000 USD
Amortisation:	20 years at 1000 USD/year
Unit Price:	0.13 USD/kWh
Current Price:	0.028 USD/kWh (March 2021)

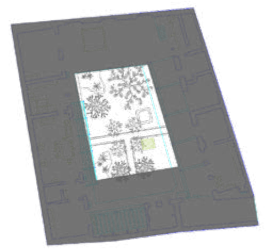
Area p.cap. required for covering the demand: 13 m²
Area p.cap. required for price neutralization through resell: 60 m²



108 sqm



560 sqm



ABU BAKR SHOSHIJ

Total Roof Area > 96’472 m²
Population: 5200
Demand: 9’750 MWh/year
Demand cover area: 67’600 m²

CALCULATIONS

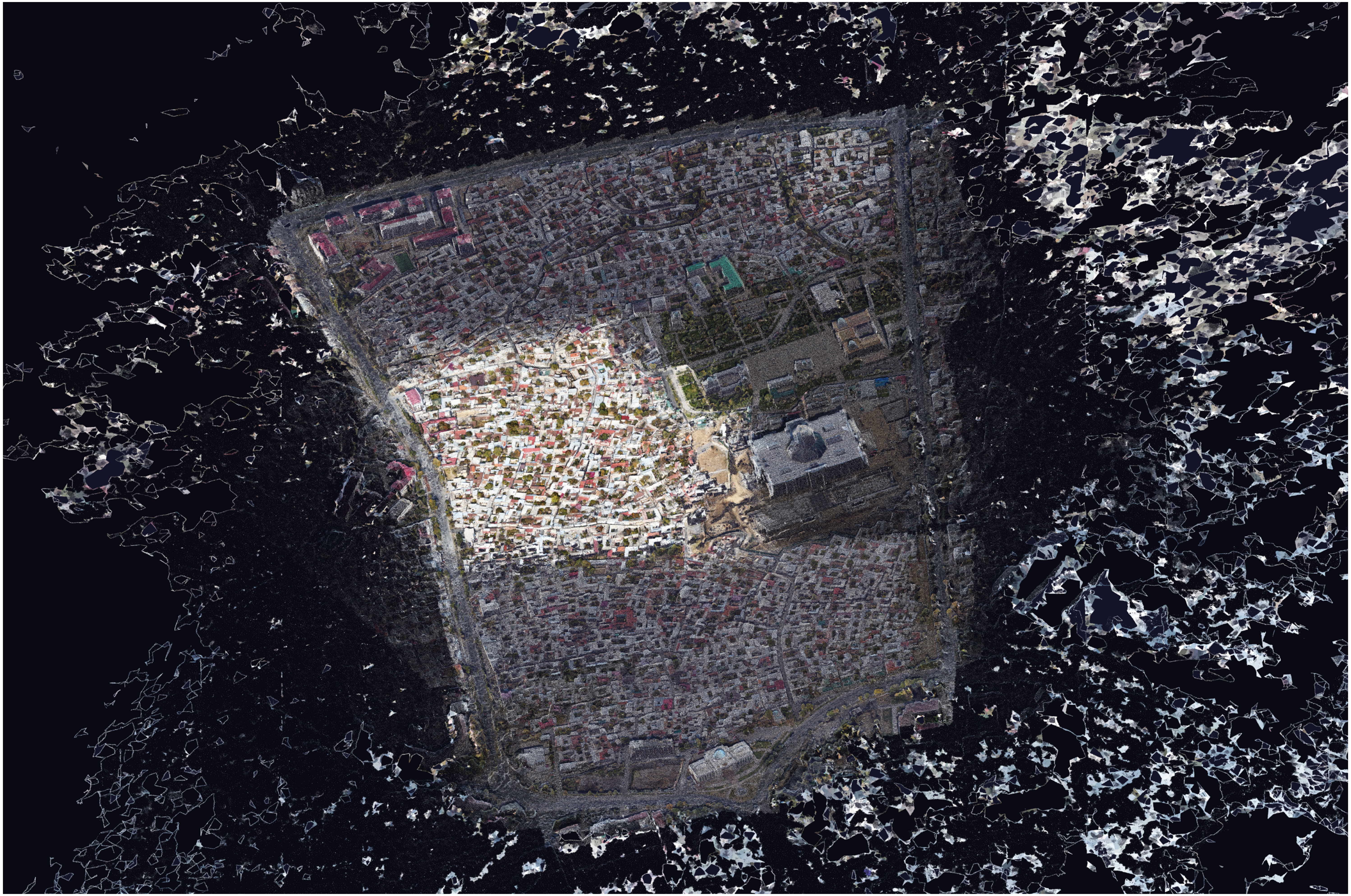
The courtyard houses in the mahallas accomodate various generations under one roof. The close constellation of these houses, with their similar typology, allow for the extension of this idea of one roof across the territory of mahalla.

The territory, however, was not modelled digitally prior to the time of this project. Only the 2D satellite imagery was to be found in the conventional geoservice providers, such as Google or Yandex. Initial supplement of the project was a cadaster map from previous years, which did not hold fidelity to the reality due to alterations, demolitions and undocumented extensions.

To compensate for this knowledge gap, a drone scanning was done during the site visit. Through the photogrammetric scan, a 3D model of the territory was constructed, which would then give the base condition for the proposed superstructure.

House near Tarusa, A. Brodsky

Yuri Palmin



PHOTOGRAMMETRIC ORTHOPHOTO

PHOTOGRAMMETRIC CLOSE-UP

0 100

ORTHOPHOTO AS-BUILT

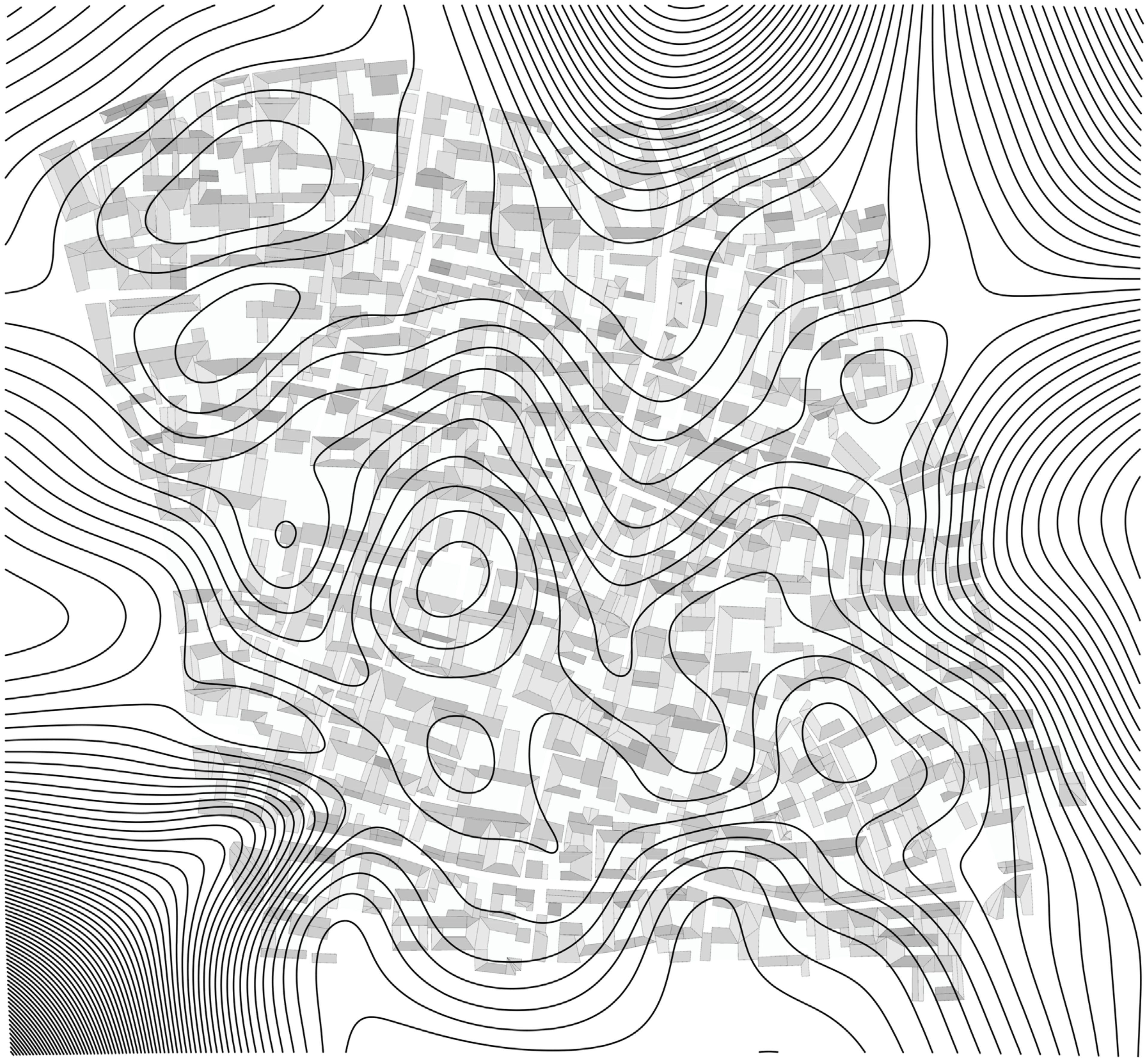
Designed canopy for the solar superstructure above the mahallas parametrizes the following:

-The existing ridge and eave heights
-The orientation along cardinal directions
-The road network
-The courtyards
-Shading imposed from the existing trees

0 100

SITUATION

An initial theoretical canopy is spanned through the nodes of the existing ridge and eave lines. The created surface is then subdivided into a fine raster. The newly created points of the raster were manipulated along the street network to levitate above the initial eave heights, which would give the new face of the mahalla with the exposed panels towards the street.



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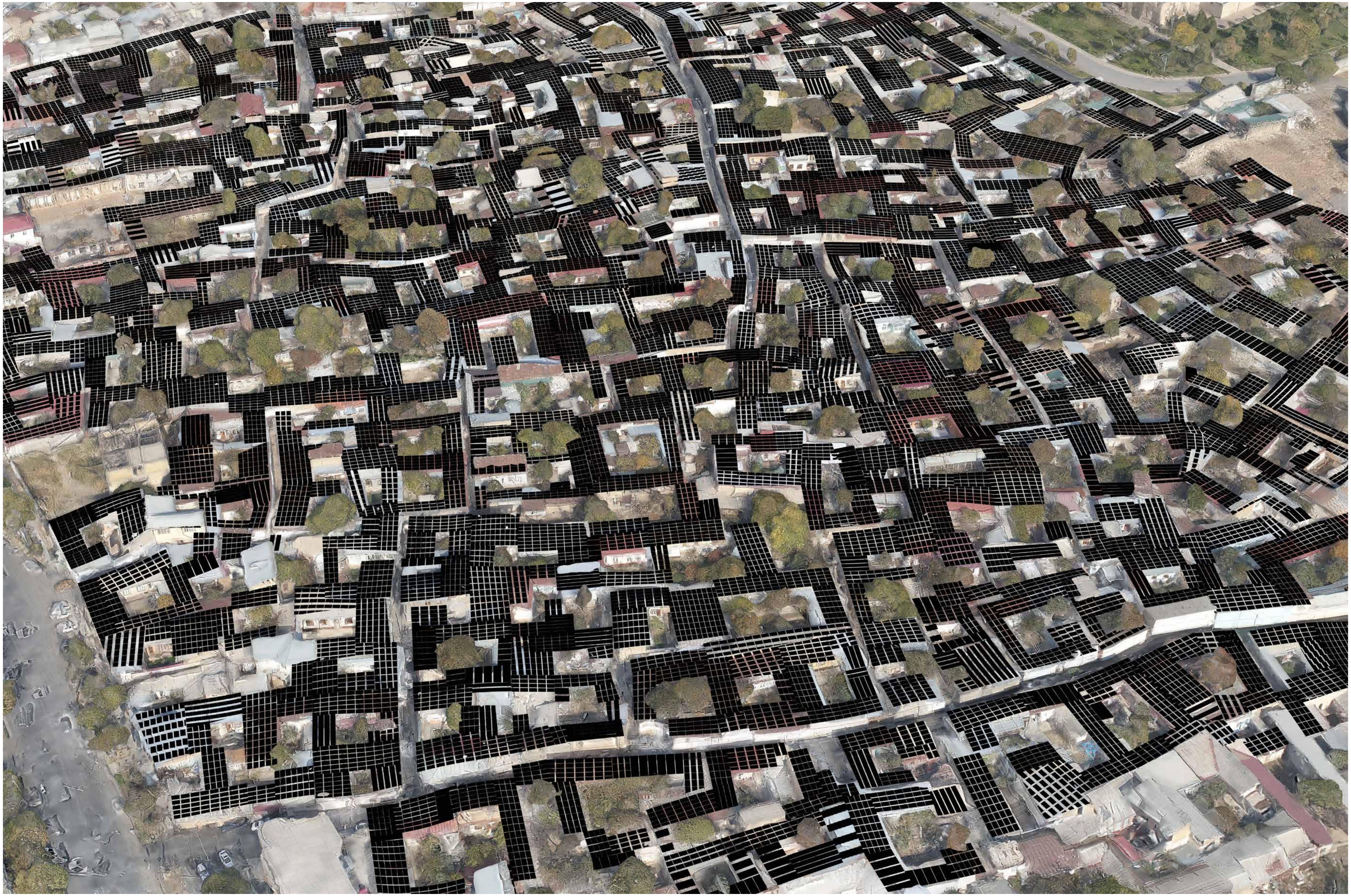
CANOPY CONTOURS

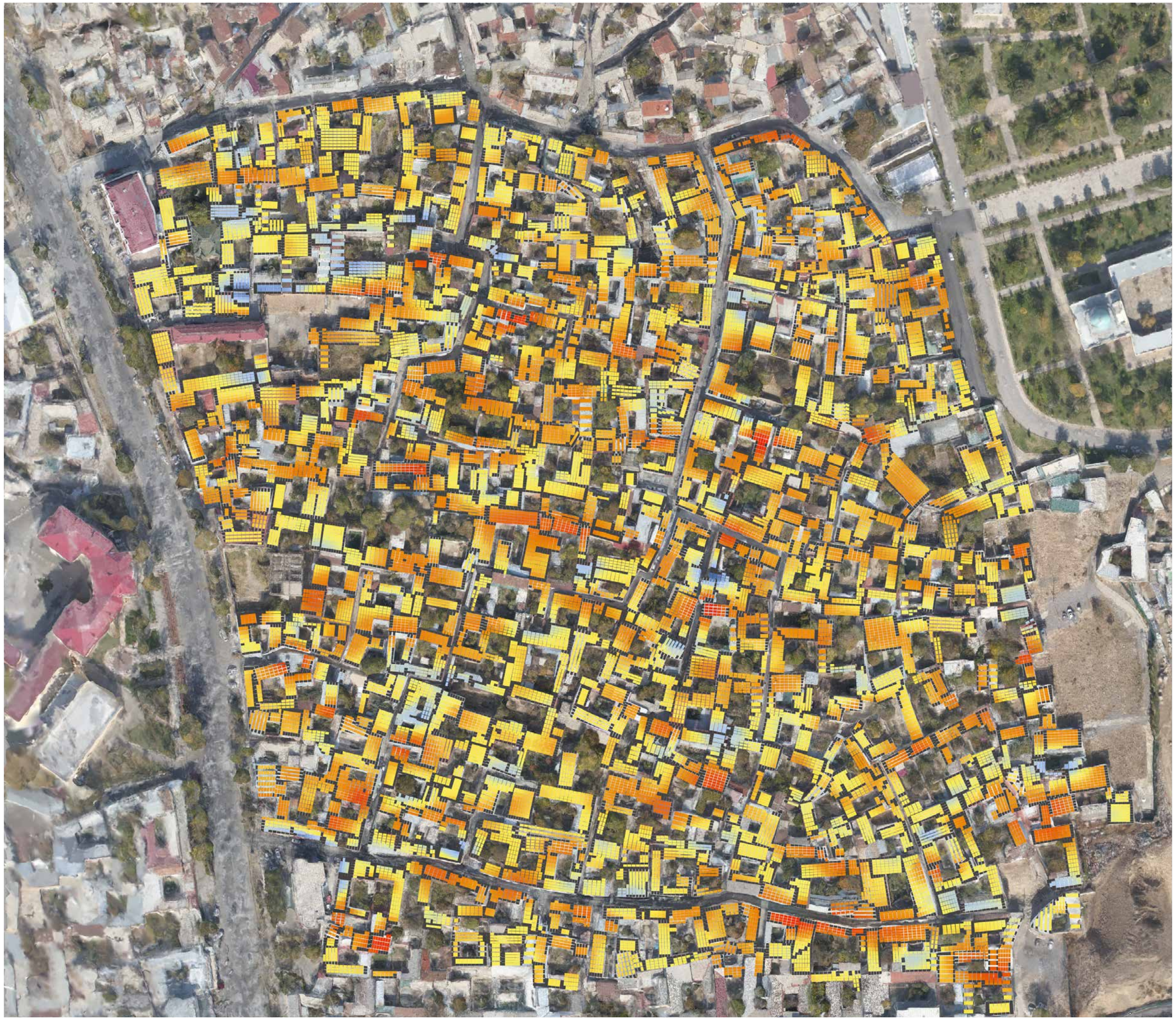
Afterwards, the roof footprint of the existing structures were manipulated towards courtyards, to allow for overhangs that would cast shadings to the west and south facing facades of the structures. The new roof footprint is then subdivided into standard sized panels (1.05m x 1.70m) and projected to the new canopy. A differentiation is made between full panels that contain PV modules, and optical non-functioning panels that do serve as aesthetical fillers. The normals of the projected panels were then adjusted to the normal of the canopy at every individual point. Moreover, the existing greenery was described through primitive volumes, which would cast shadows on to the functioning panels.

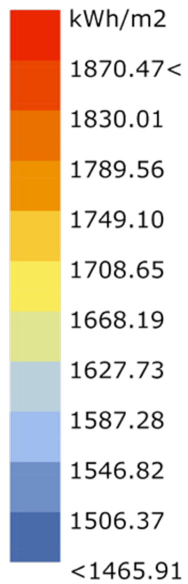
0 100

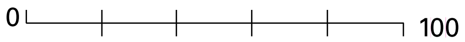
PANELING OVERVIEW



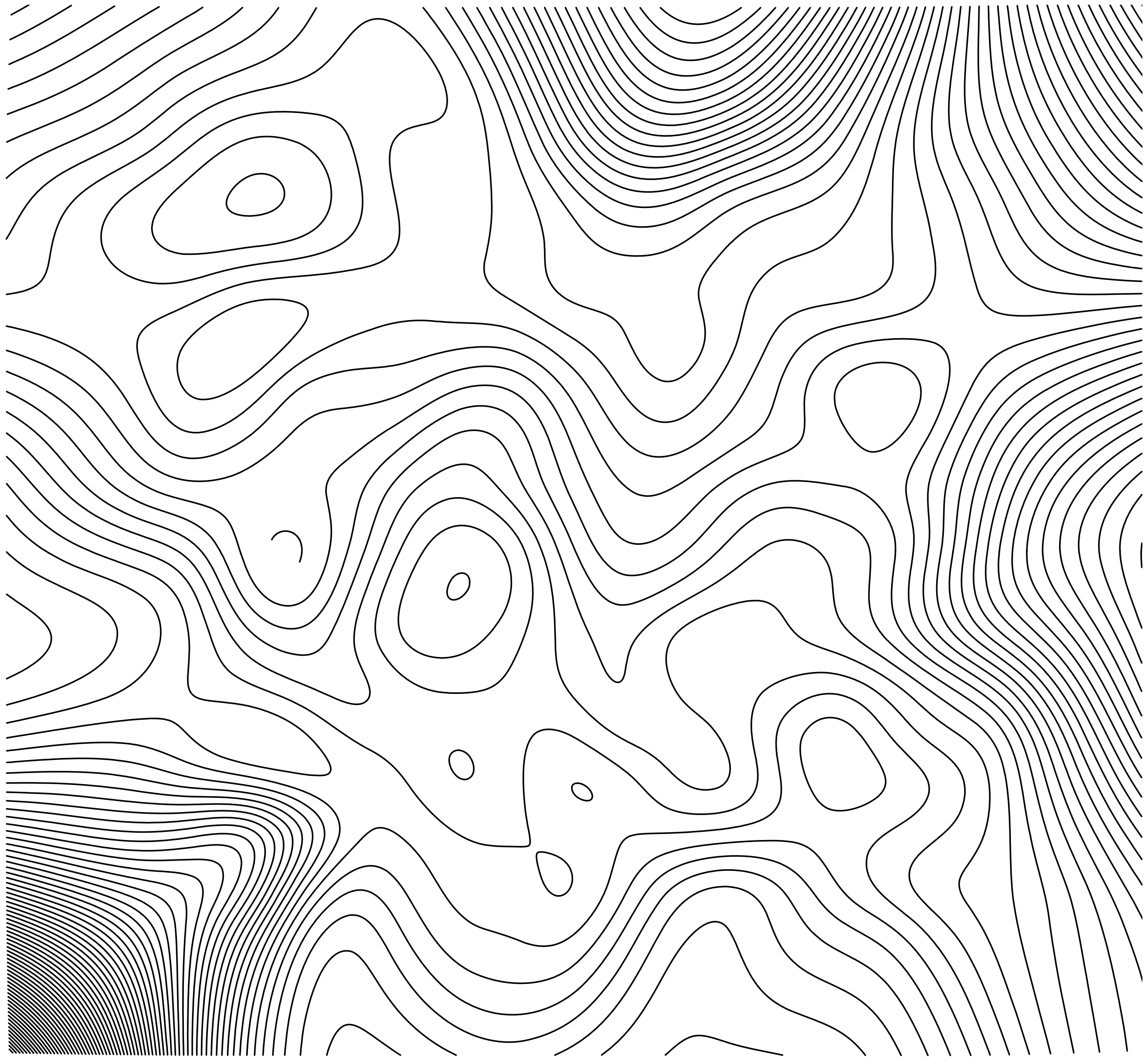
SATELLITE MOCK-UP



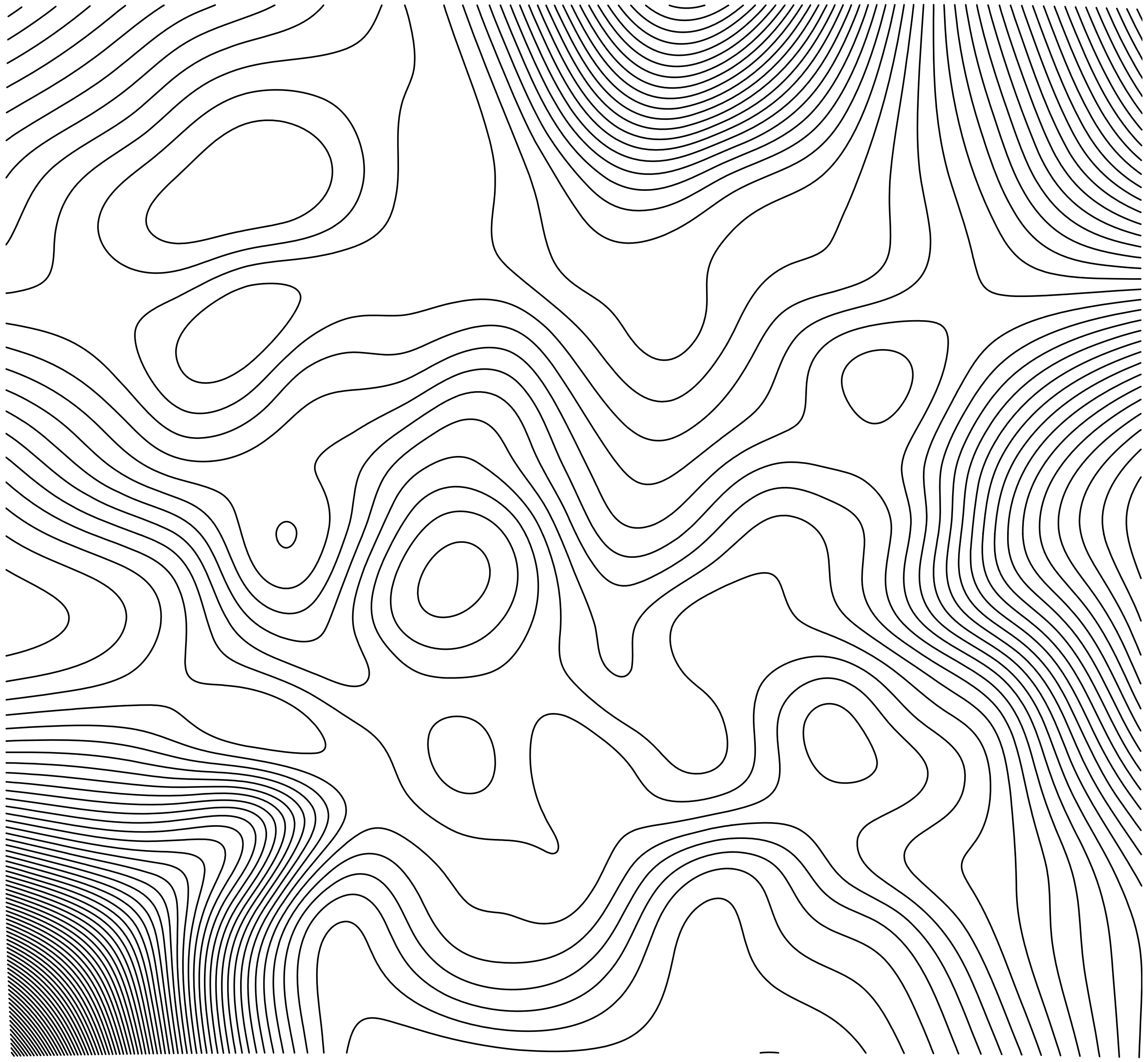




IRRADIANCE OF FULL PANELS AND OPTICAL PANELS



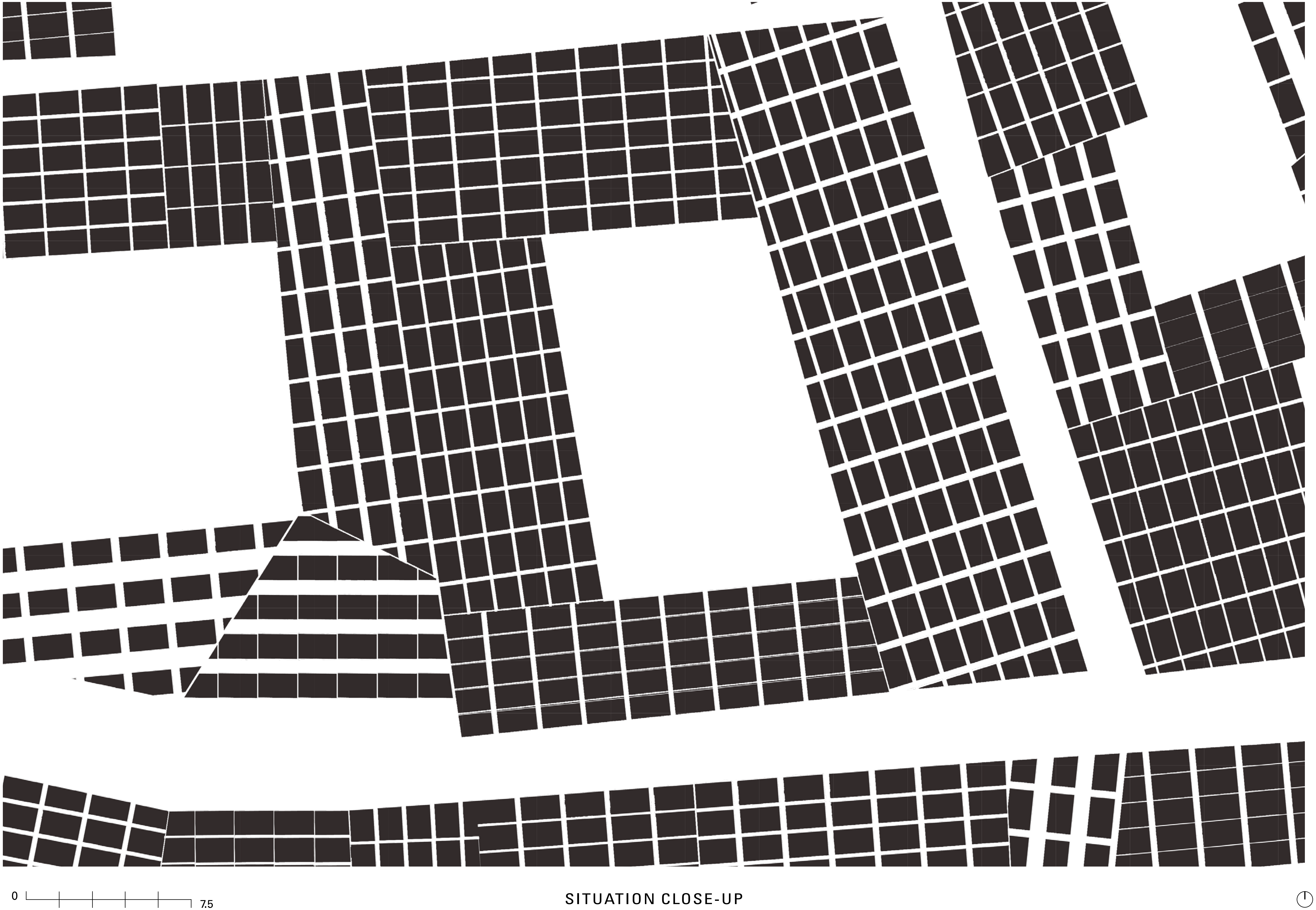
Average Panel Performance (pre-iteration): 1612 kWh/m^2



Average Panel Performance (post-iteration): 1704 kWh/m^2

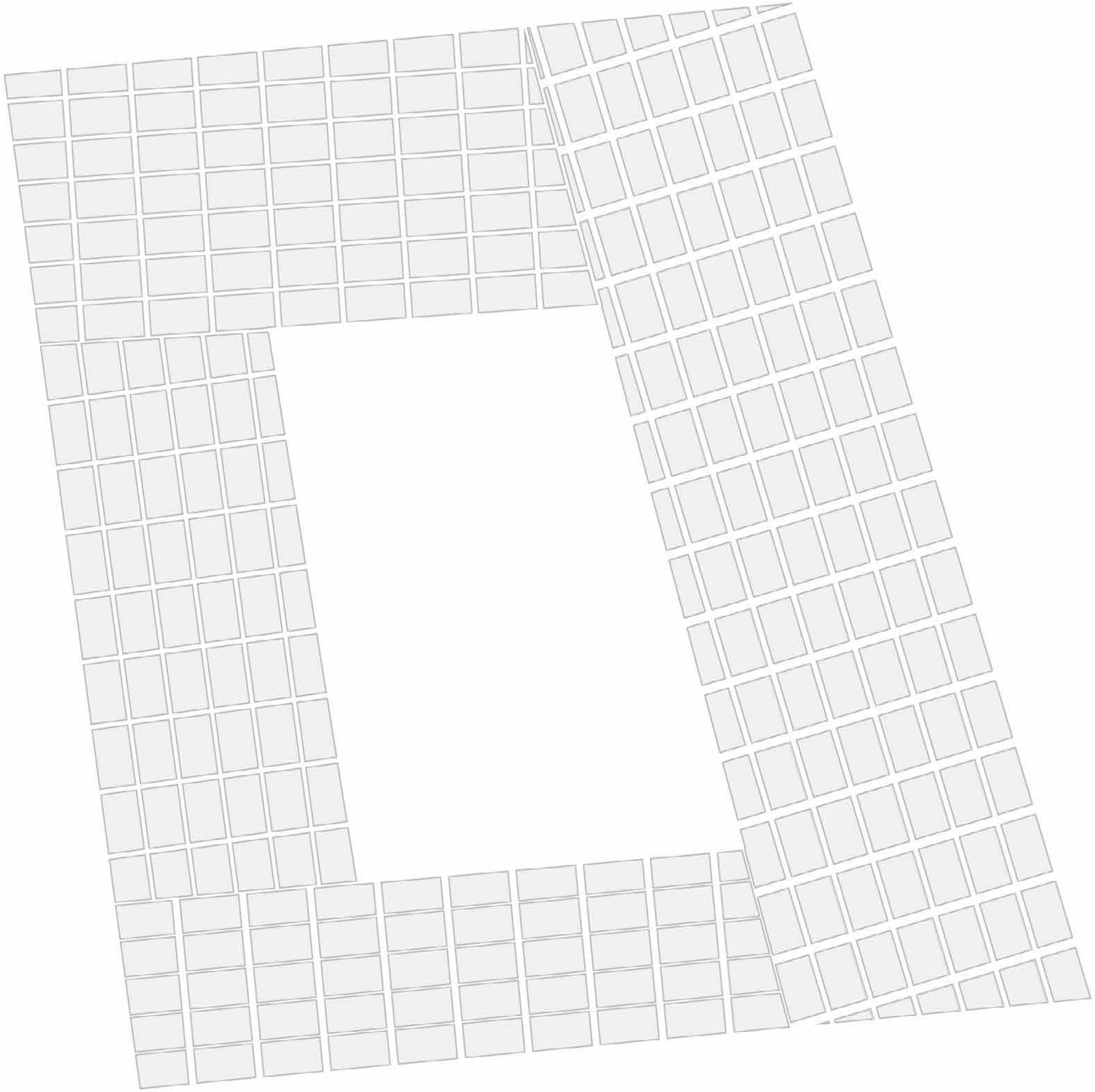
Finally the iterations of genetic algorithms were solved for the final solar irradiation above full panels, while adjusting for the node heights of the canopy; in order to achieve higher efficiency through optimization.

0 200



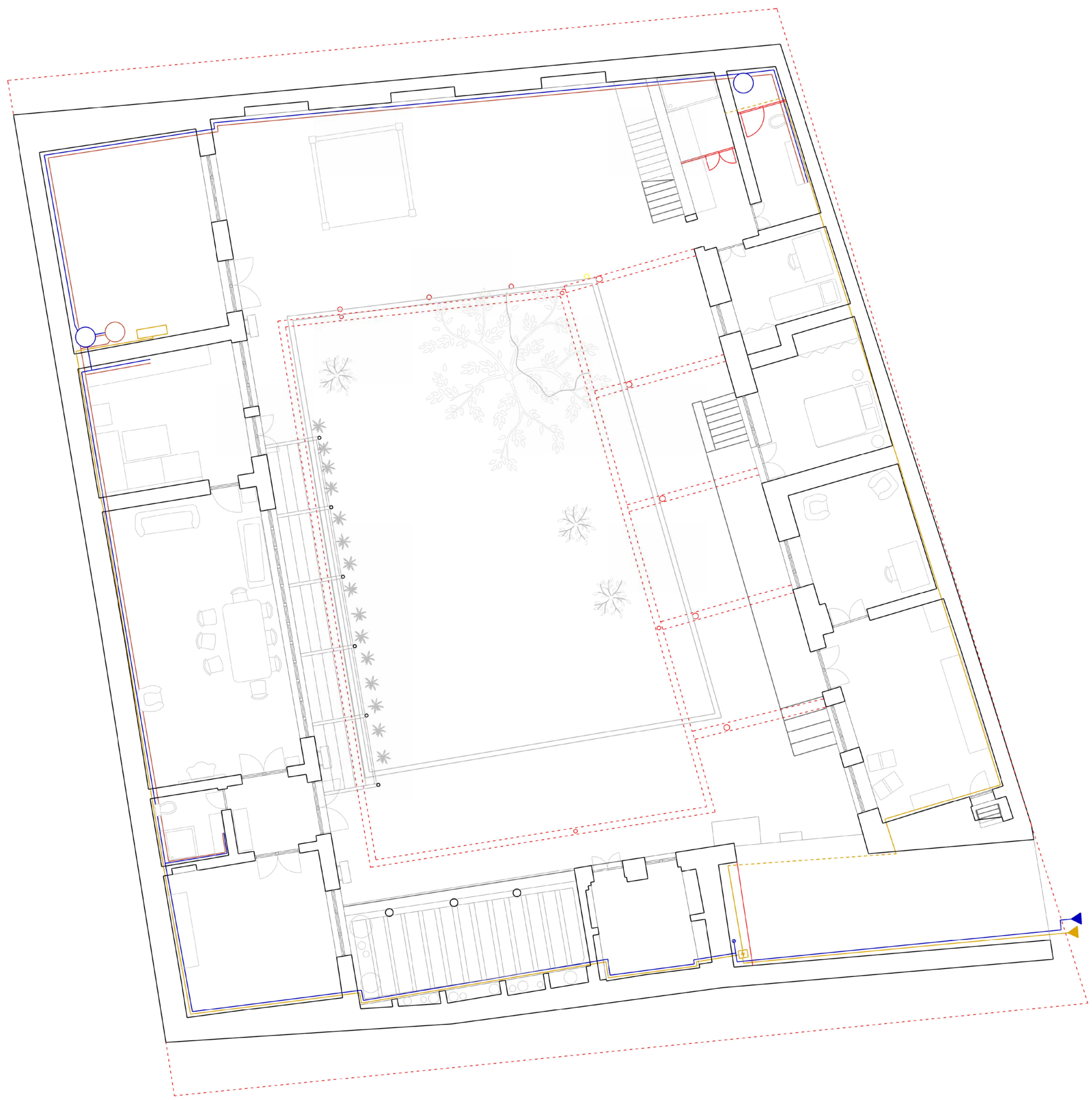
SITUATION CLOSE-UP

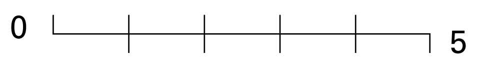
PLAN VIEW - IRRADIATION CLOSE-UP



0 7.5

PLAN VIEW - PANELING



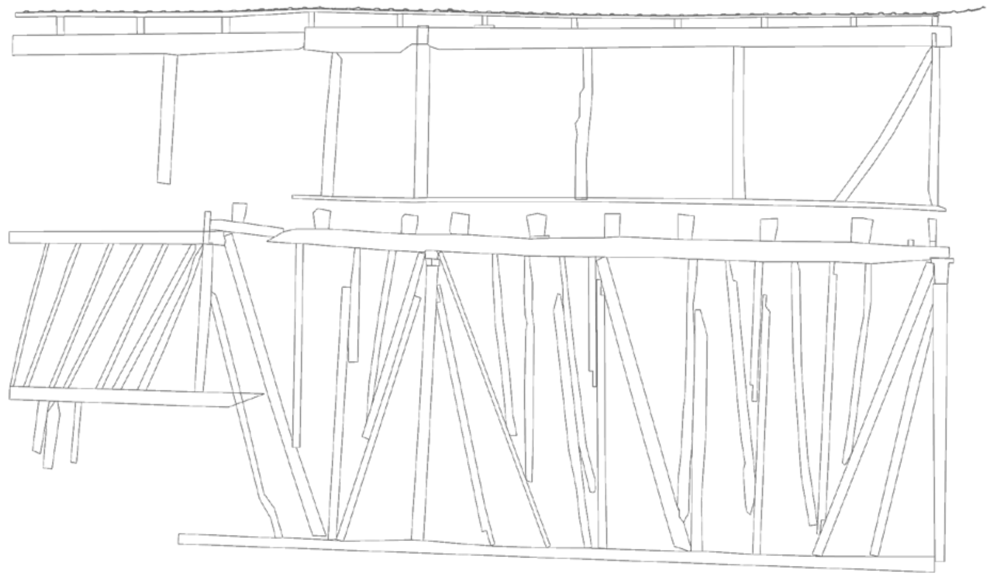


PLAN VIEW 1:100

VIEW FROM THE STREET

VIEW FROM THE ENTRANCE

VIEW BELOW THE ROOFSCAPE

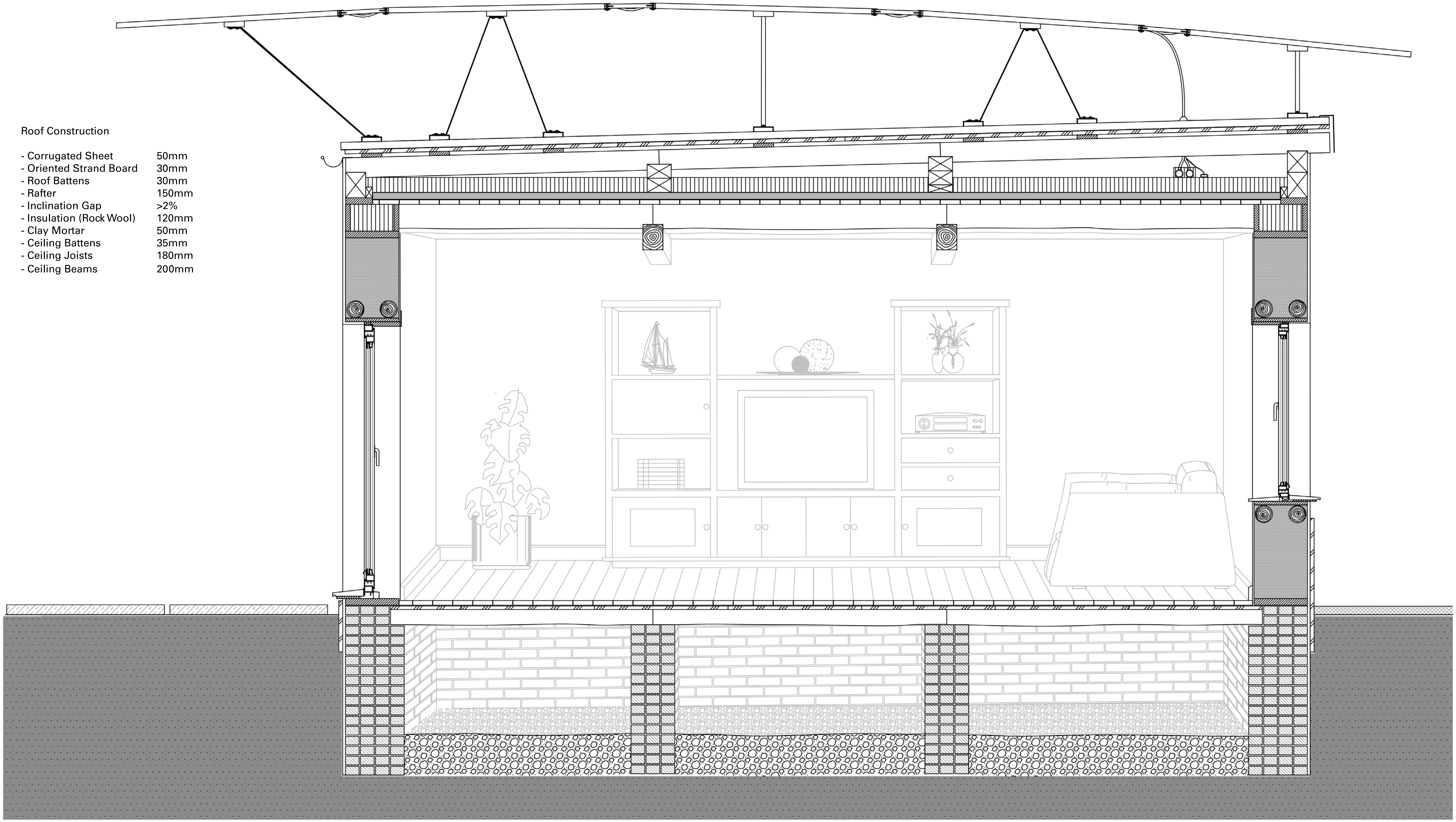


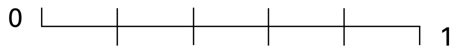
Construction sketch of a house in Abu-Bakr Shoshij

SKETCH OF THE VERNACULAR „SYNCH“ CONSTRUCTION

Roof Construction

- Corrugated Sheet	50mm
- Oriented Strand Board	30mm
- Roof Battens	30mm
- Rafter	150mm
- Inclination Gap	>2%
- Insulation (Rock Wool)	120mm
- Clay Mortar	50mm
- Ceiling Battens	35mm
- Ceiling Joists	180mm
- Ceiling Beams	200mm





DETAIL 1:20