Kigali, Rwanda

4.432/4.433 | Modeling Urban Energy Flows
Towards Sustainable Cities and Neighborhoods
A New Neighborhood | Kigali, Rwanda

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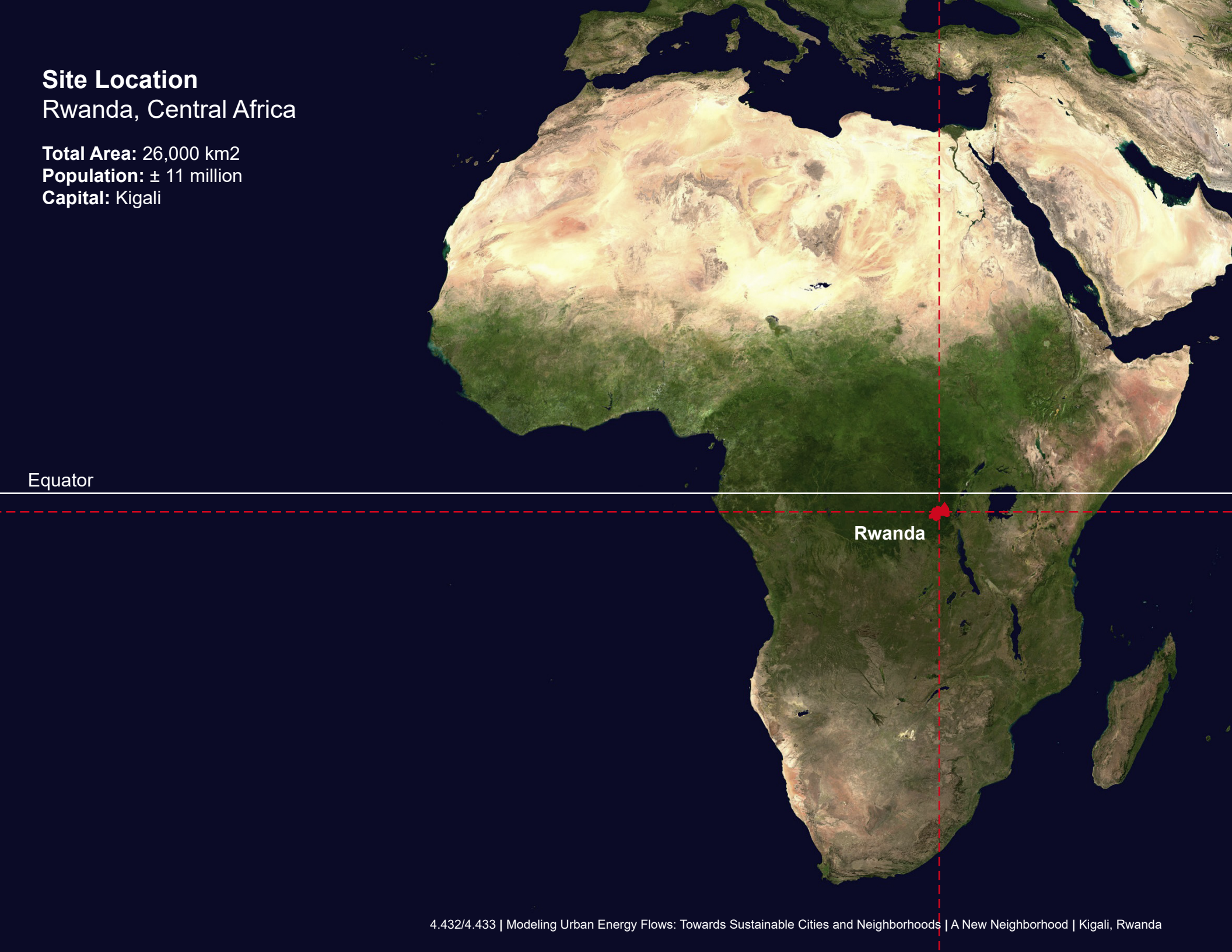
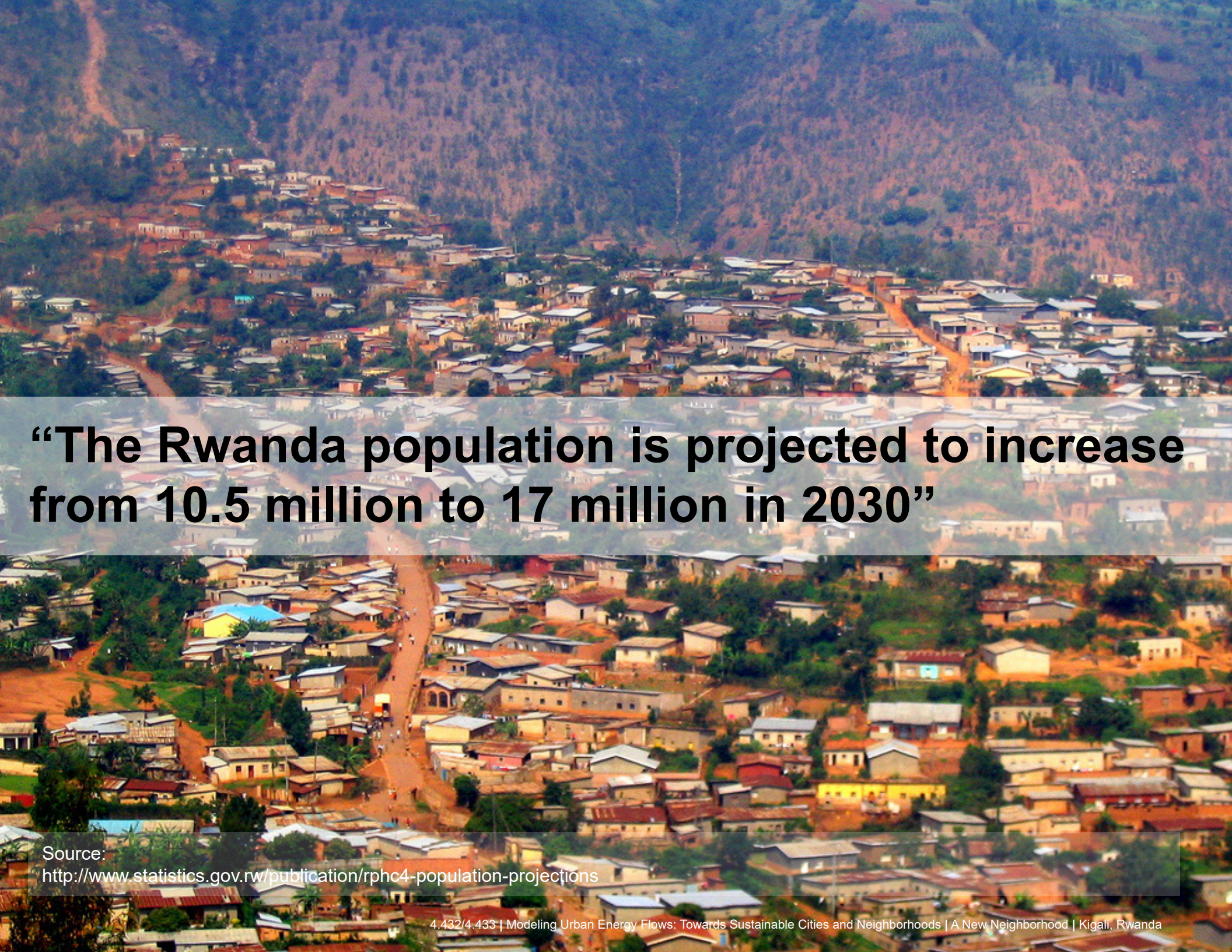
Kigali, Rwanda

Site Location
Rwanda, Central Africa

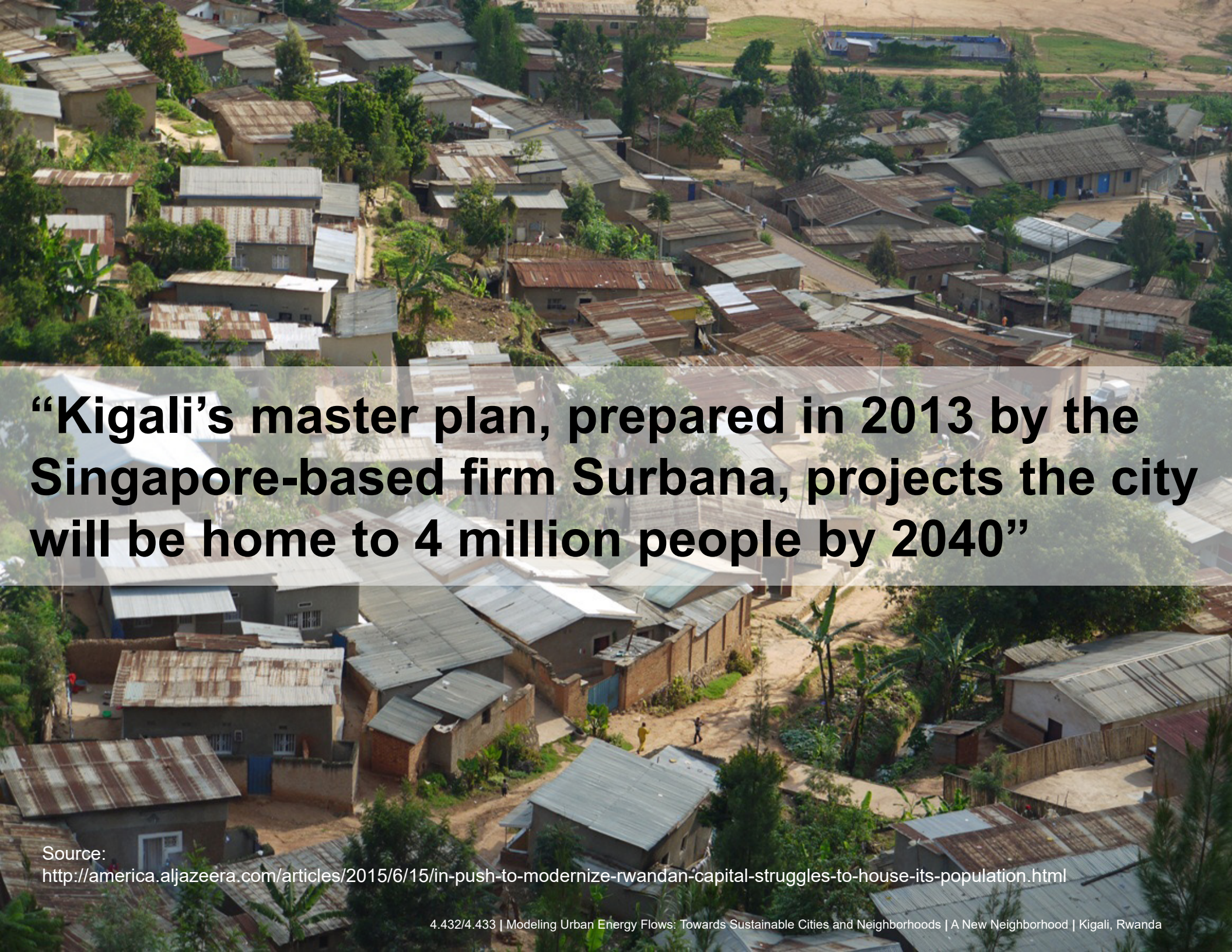
Total Area: 26,000 km2
Population: ± 11 million
Capital: Kigali





“The Rwanda population is projected to increase from 10.5 million to 17 million in 2030”

Source:
http://www.statistics.gov.rw/publication/rphc4-population-projections



“Kigali’s master plan, prepared in 2013 by the Singapore-based firm Surbana, projects the city will be home to 4 million people by 2040”

Source:
http://america.aljazeera.com/articles/2015/6/15/in-push-to-modernize-rwandan-capital-struggles-to-house-its-population.html

“According to a 2012 City of Kigali study, the projected population increase and inadequacy of much of the city’s current housing stock mean Kigali will require 344,000 new housing units by 2022.”

Source:
http://america.aljazeera.com/articles/2015/6/15/in-push-to-modernize-rwandan-capital-struggles-to-house-its-population.html

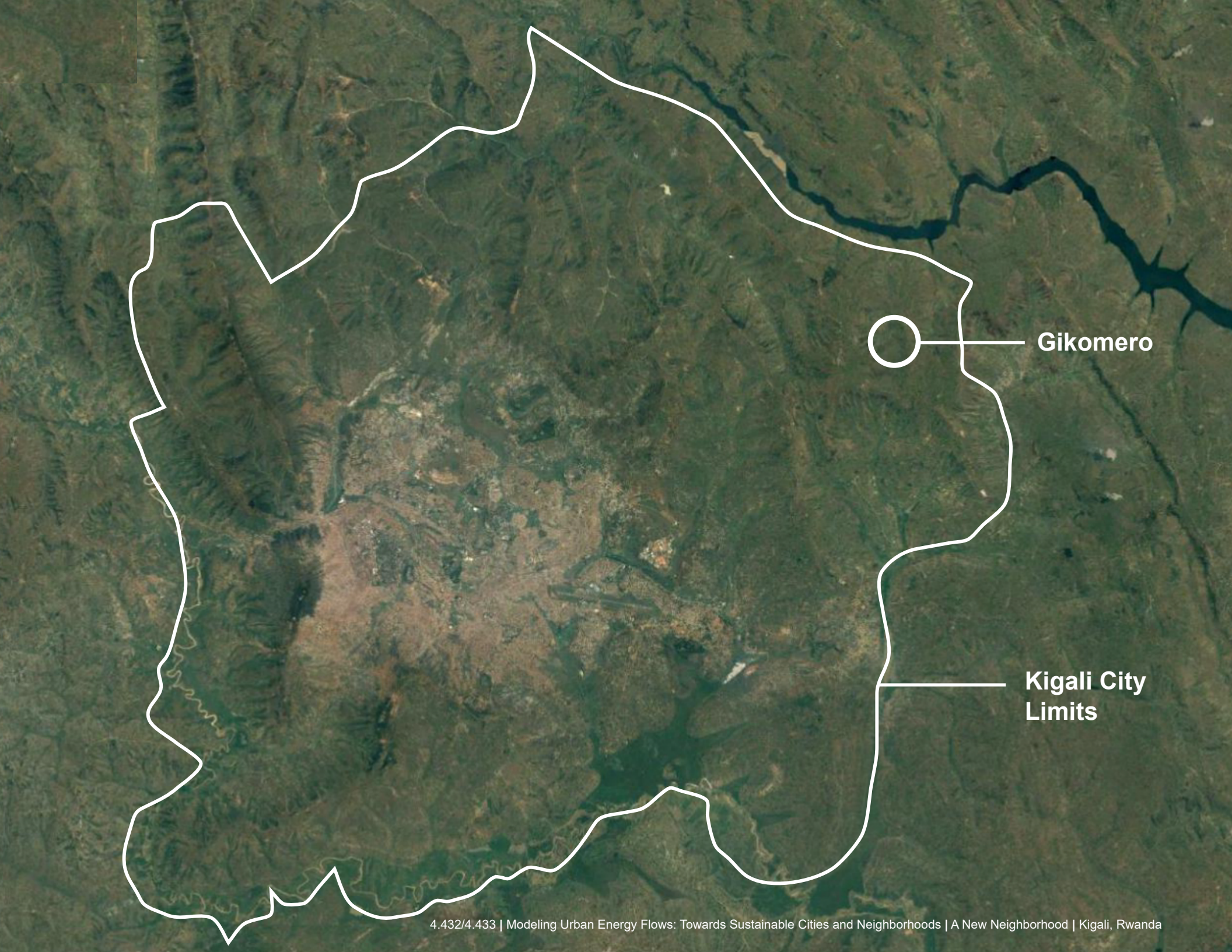
Growth of Urban Area & Population in Kigali

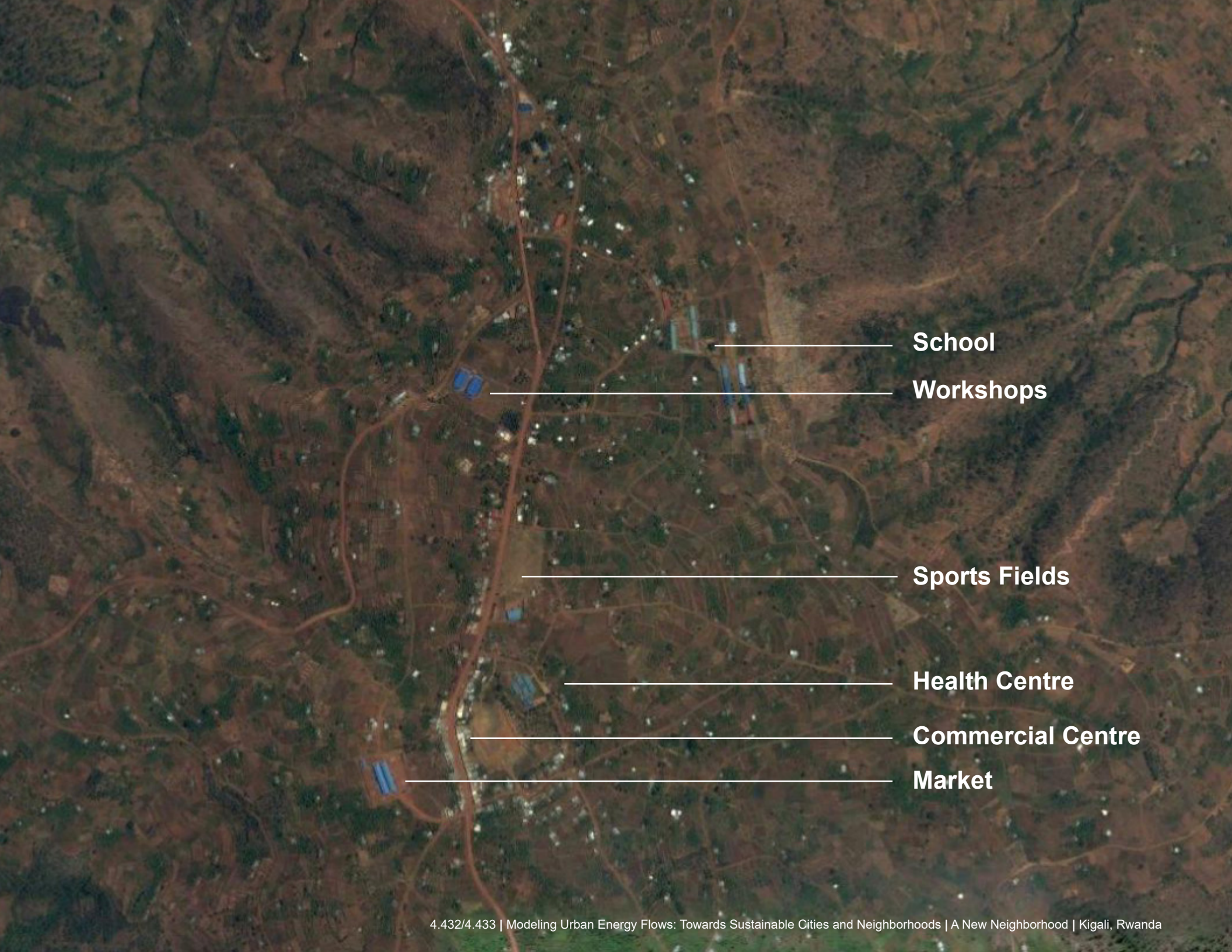
Increased demand in housing and commercial

Population: **±200,000** (1990)

Population: **±1,100,000** (2017)

Rwanda Housing Authority
Integrated Development Project


Gikomero
Kigali City Limits


School
Workshops
Sports Fields
Health Centre
Commercial Centre
Market

RHA Unit Plan

3.5 Bedrooms
Outdoor Kitchen/WC

85 m2 total floor area

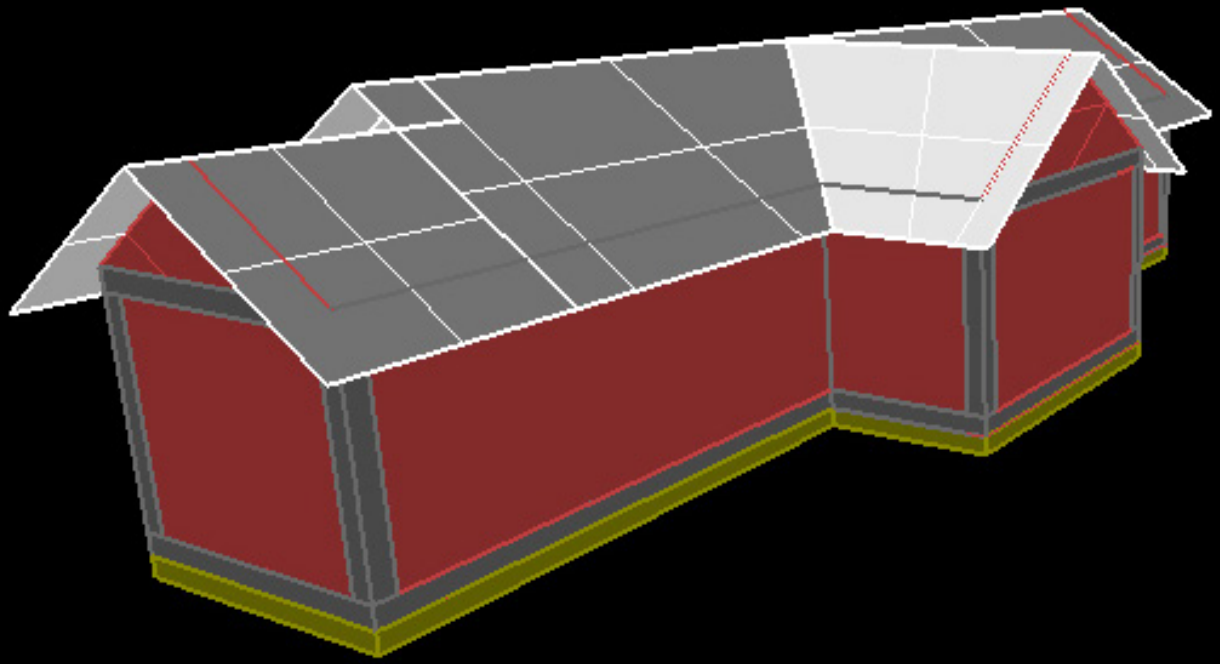
Cyclopean Stone
Foundation

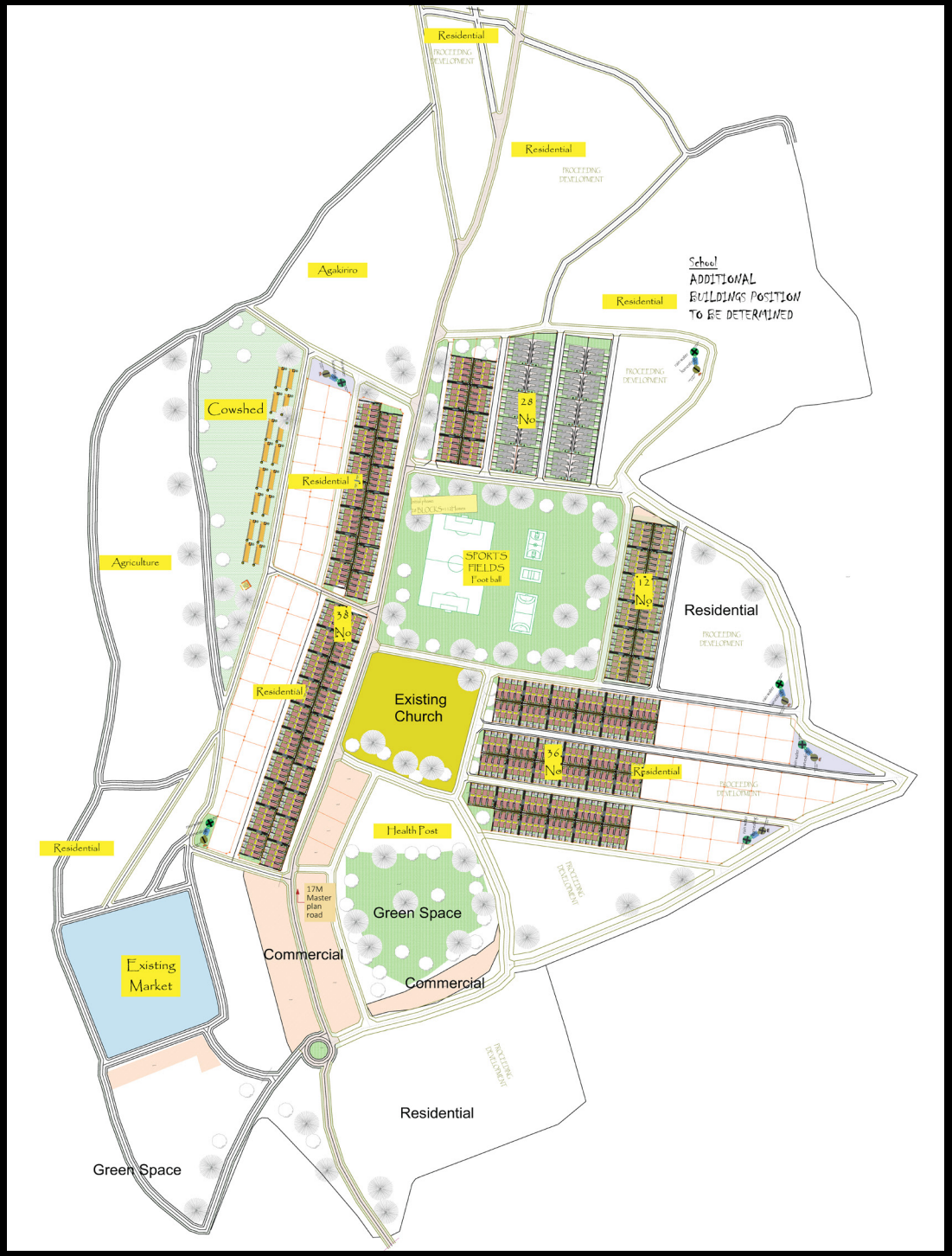
Fired Clay Brick

Reinforced Concrete

Sawn Pine/Eucalyptus
Roof Frame

Corrugated Tin Roof

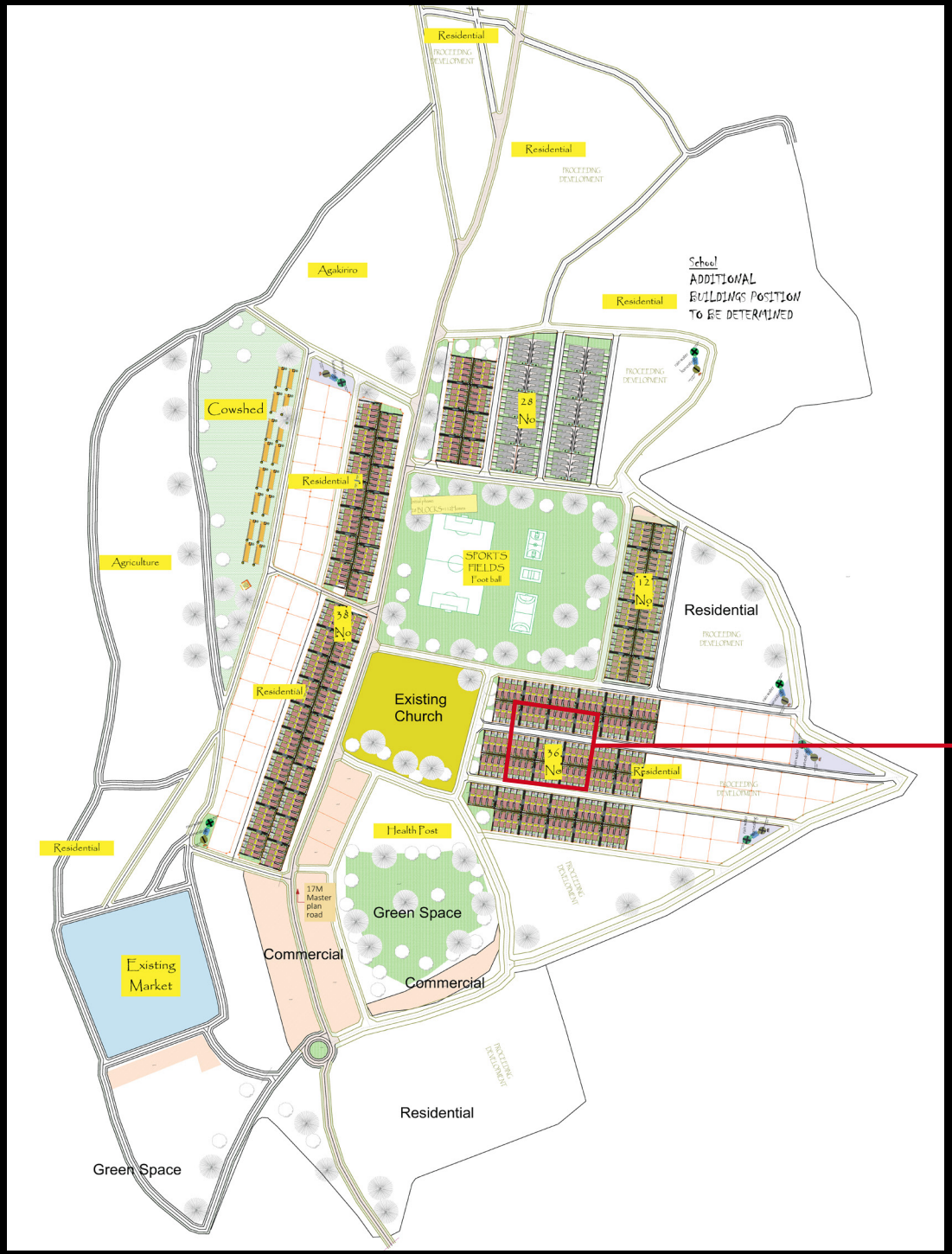




Gikomero Master Plan

Phase one:
- 156 units
- 190 new residents

Added amenities:
- Technology Hub
- Additional Sports Fields
- New School
- Cowsheds

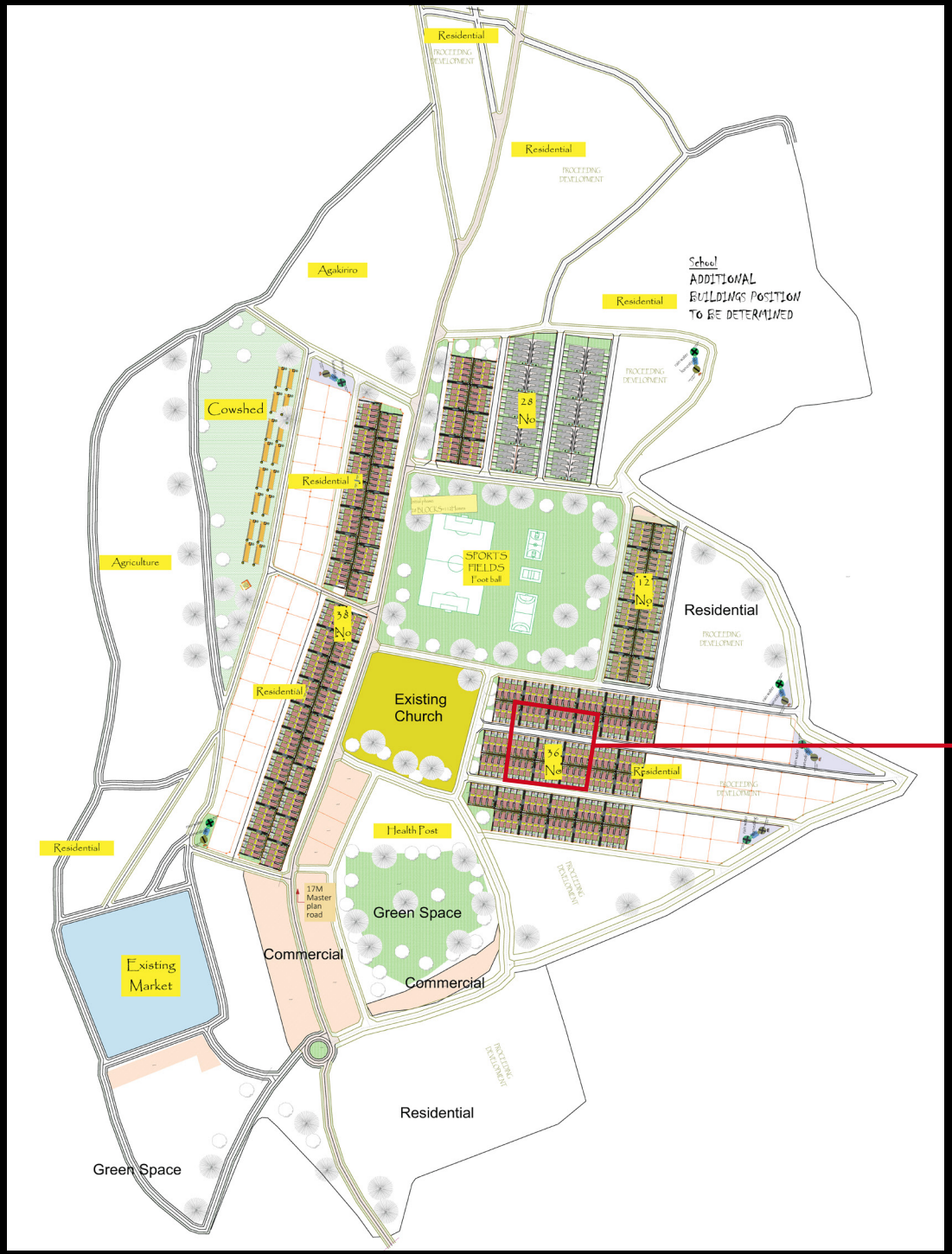


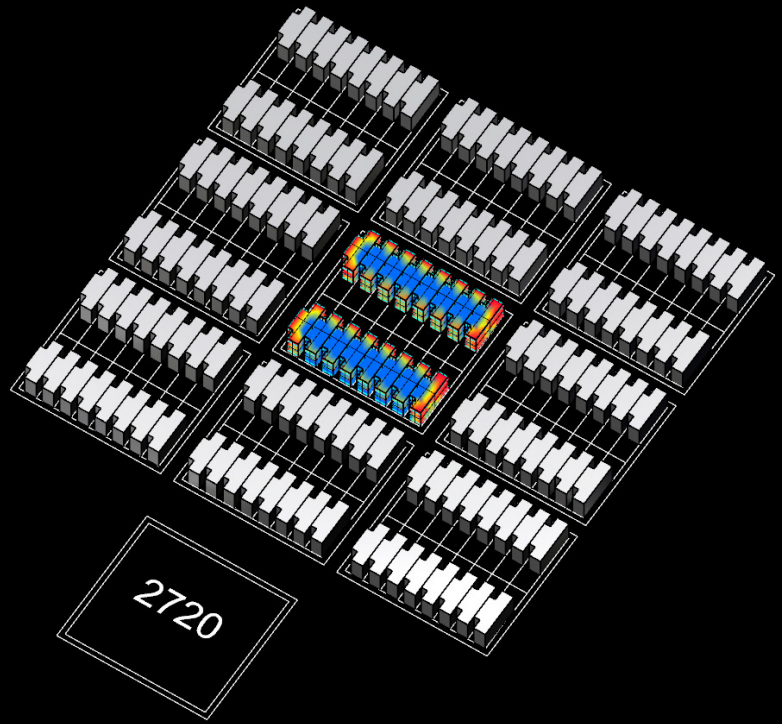
Gikomero Master Plan

Phase one:
- 156 units
- 190 new residents

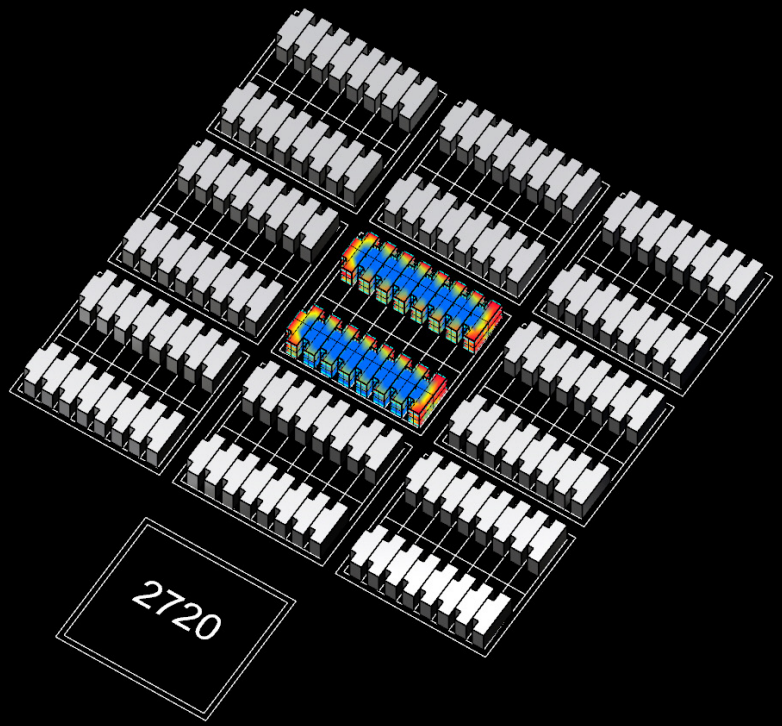
Added amenities:
- Technology Hub
- Additional Sports Fields
- New School
- Cowsheds

Block of 39 units
selected for analysis

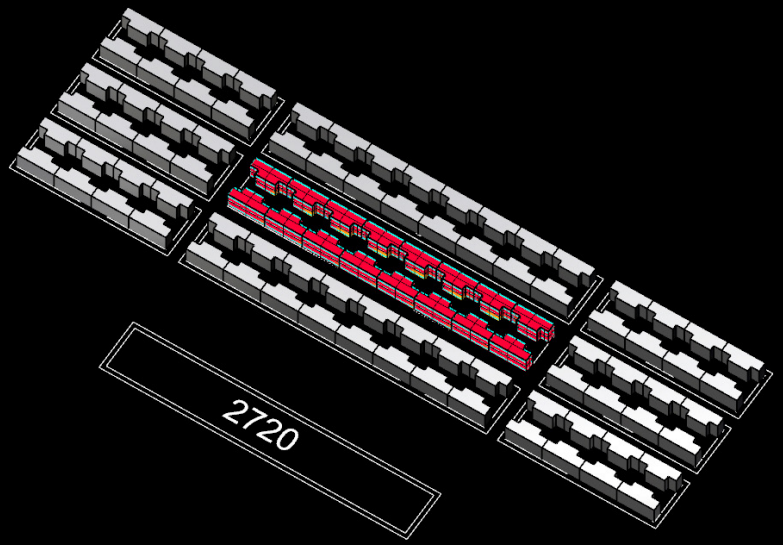

Residential
PROCEEDING DEVELOPMENT
Residential
PROCEEDING DEVELOPMENT
Agakiriro
Residential
School
ADDITIONAL
BUILDINGS POSITION
TO BE DETERMINED
Cowshed
28 No
PROCEEDING DEVELOPMENT
Residential
SPORTS FIELDS
Foot ball
12 No
Residential
PROCEEDING DEVELOPMENT
Agriculture
38 No
Residential
Existing Church
36 No
Residential
PROCEEDING DEVELOPMENT
Health Post
Residential
17M Master plan road
Green Space
Existing Market
Commercial
Commercial
PROCEEDING DEVELOPMENT
Residential
Green Space


2720

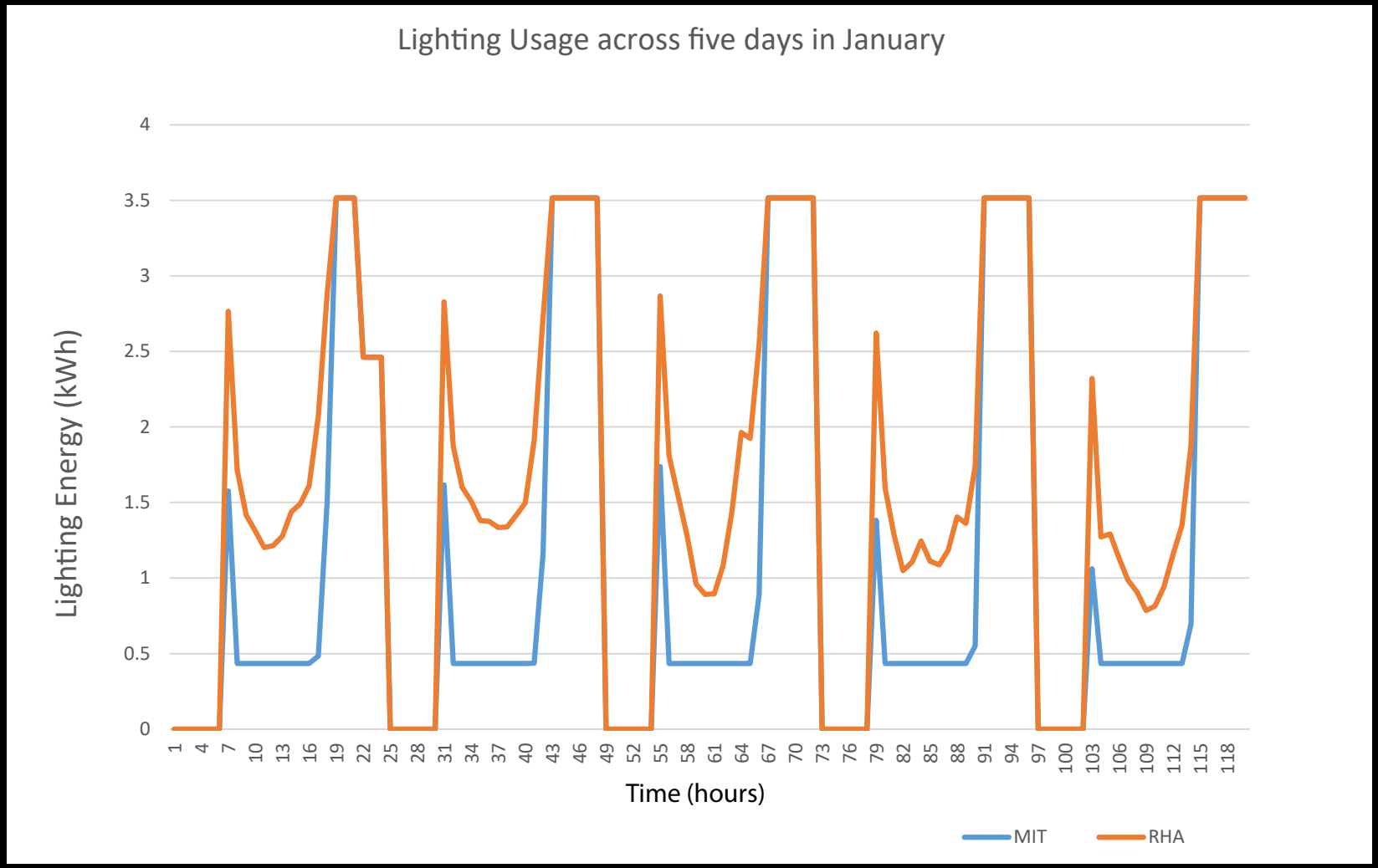
Comparison: Daylighting



RHA protoblock

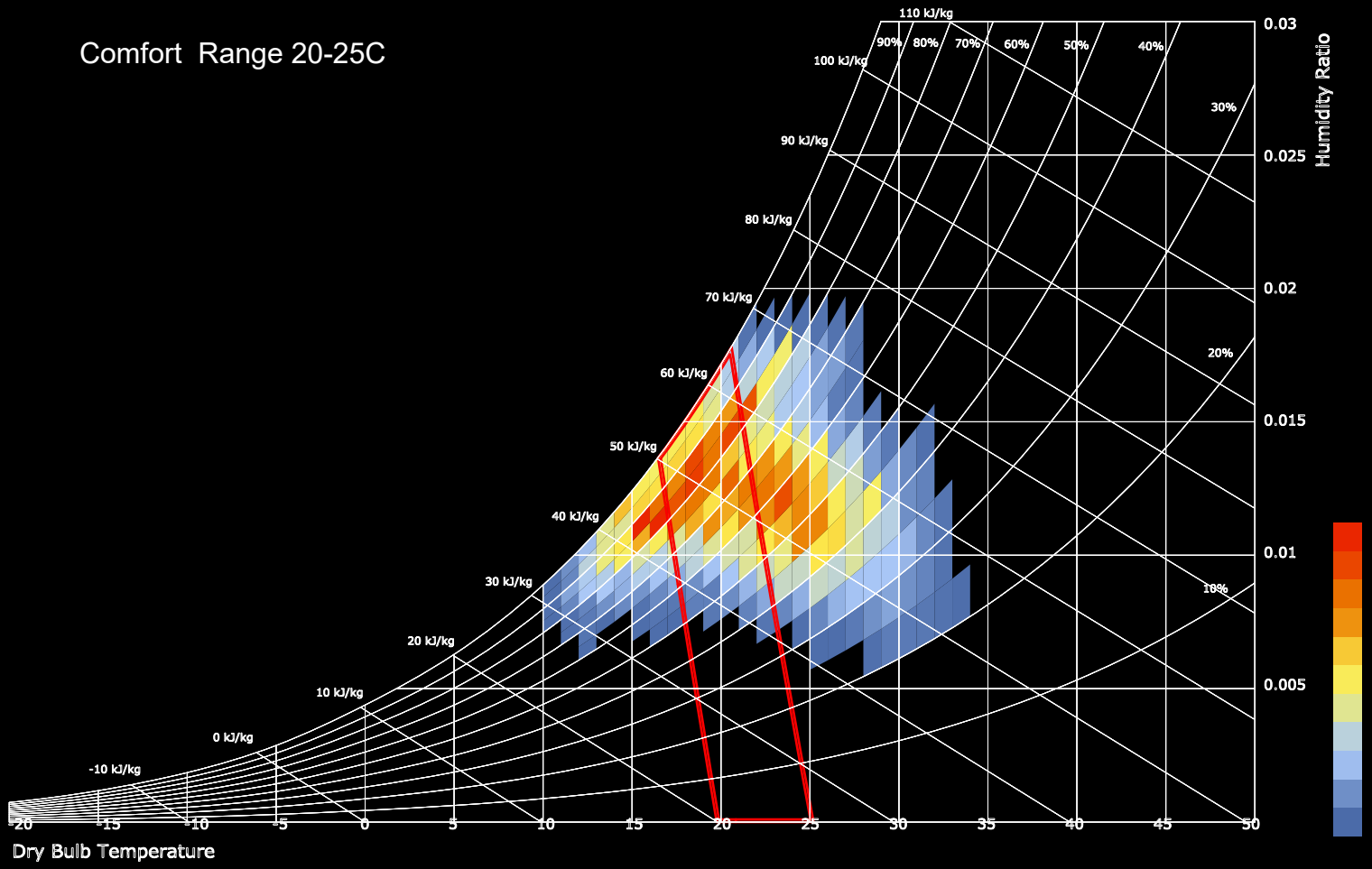


MIT protoblock


Lighting Usage across five days in January
Lighting Energy (kWh)
4
3.5
3
2.5
2
1.5
1
0.5
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97 100 103 106 109 112 115 118
Time (hours)
MIT
RHA

19% daylight saving

Thermal Comfort

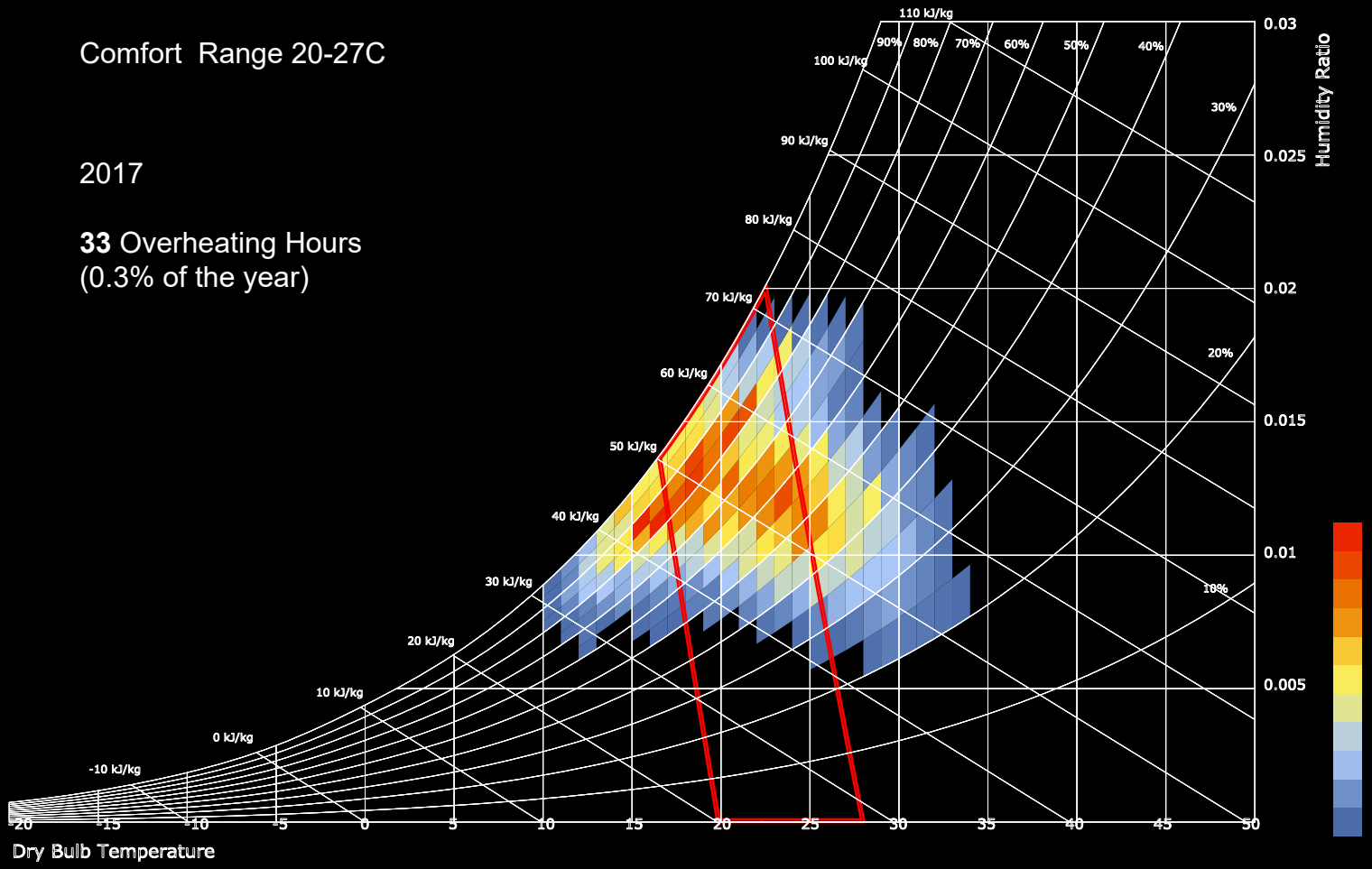


Thermal Comfort

Comfort Range 20-27C

2017

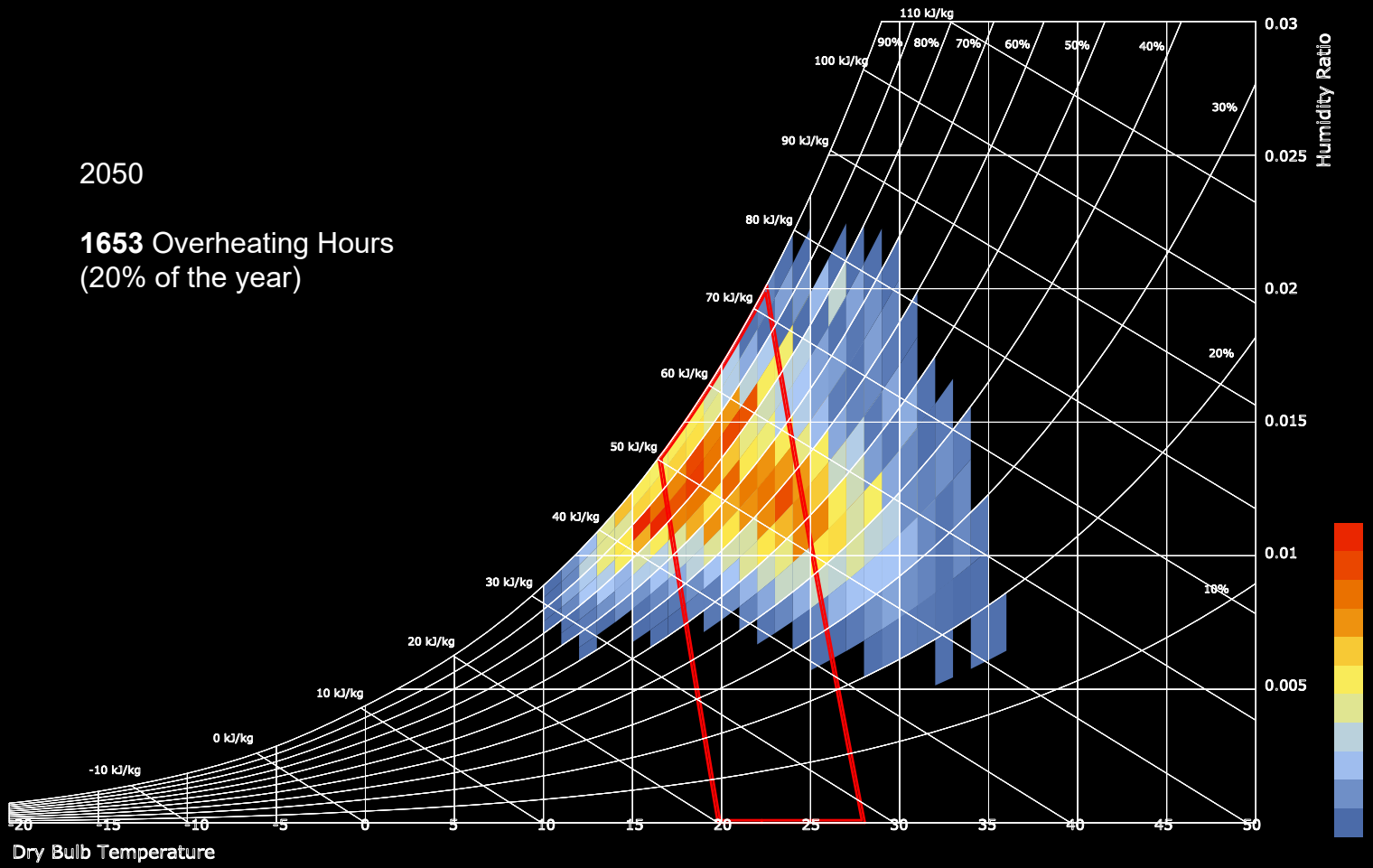
33 Overheating Hours
(0.3% of the year)



Thermal Comfort

2050

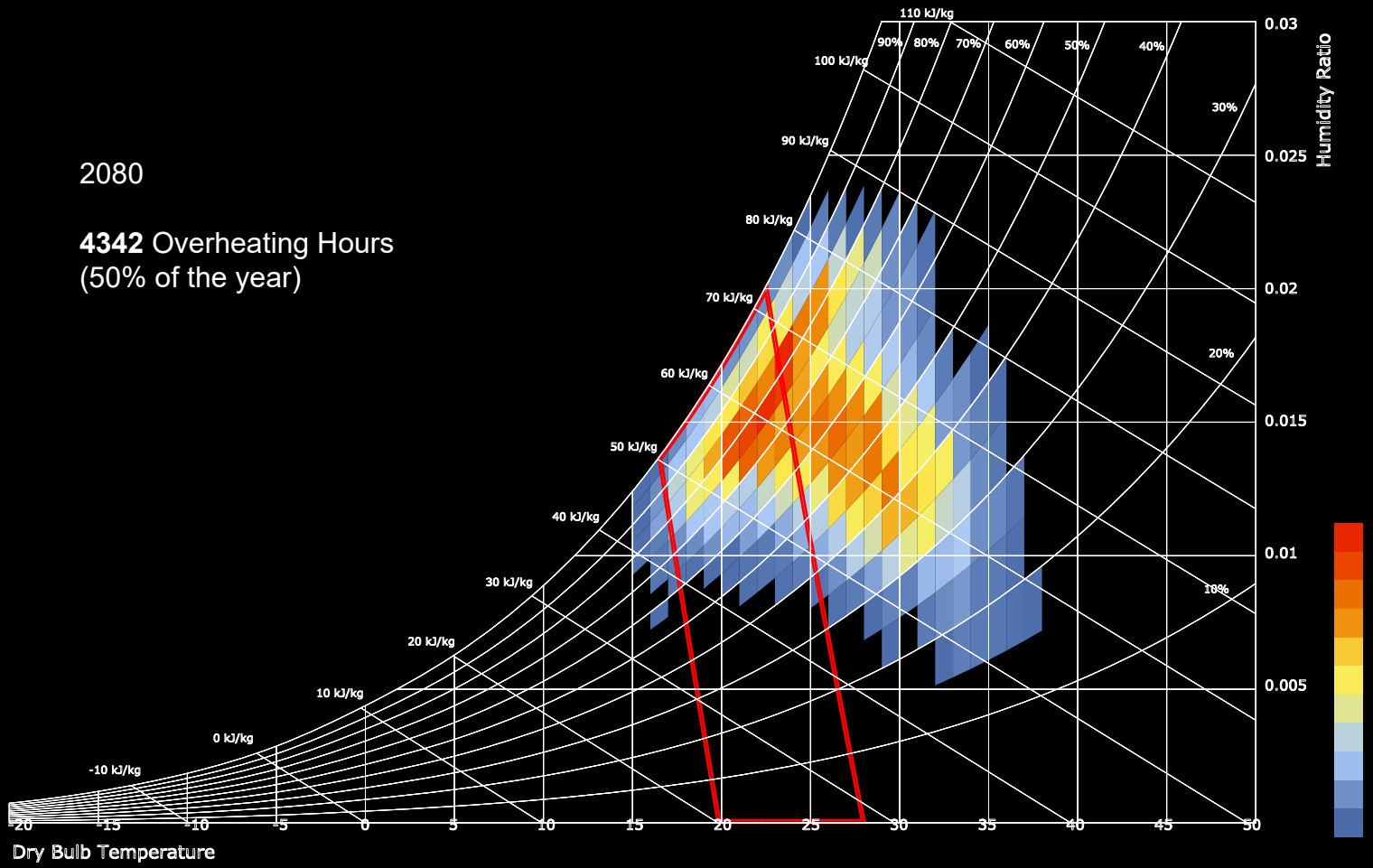
1653 Overheating Hours
(20% of the year)



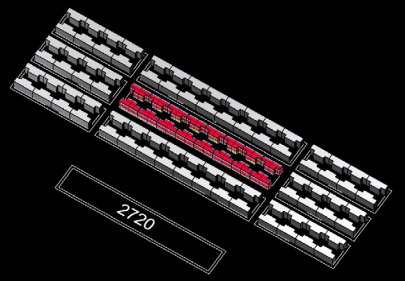
Thermal Comfort

2080

4342 Overheating Hours
(50% of the year)



Cooling in 2080



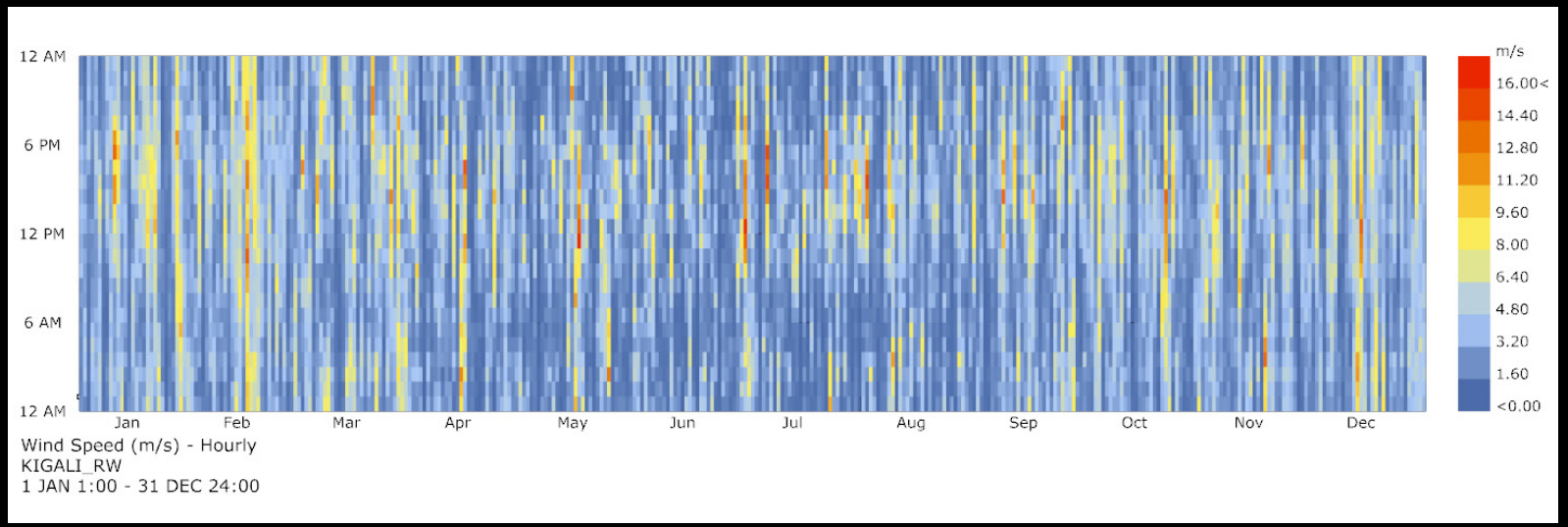
27 •C _____ 210,233 kwh

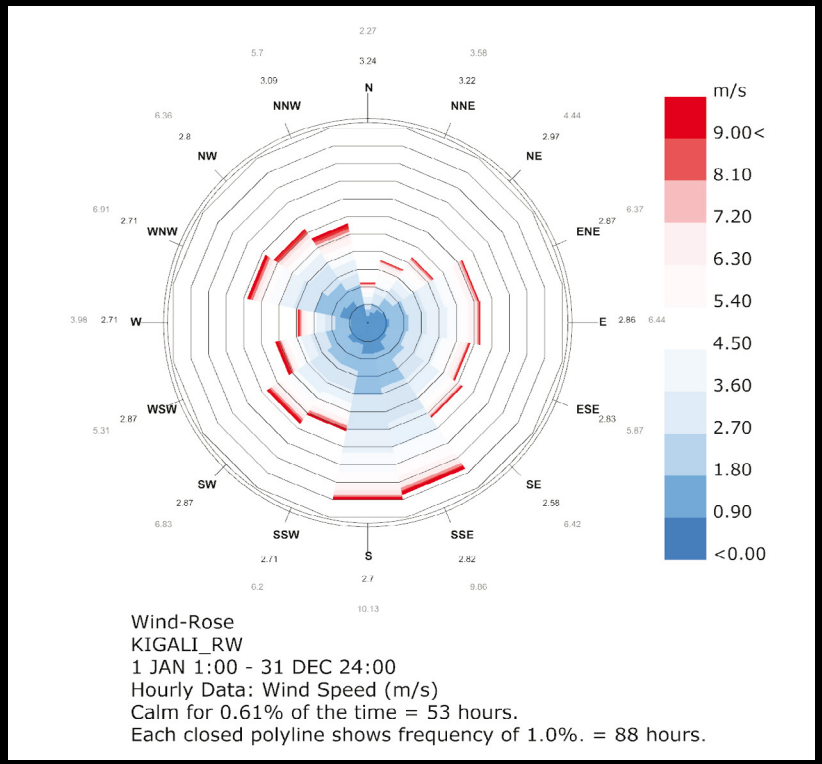
29 •C _____ 117,773 kwh

31 •C _____ 56,962 kwh

33 •C ___ 28,958 kwh

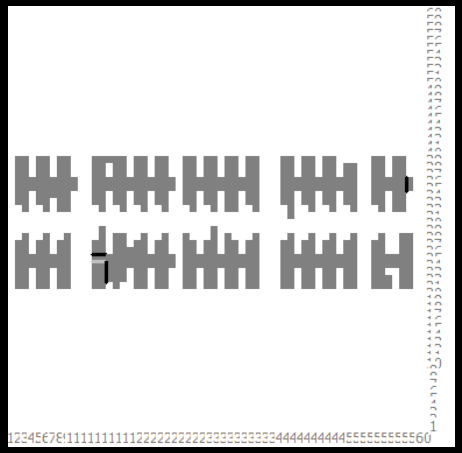
35 •C __ 26,328 kwh





25% winds are higher than 2m/s

Most winds come from the south



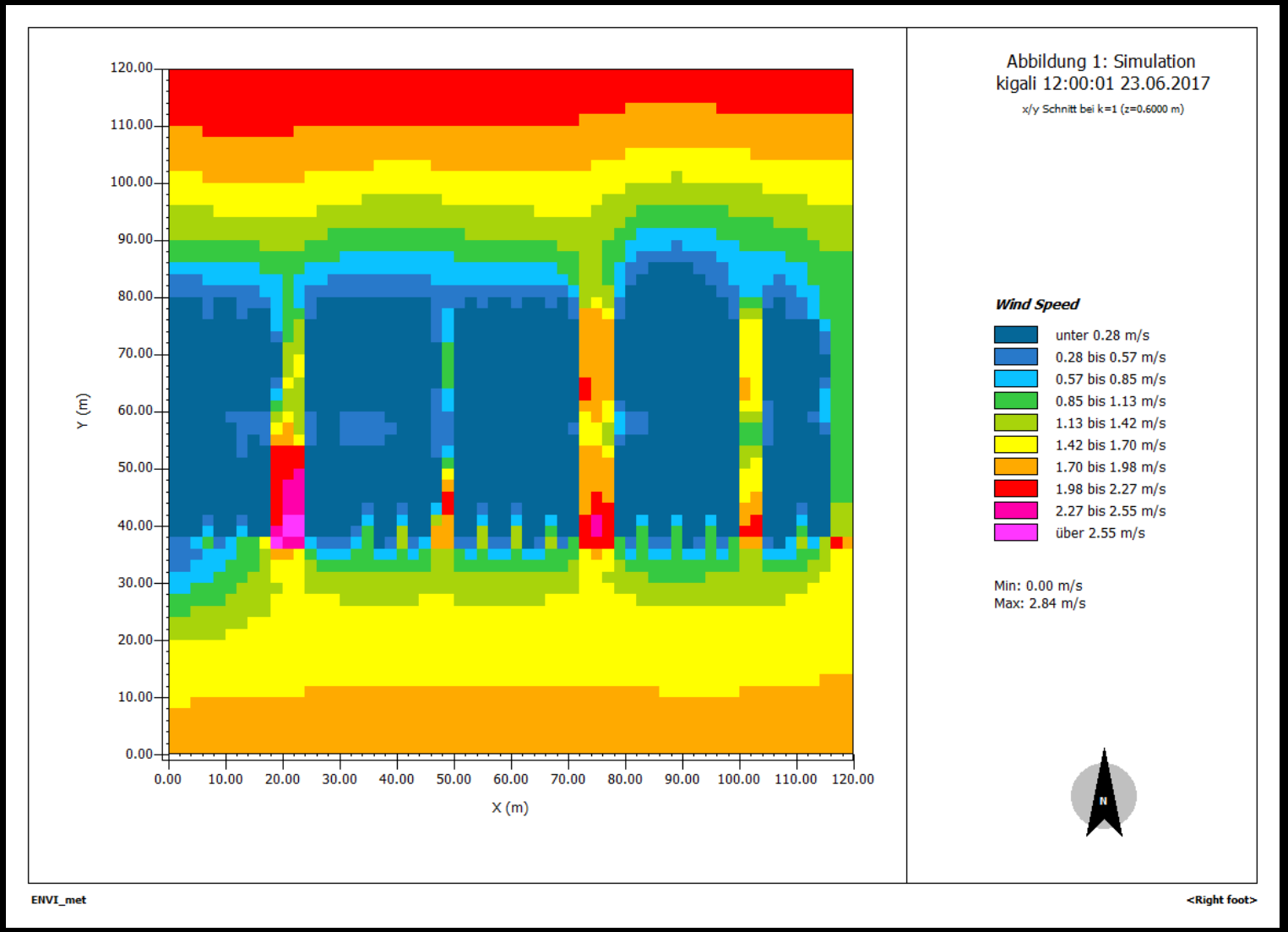
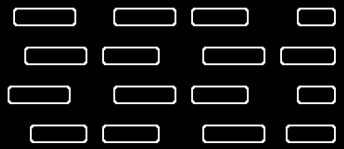
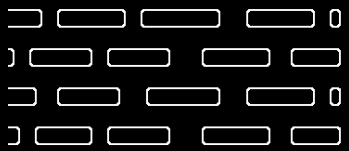


Abbildung 1: Simulation
kigali 12:00:01 23.06.2017
x/y Schnitt bei k=1 (z=0.6000 m)
Wind Speed
unter 0.28 m/s
0.28 bis 0.57 m/s
0.57 bis 0.85 m/s
0.85 bis 1.13 m/s
1.13 bis 1.42 m/s
1.42 bis 1.70 m/s
1.70 bis 1.98 m/s
1.98 bis 2.27 m/s
2.27 bis 2.55 m/s
über 2.55 m/s
Min: 0.00 m/s
Max: 2.84 m/s
Y (m)
X (m)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
110.00
120.00
N
ENVI_met
<Right foot>

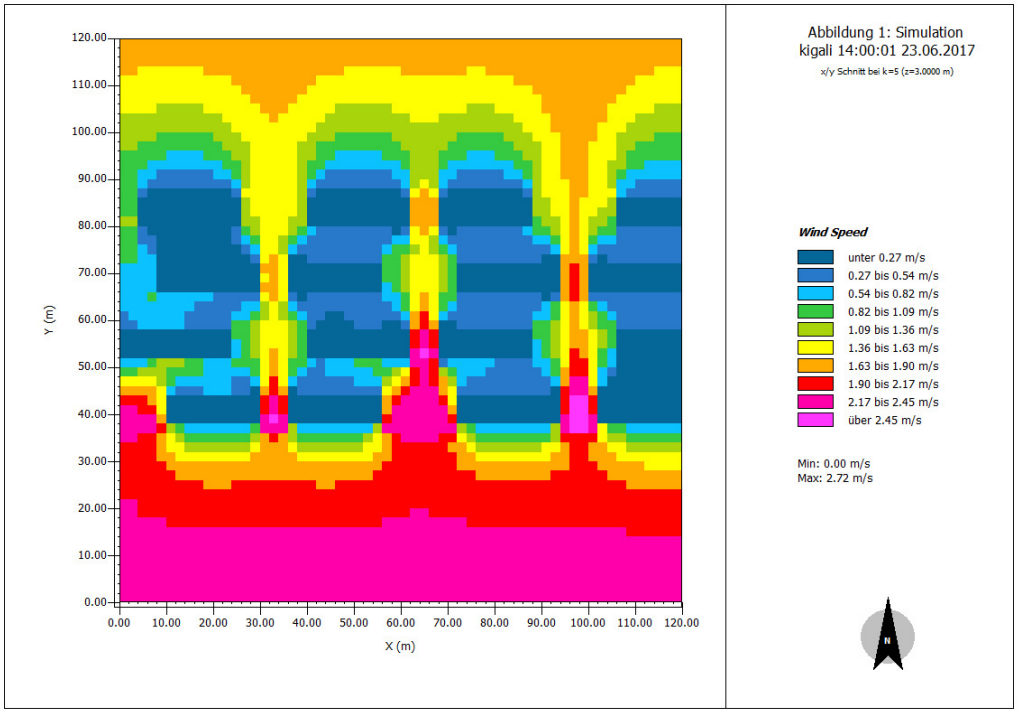
Wind Ventilation Potential

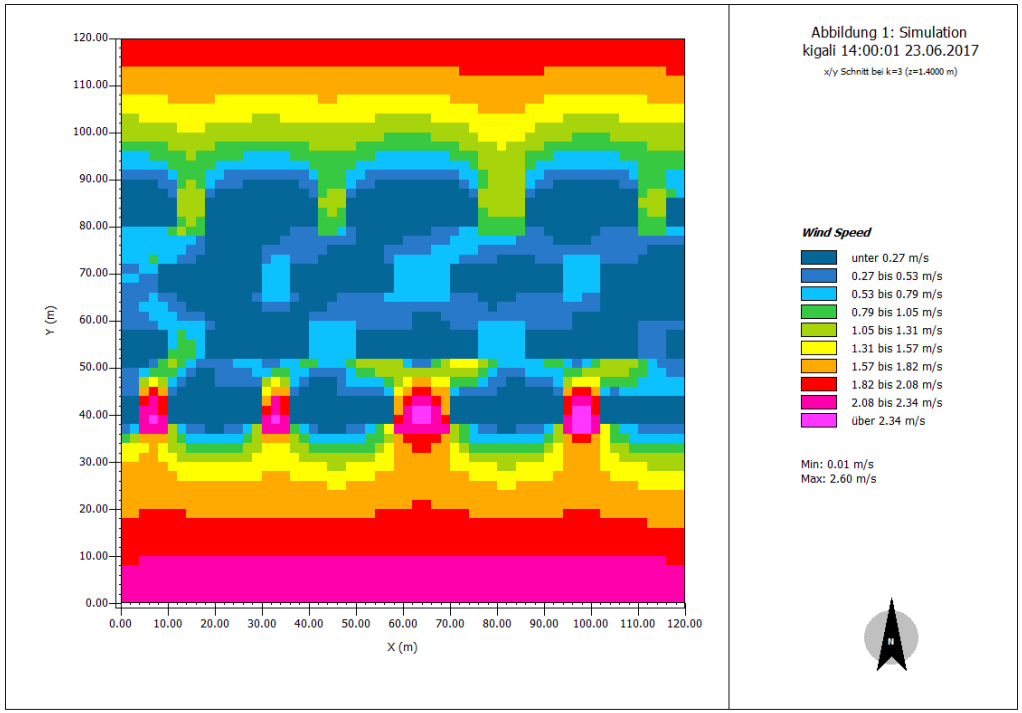


Space between

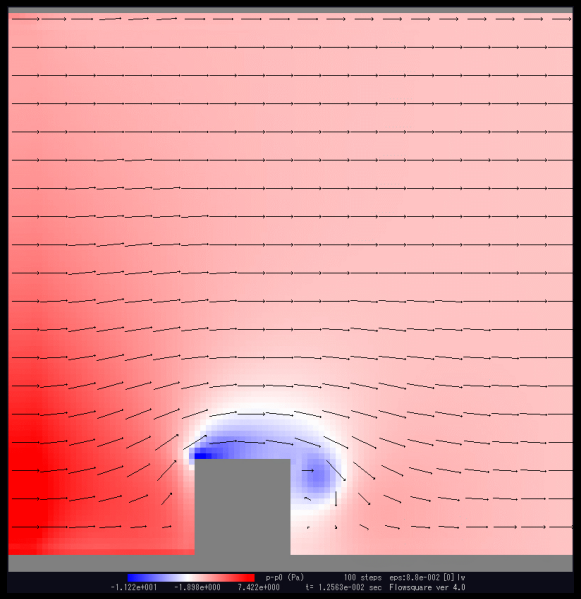


Brick Bond



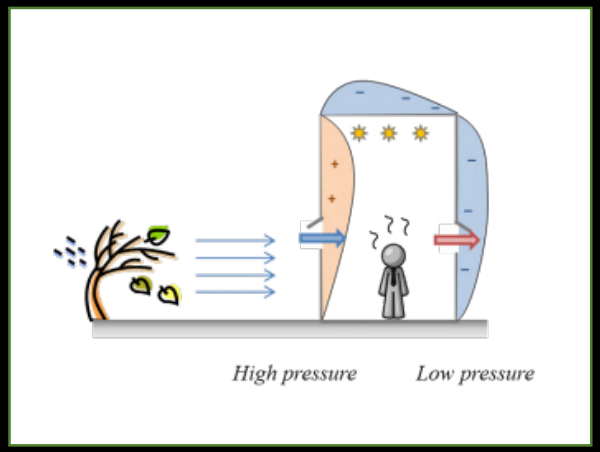


2m/s →

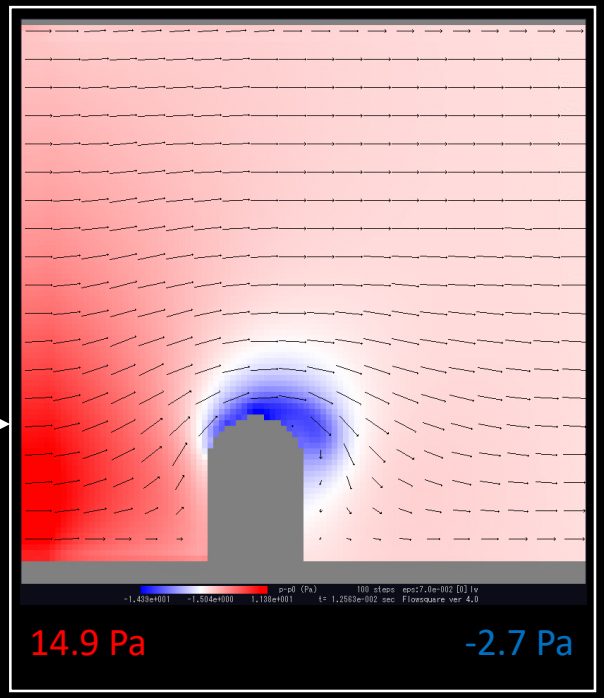


1.02 Pa

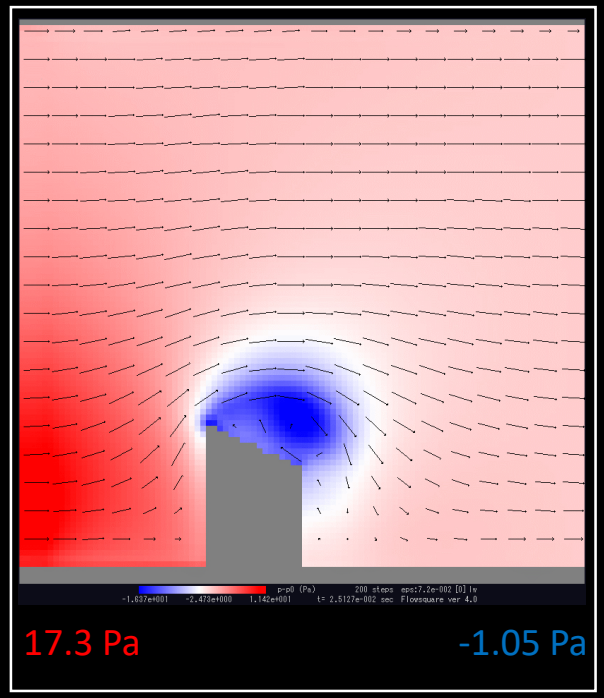
-2.7 Pa



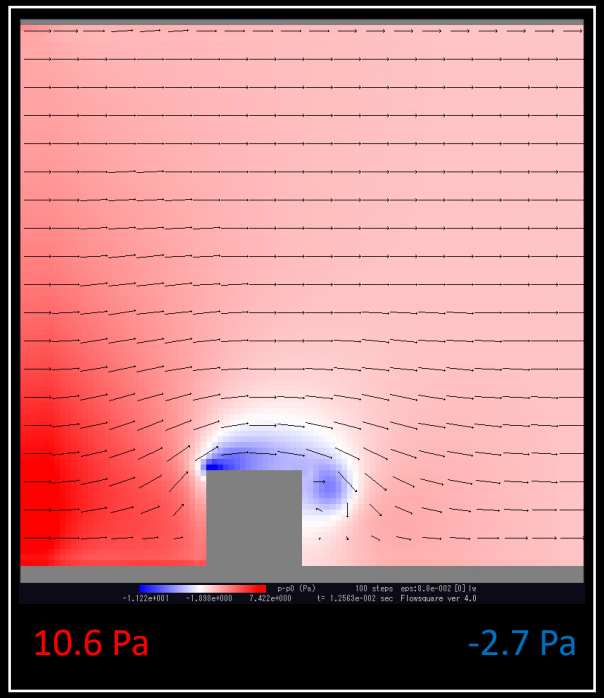
2m/s



17.6 Pa



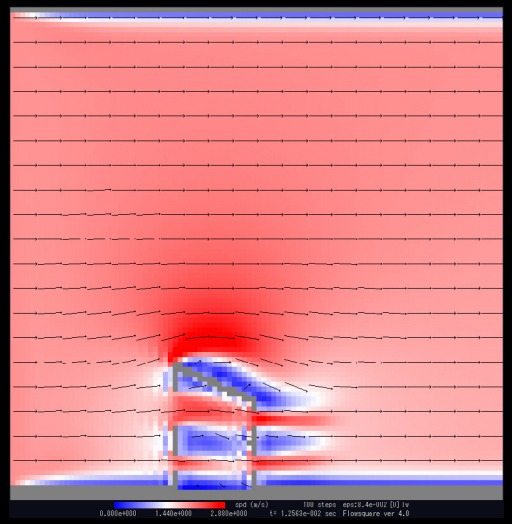
18.35 Pa



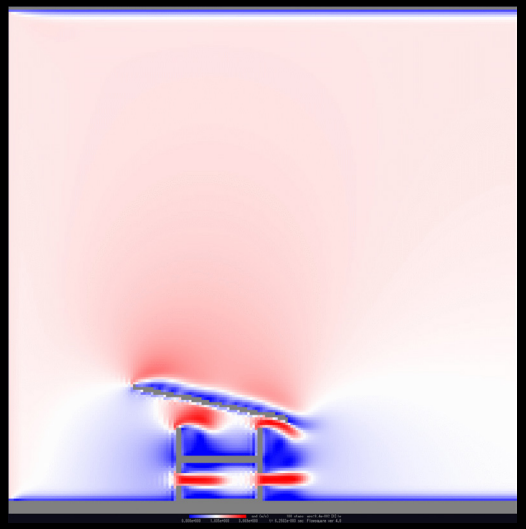
13.3 Pa

Max wind speed

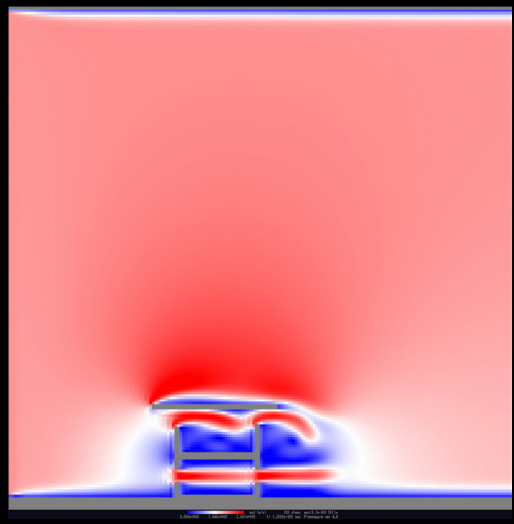
2.86 m/s



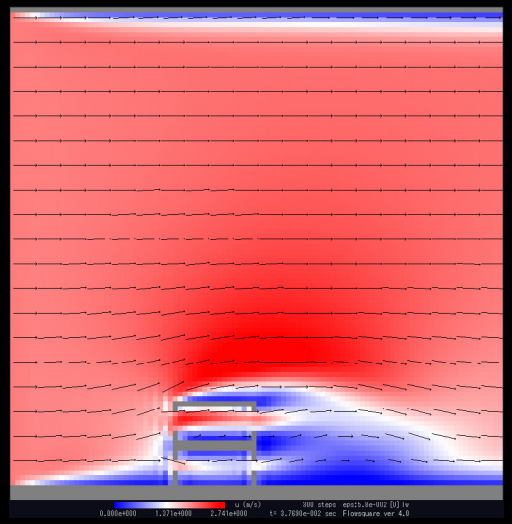
3.21m/s



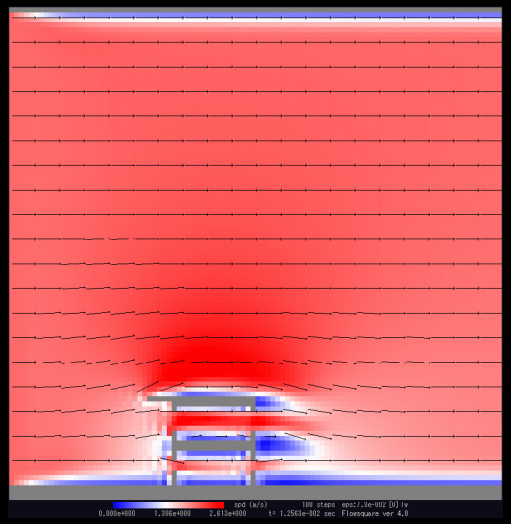
2.99m/s



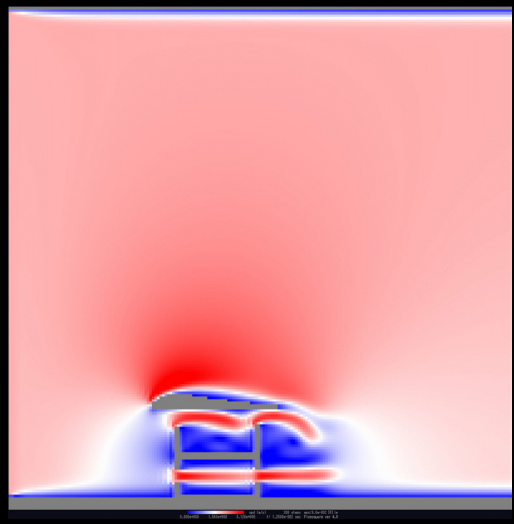
2.76 m/s

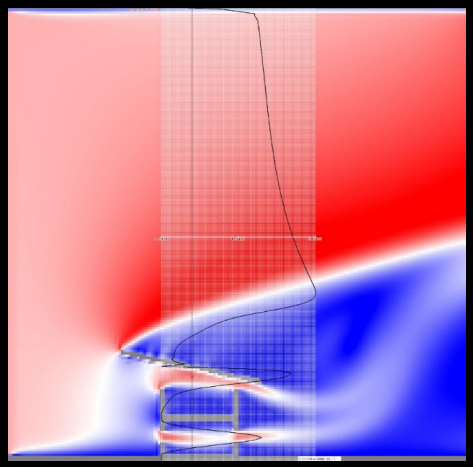


2.95m/s

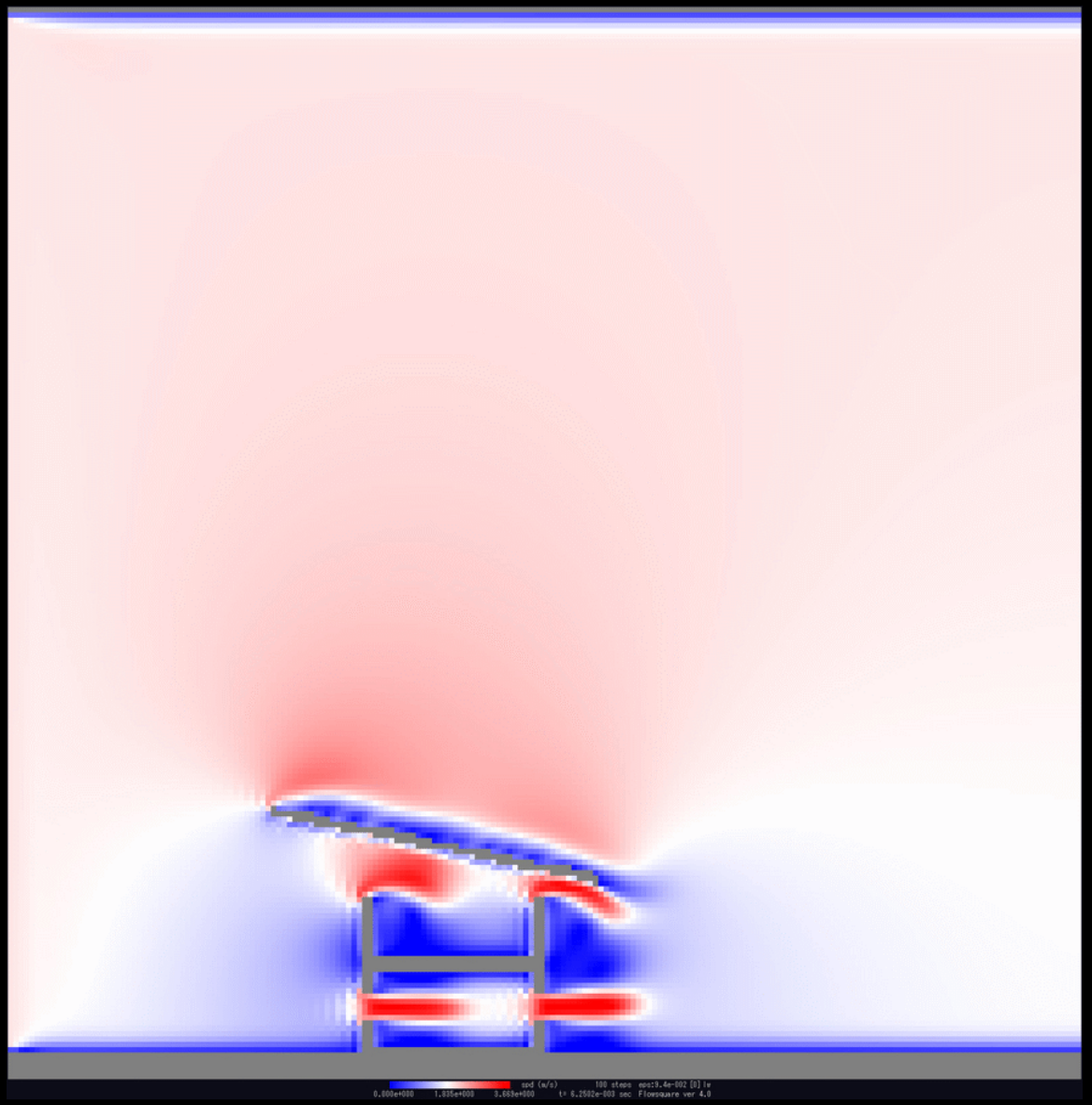


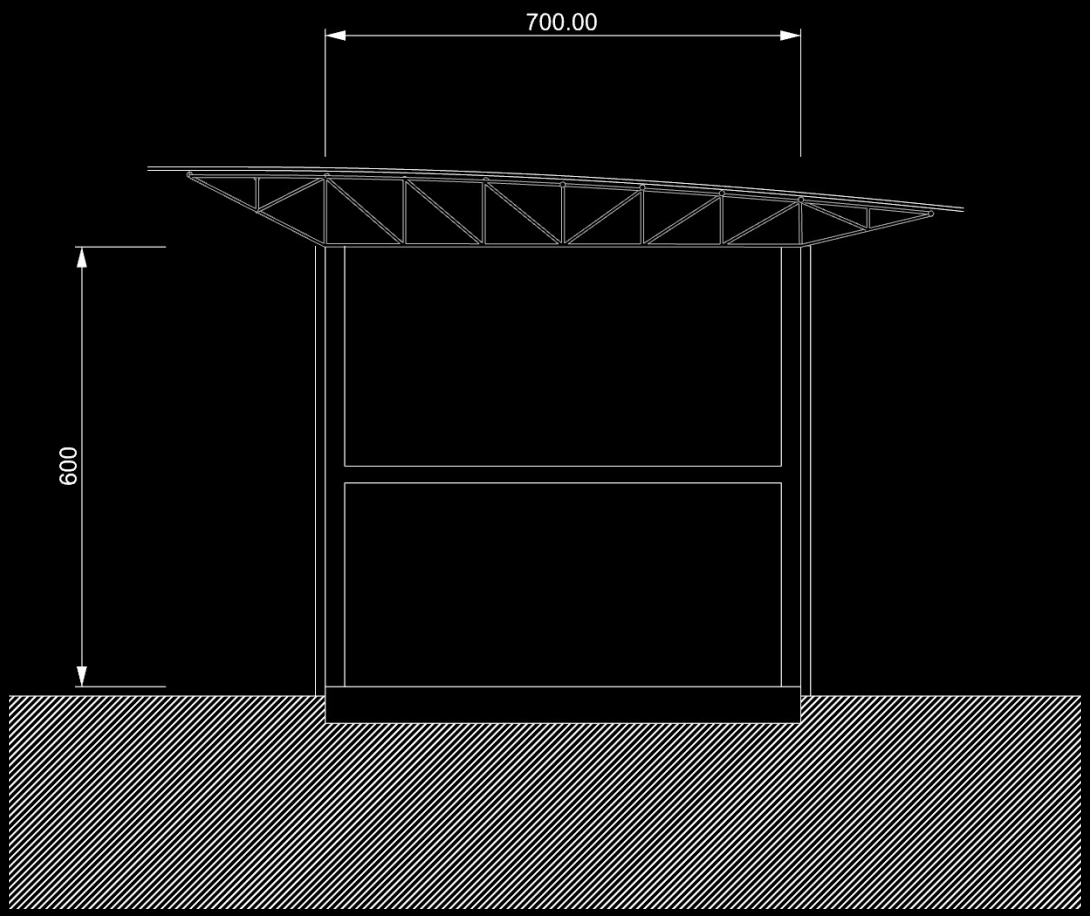
3.28m/s



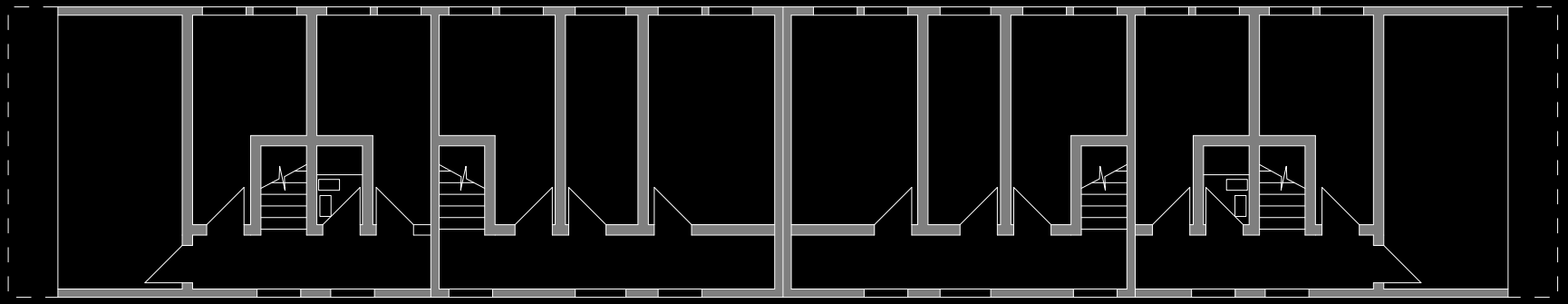


Peak flow
inside=
2.5 m/s

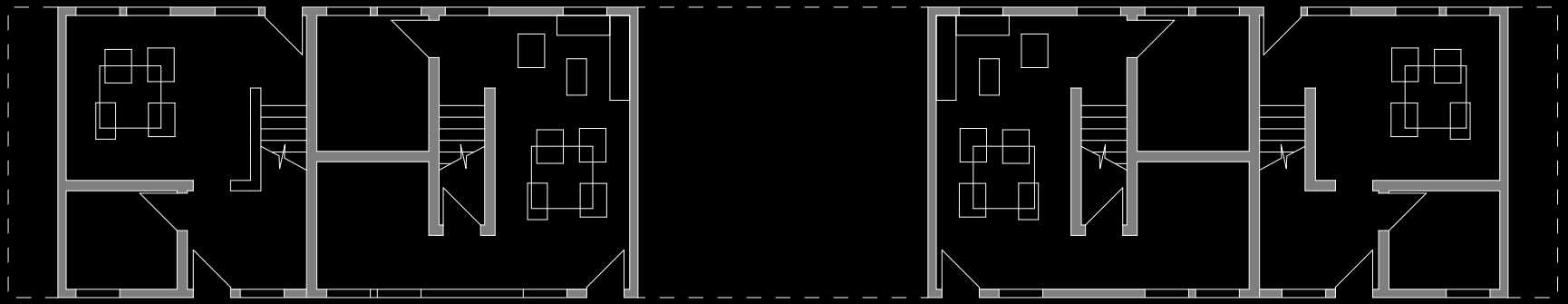



700.00
600

4433 Unit Plan



First Floor



Ground Floor

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Embodied Energy

“Although operating energy accounts for a much higher portion of CO2 and greenhouse gas emissions during the building lifecycle [2,15,17] (75%–90% operational compared to 10%–25% embodied carbon [14]), due to the negligible operational energy in Ugandan low-income housing, the embodied energy of building materials is key to evaluating the environmental impacts of the low-income housing sector.”

Hashemi, Cruickshank, and Cheshmehzangi, “Environmental Impacts and Embodied Energy of Construction Methods and Materials in Low-Income Tropical Housing.”

“According to Cabeza et al. [1], almost all available studies in the area of Life Cycle Assessment (LCA) and embodied energy have been carried out in developed countries, and there are no case studies in African countries. Ramesh et al. [2] also mention that most available studies on LCA are from “cold countries” where space heating is the major concern. There is therefore a clear gap in the literature regarding the environmental impacts and embodied energy of construction methods and materials in African countries.”

Electric Generation (15 yr Analysis)

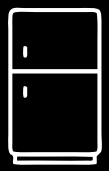
Municipal Electric Grid

On-site Diesel Generation

Localized PV Generation

Loads (not considering cooling)

Equipment



1.1 kwh/family

Lighting

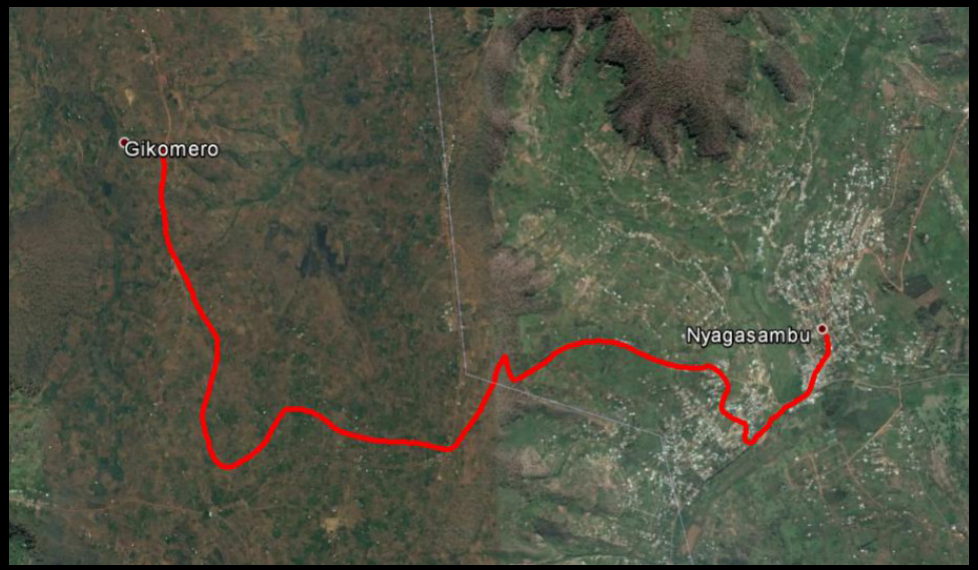
0.2 kwh/family

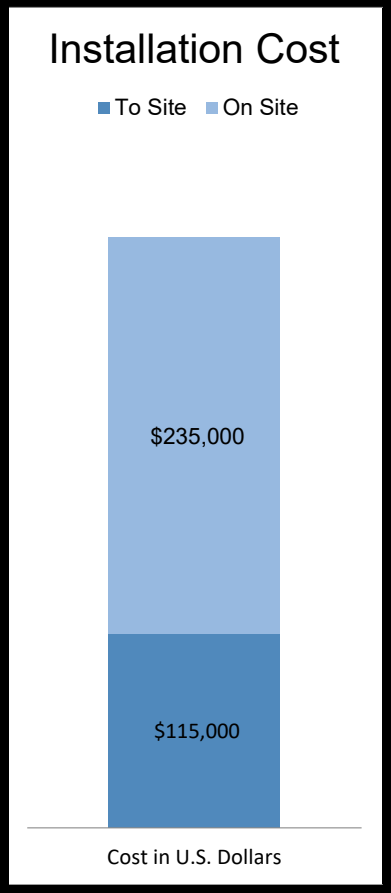
Total = 1.3kwh/family or .325kwh/person

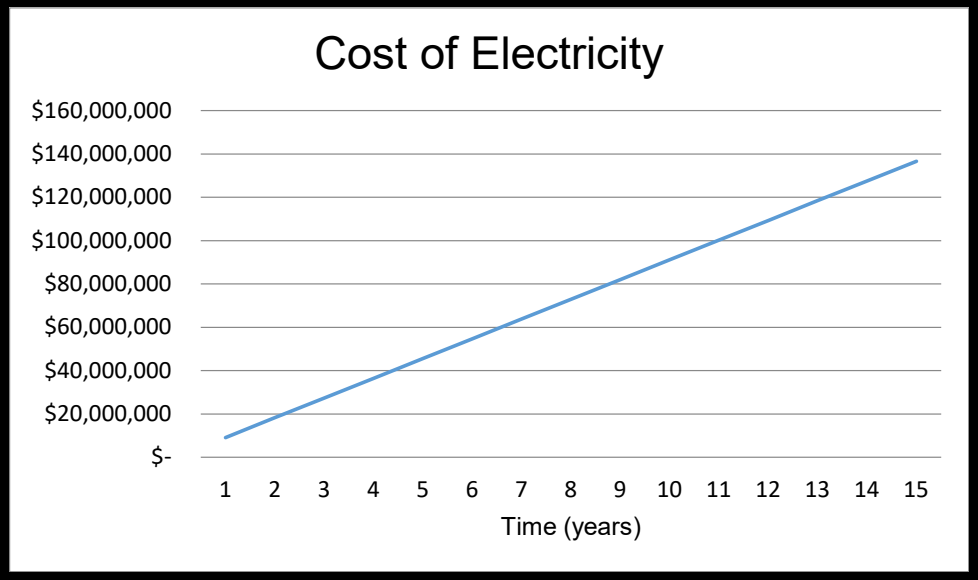
Electric Grid (10,000 people)

Factors:

Distance to transport power to site - 8km
Distance to transport power on site - 12km
cost of electricity - $0.32 / kwh



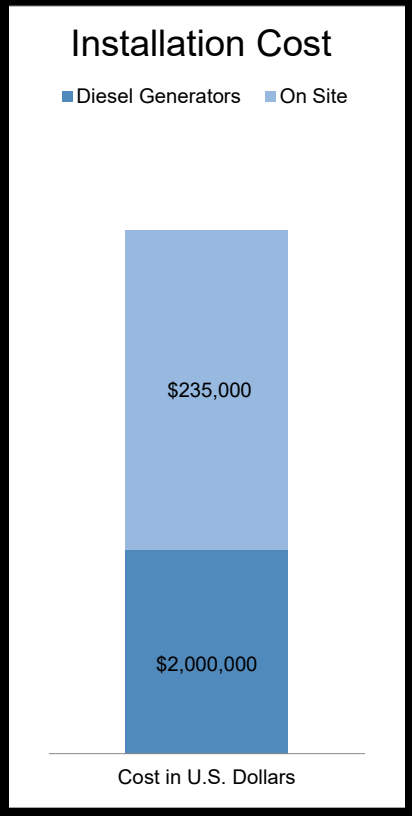


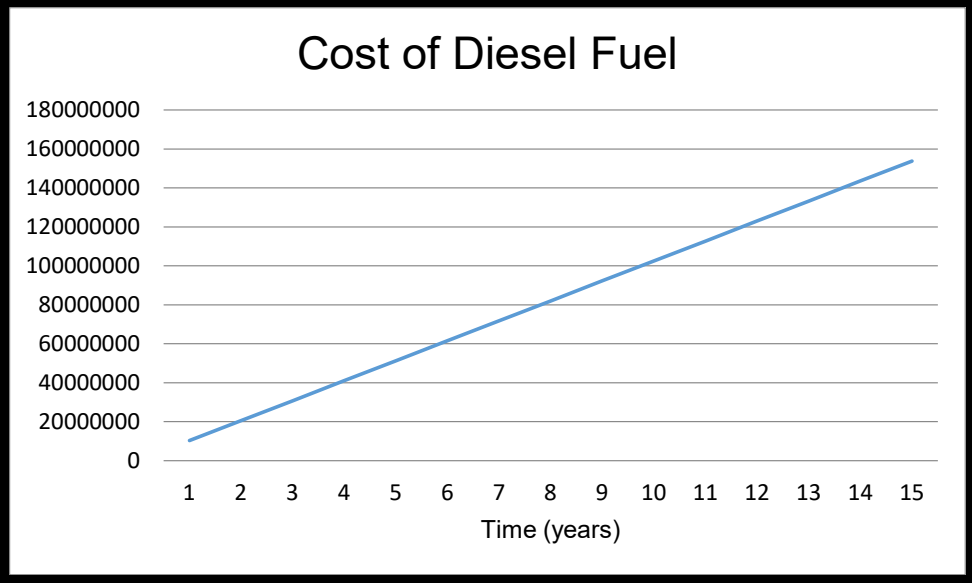


Diesel Generation (10,000 people)

Factors:

Diesel Generator Cost - $2,000,000 (for 200)
Distance to transport power on site - 12km
cost of fuel - $0.36 / kwh

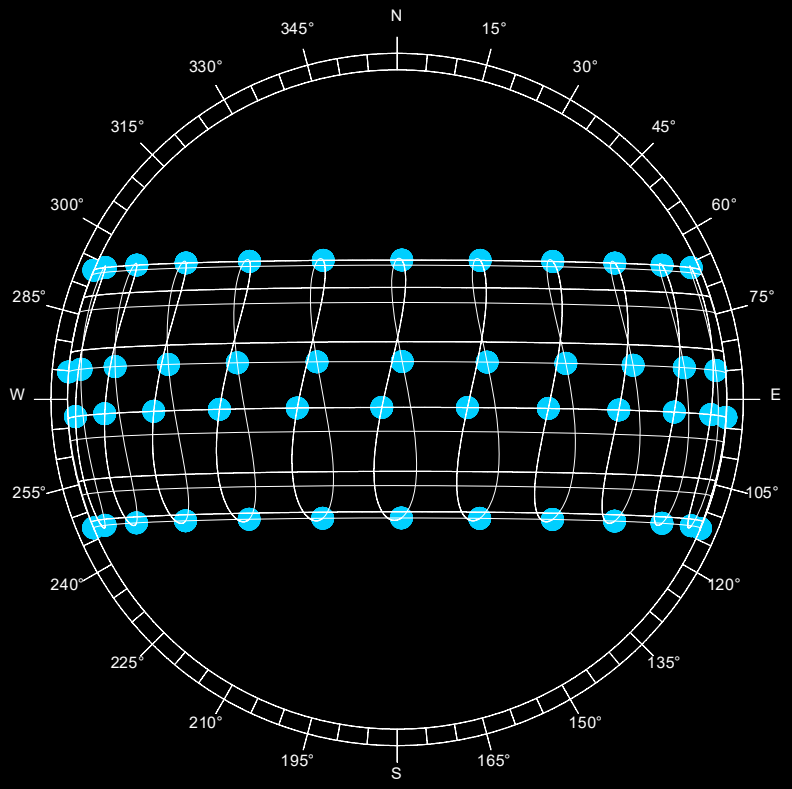




Solar PV Generation (4 people)

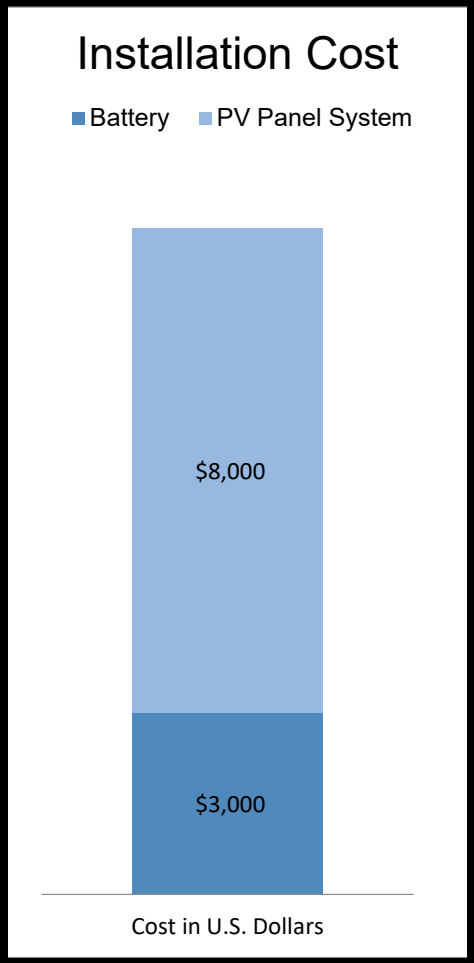
Factors:

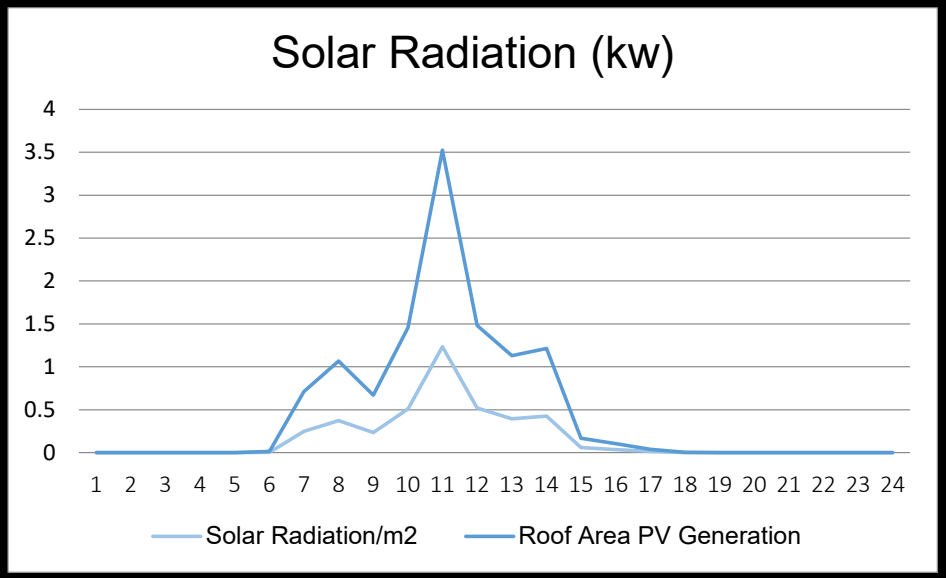
Potential Solar Radiation Generation
Amount of PV Area Coverage - 10% roof area
cost of PV system and Battery

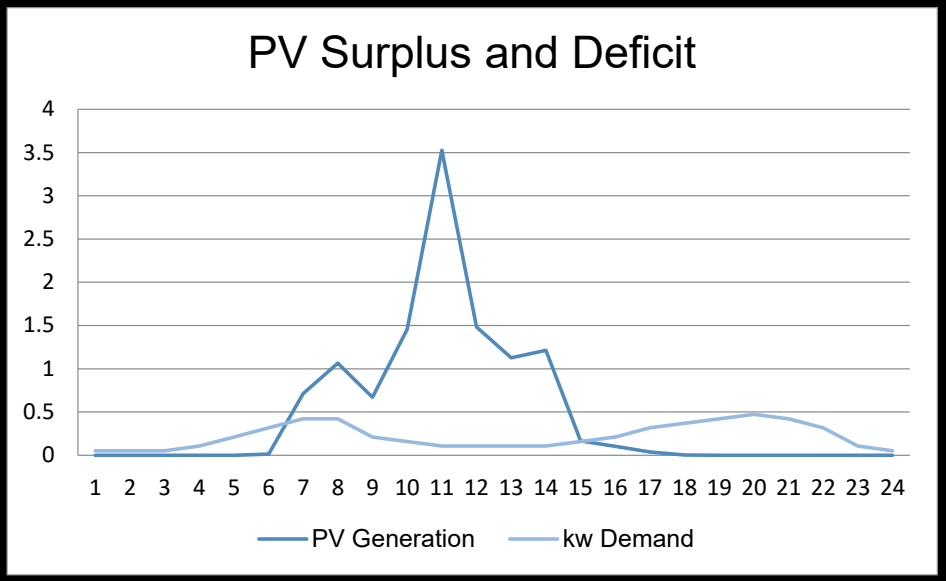


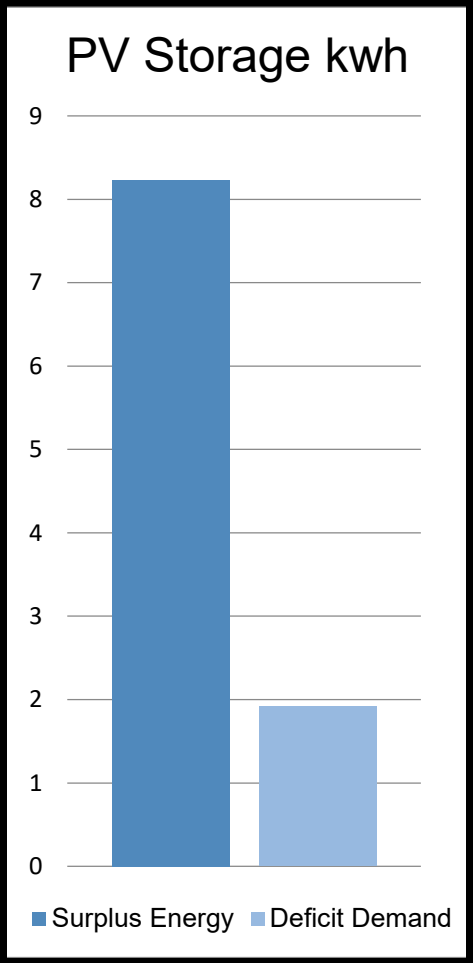
Rwanda Sunpath

Solar PV Generation (4 people)



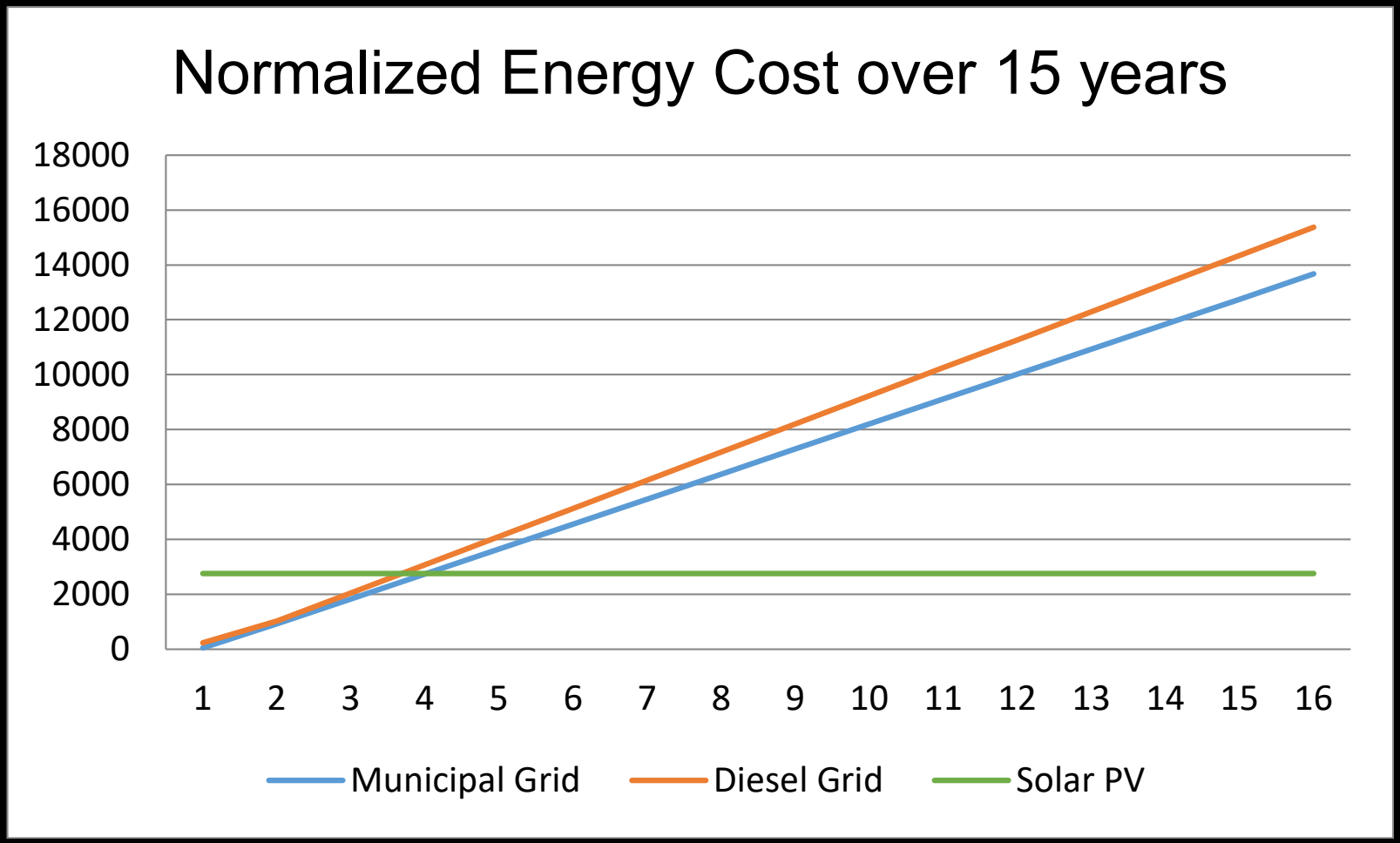






Energy Generation Normalized for 1 Person

Installation/person: Electric Grid ($35) Diesel Grid ($223) PV System ($2,750)

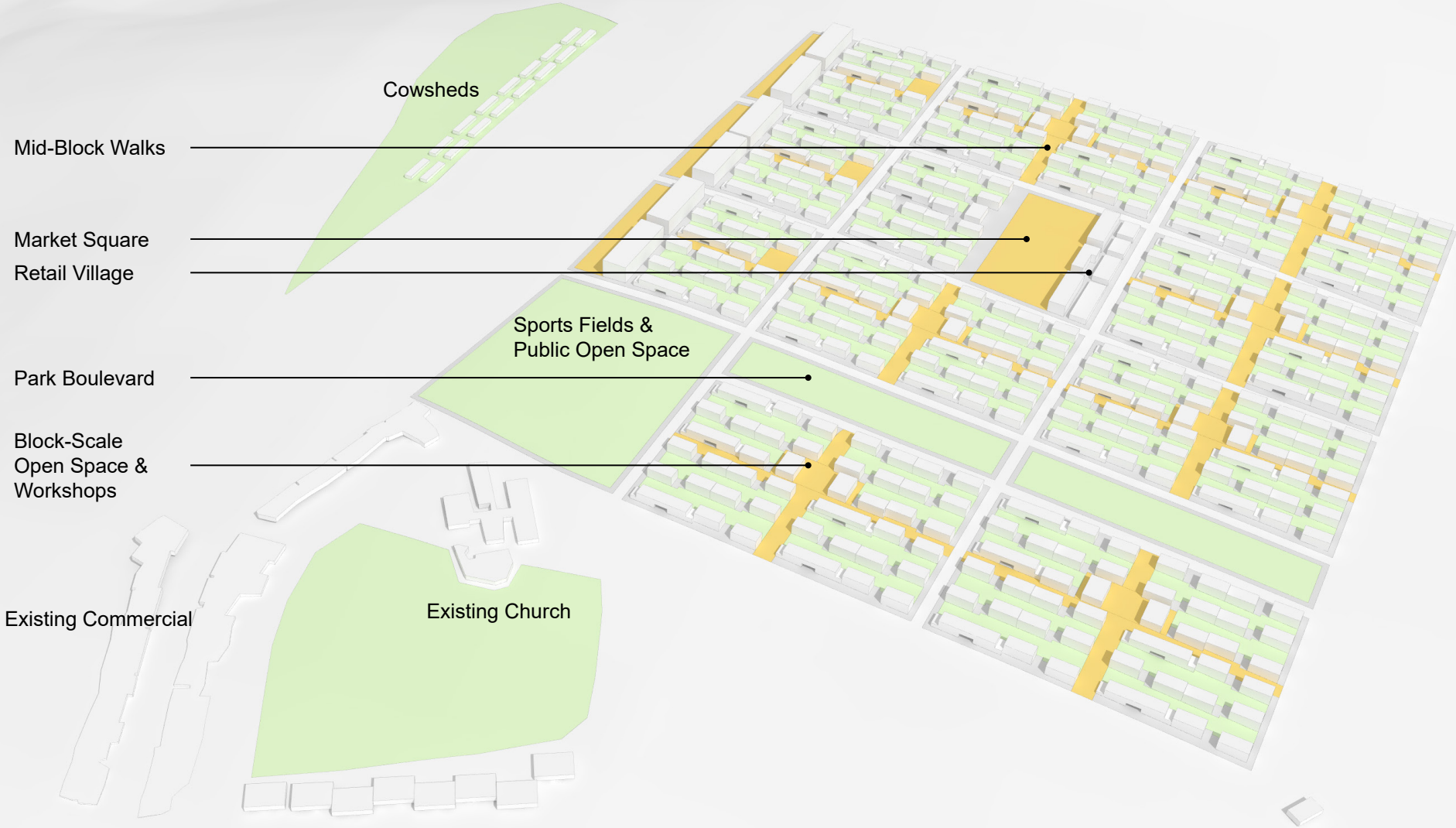


*not accounting for inflation or changes in price or technology

Lifestyle

Gikomero Current Master Plan

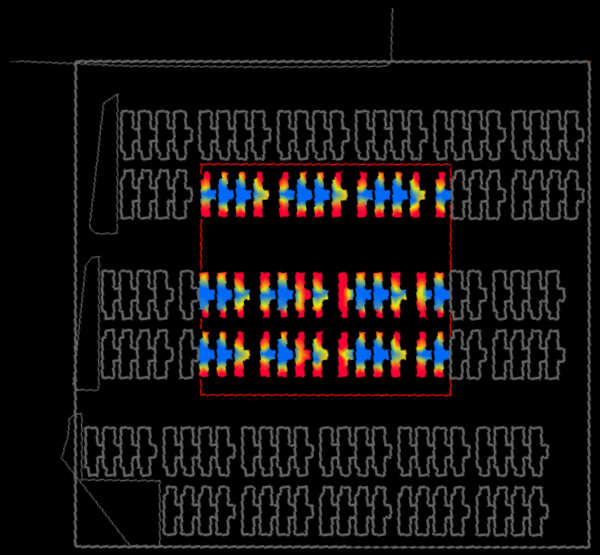
Gikomero 4433 Master Plan




Community Building
Block-Scale
Open Space &
Workshops
Mid-Block Walk
Farming
Expansion Space
(Upper)
Expansion Space
(Lower)

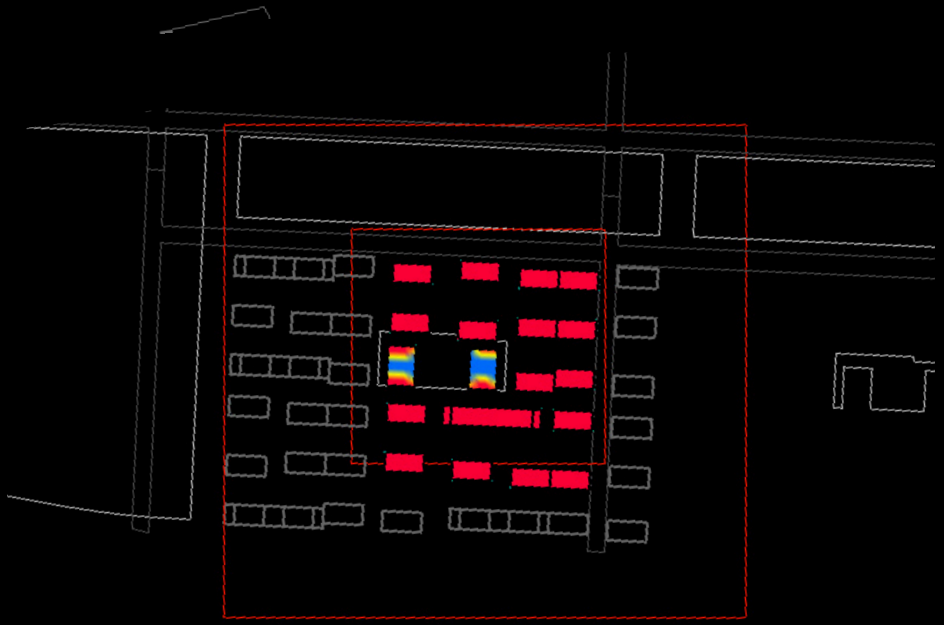
Comparison: Daylighting

RHA



42% sDA

4433

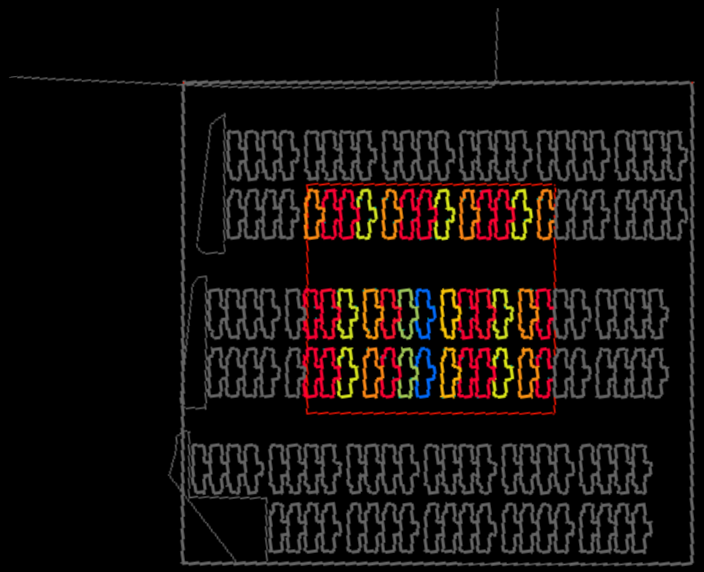


94% sDA

East West orientation and narrow floor plates increase day lighting potential

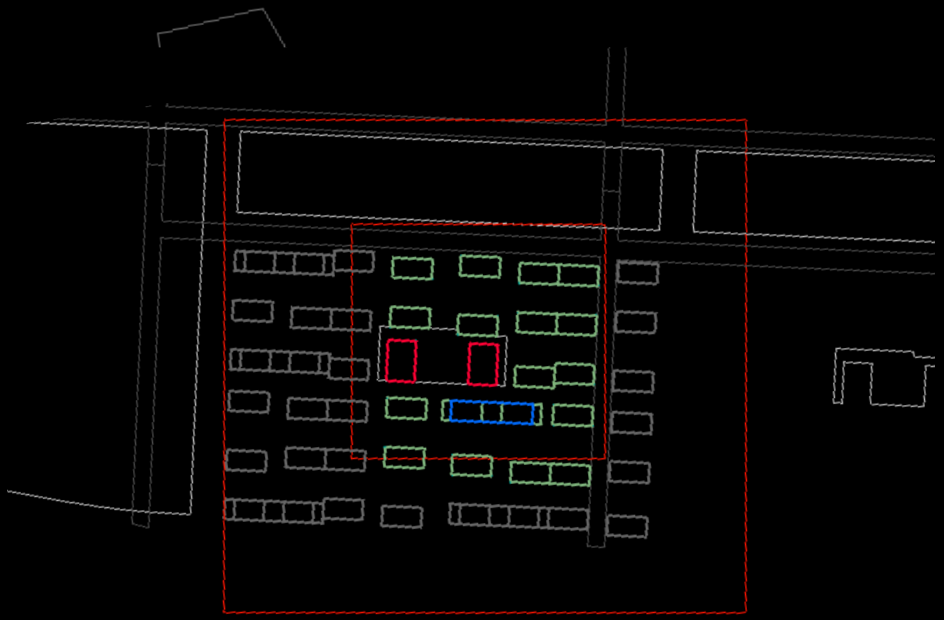
Comparison: Density

RHA



35m²/per person

4433

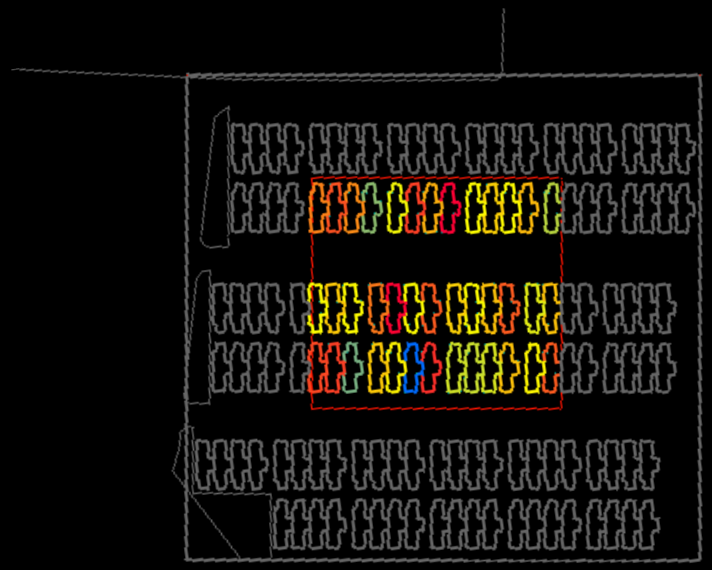


38m²/per person

2 story blocks
increase density

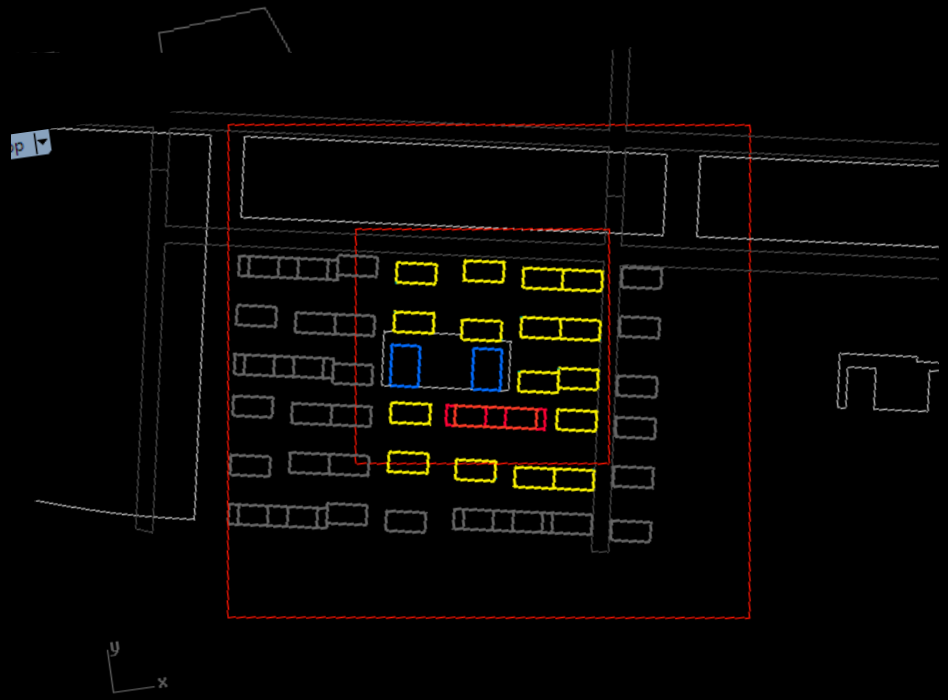
Comparison: Embodied Carbon

RHA



33.7m $KgCO2_{eq}/m2$

4433

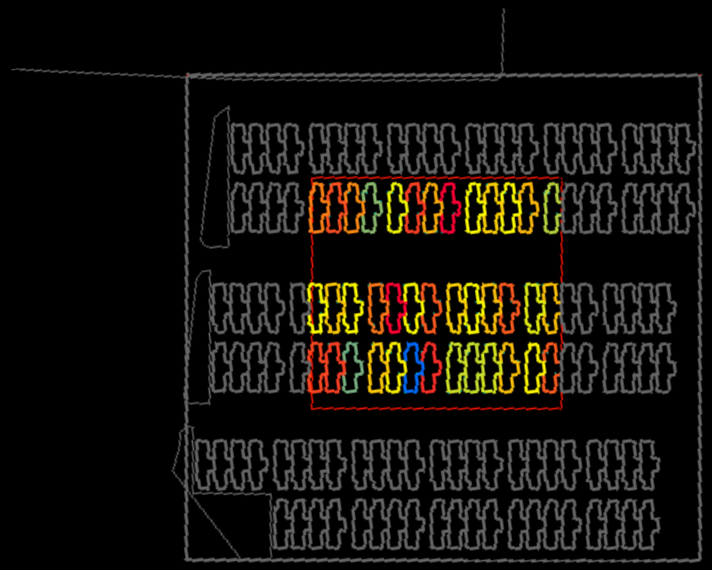


29m $KgCO2_{eq}/m2$

Shared walls and multi story construction reduces mtaerial per m2 of building

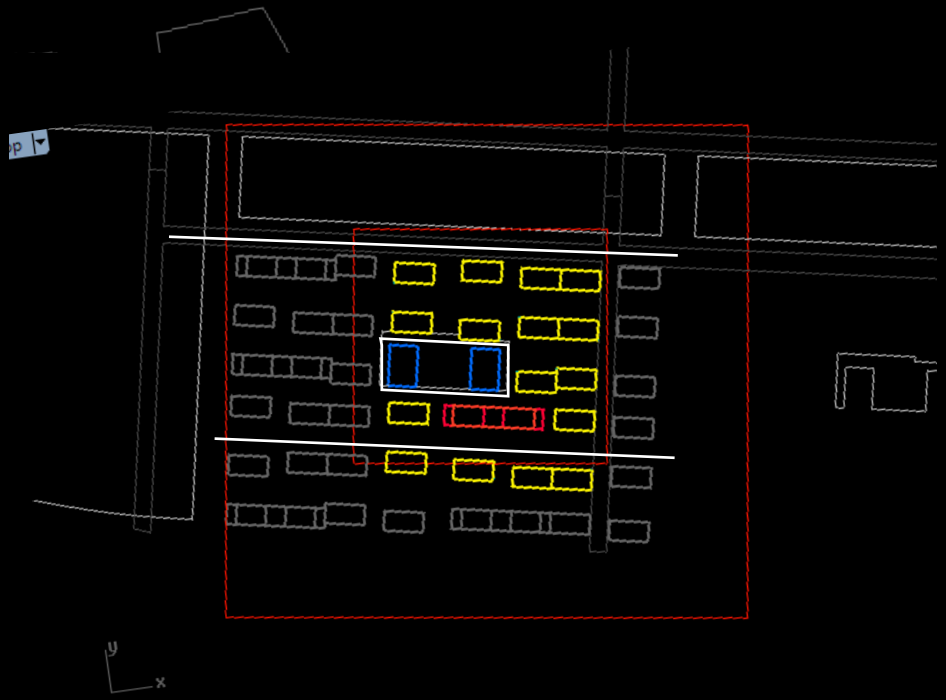
Comparison: Walkability

RHA



10 **avg. walkability score**

4433



63 **avg. walkability score**

Shops, parks and pathways within the block increase reduces distance to amenities

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