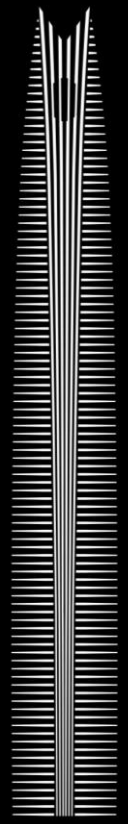


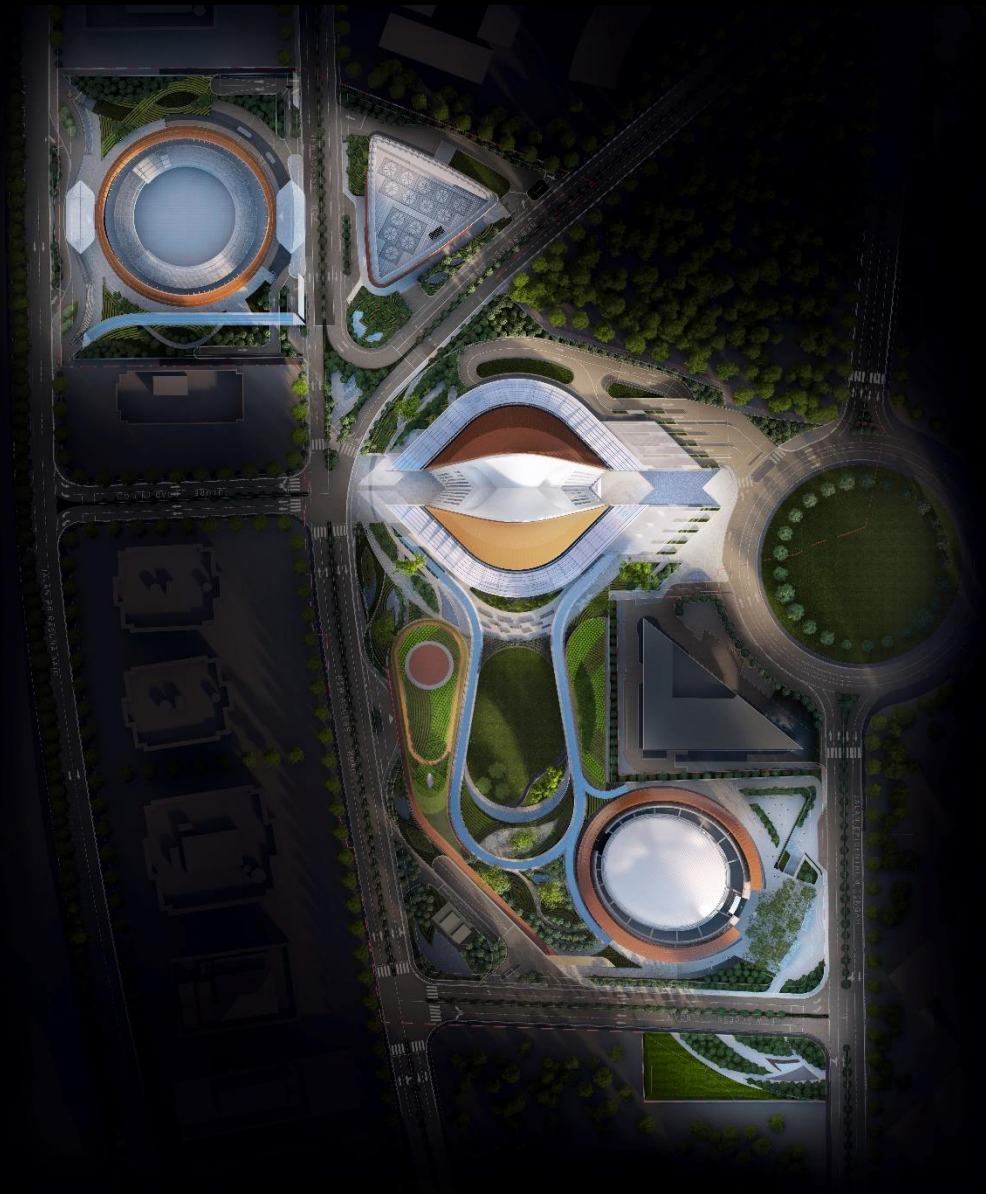
Pertamina Energy Tower

Application of deep well geothermal energy in a CHP scheme to achieve a net-zero supertall building campus in Jakarta

FEBRUARY 23, 2017

SOM

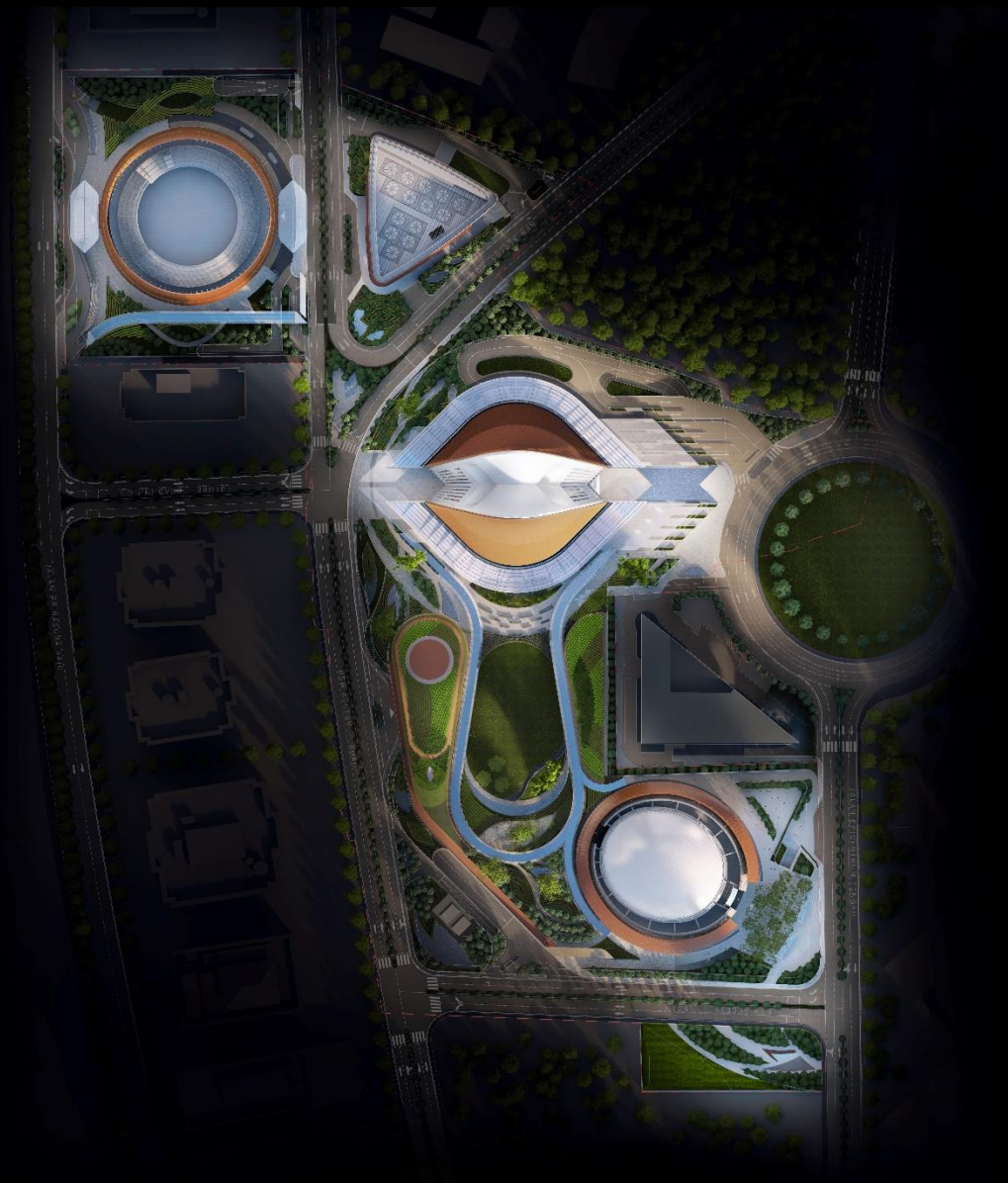
Pertamina Energy Tower Campus part of a owner’s vision



Client Goals:

- World Class Energy Company
- Water demand reduction – Zero storm discharge target
- 2020 CO2 emission reduction by 26%
- 2020 25% energy from renewable sources

Pertamina Energy Tower Campus part of a owner's vision



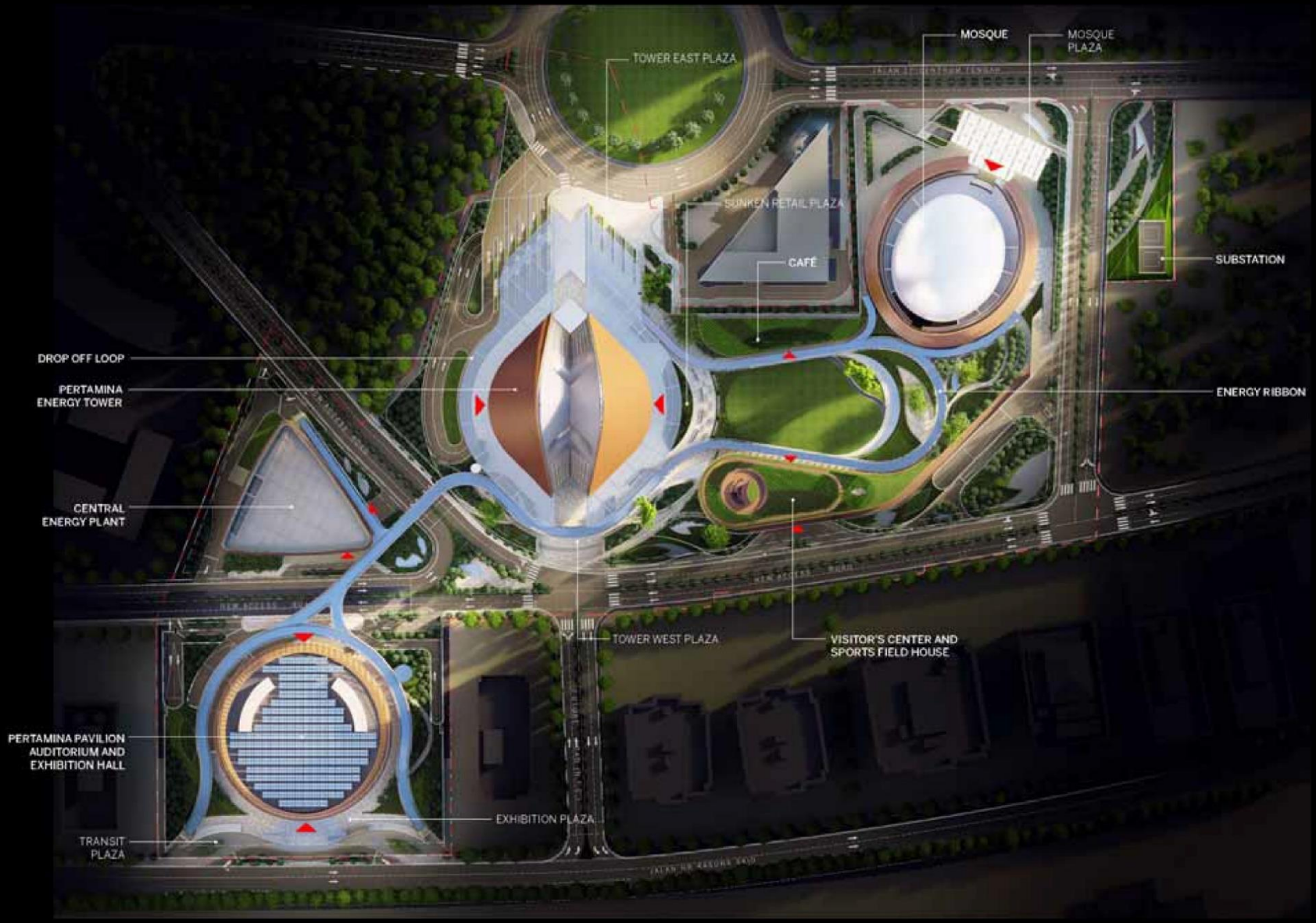
Client Goals:

- World Class Energy Company
- Water demand reduction – Zero storm discharge target
- 2020 CO_2 emission reduction by 26%
- 2020 25% energy from renewable sources

Project Pursuing:

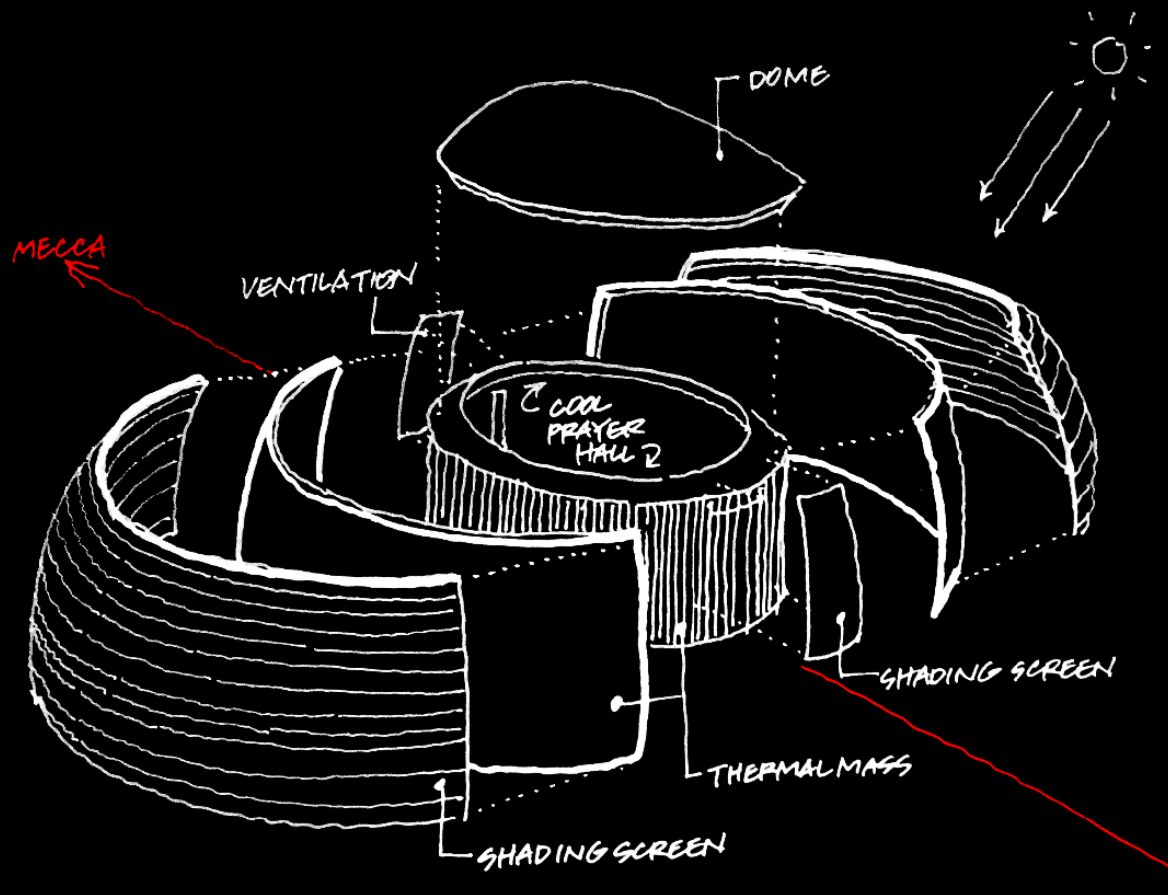
- Rain water harvesting – Zero storm discharge target
- Onsite black water treatment
- Energy management
    - Reduction demand
    - Sub-metering
    - Occupant awareness tools / behavioral changes
- Supply by mix of energy sources
    - Solar
    - Wind
    - Geothermal
    - Biodiesel

Pertamina Energy Tower Campus part of a owner's vision

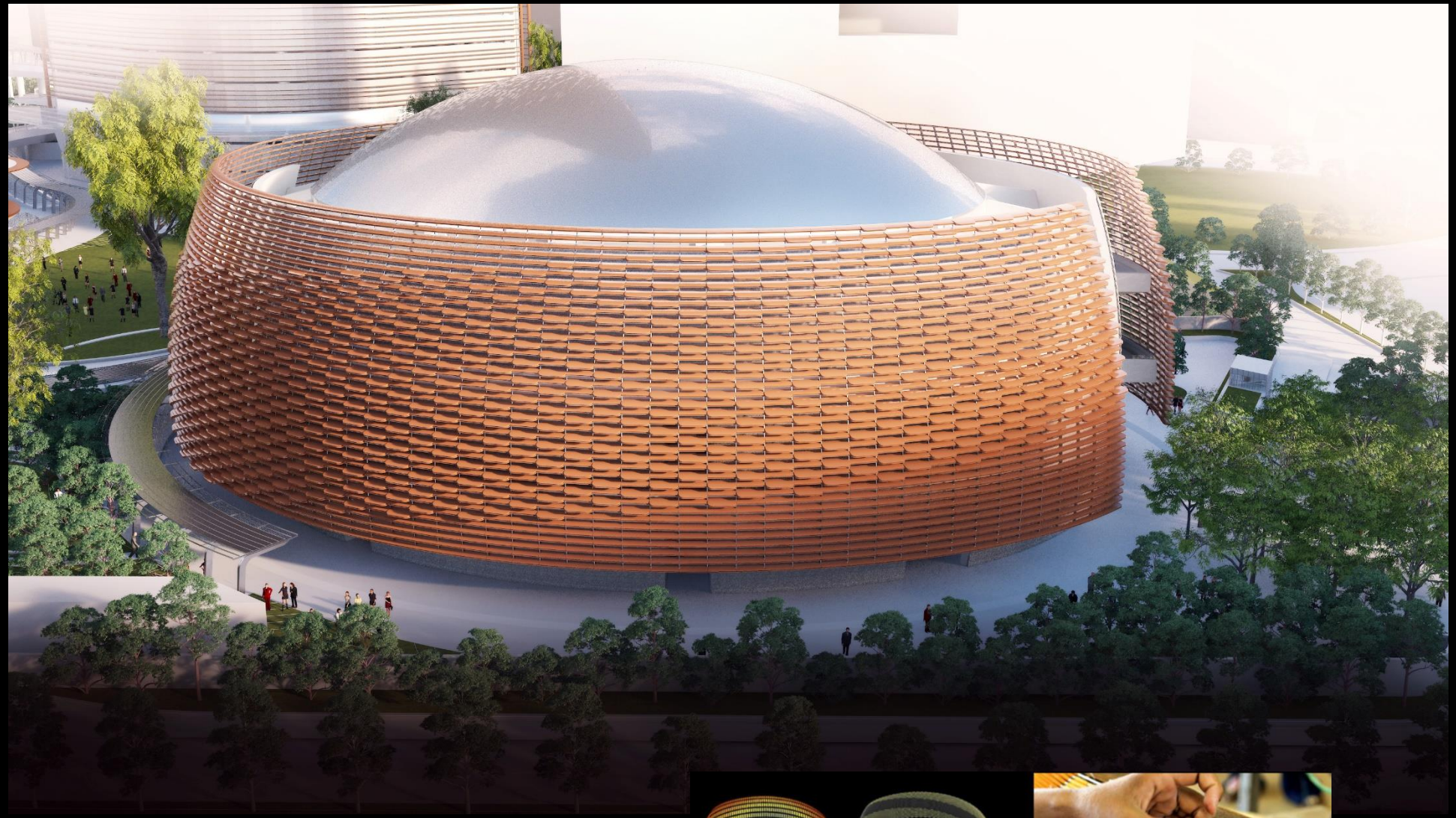


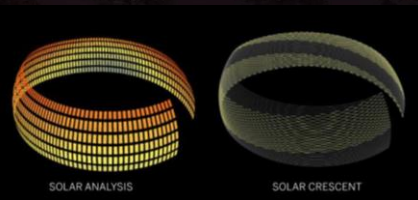
CAMPUS ENERGY 2017
SKIDMORE, OWINGS & MERRILL LLP

Mosque


DOME
MECCA
VENTILATION
COOL PRAYER HALL
SHADING SCREEN
THERMAL MASS
SHADING SCREEN

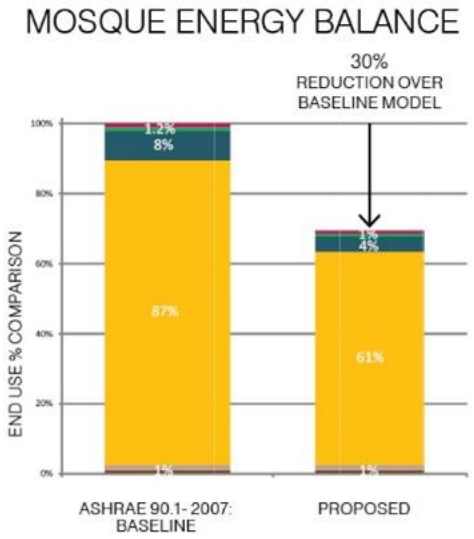
Mosque

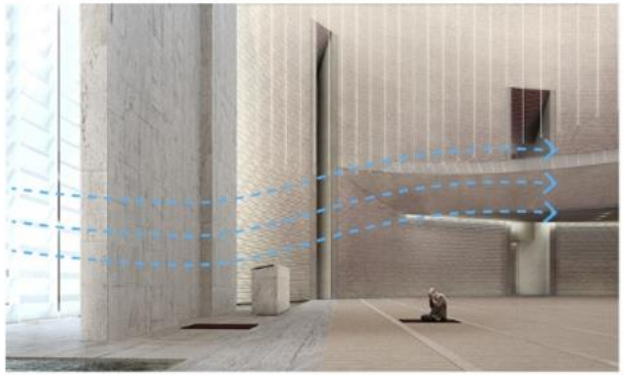




Mosque

Energy Performance

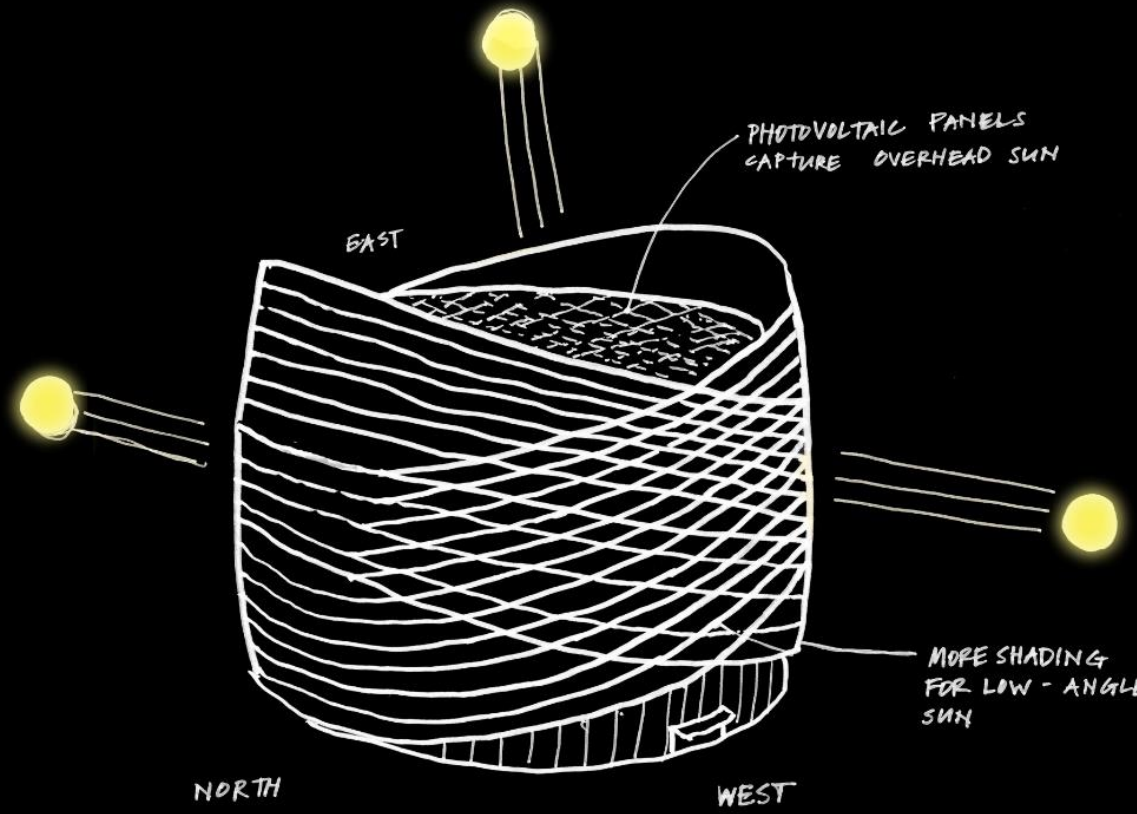




PASSIVE COOLING USING NIGHT FLUSH
AND THERMAL MASS

LEGEND
- DHW
- ELEVATOR
- FANS
- PUMPS
- COOLING
- INTERIOR EQUIPMENT
- ELEVATOR
- INTERIOR LIGHTING
- EXTERIOR LIGHTING

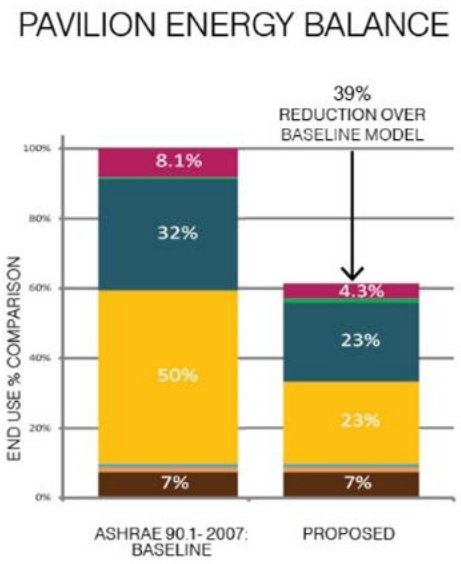
Pavilion



The exterior façade of the Pavilion is inspired by traditional Indonesian textiles and weaving, but is optimized to shade the interior from the sun: denser “weaving” is located on the east and west for low angle sun and horizontal shades for the north and south sun.

Pavilion

Pavilion



EXTERIOR FINS BLOCK DIRECT SOLAR IRRADIATION

FILTERED DAYLIGHT

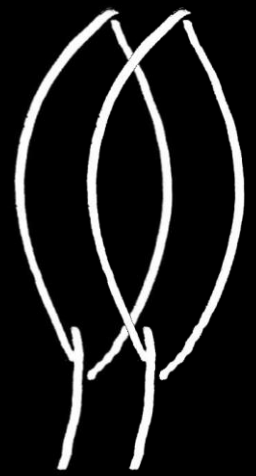
LEGEND
- DHW
- ELEVATOR
- FANS
- PUMPS
- COOLING
- INTERIOR EQUIPMENT
- ELEVATOR
- INTERIOR LIGHTING
- EXTERIOR LIGHTING

Energy Tower

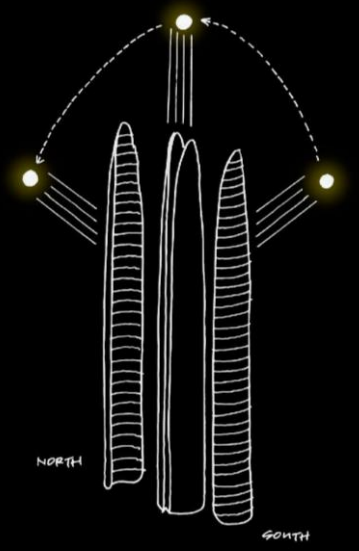
A Design shaped by the Sun

The design concept for the project is inspired by the protective qualities of the leaf, a symbol of the lush Indonesian landscape and a symbol of Pertamina and its sustainability mission.

The Leaf



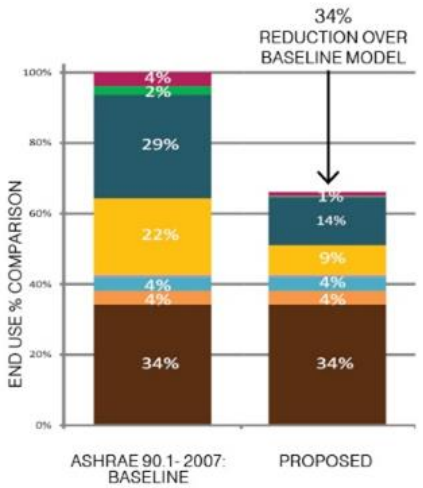
Two Leaves

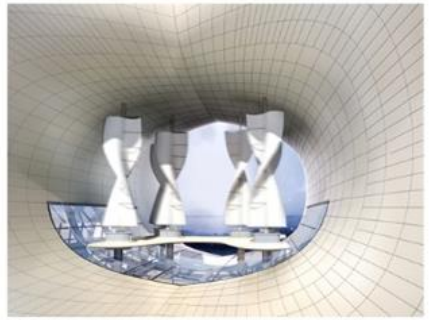


The Twin-Leaf Tower

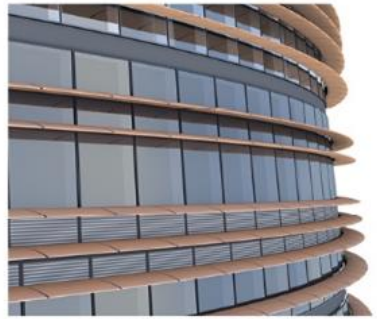
Energy Tower

TOWER ENERGY BALANCE





WIND FUNNEL ACCELERATES WIND OVER WIND TURBINES

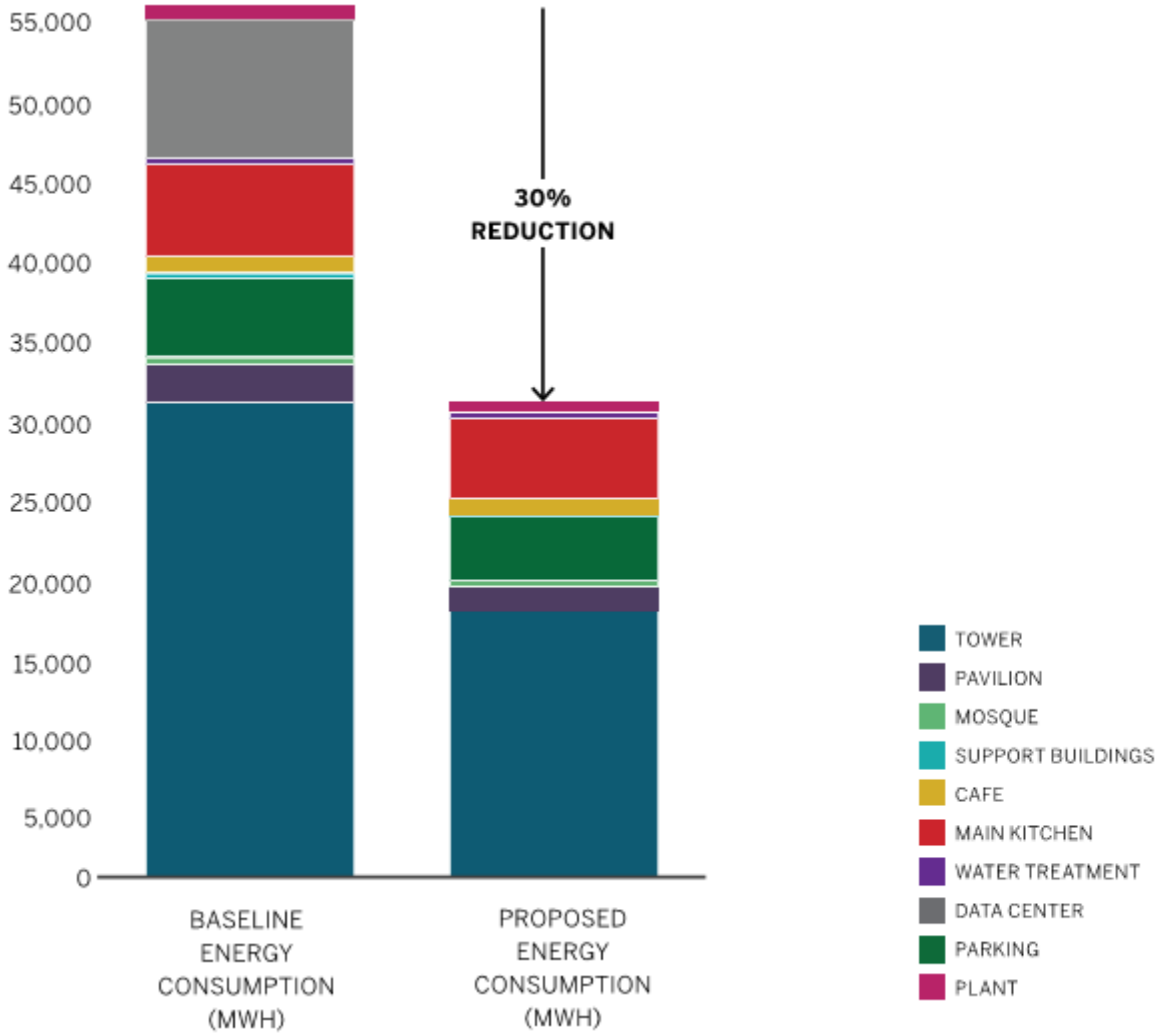


EXTERIOR FINS BLOCK DIRECT SOLAR IRRADIATION

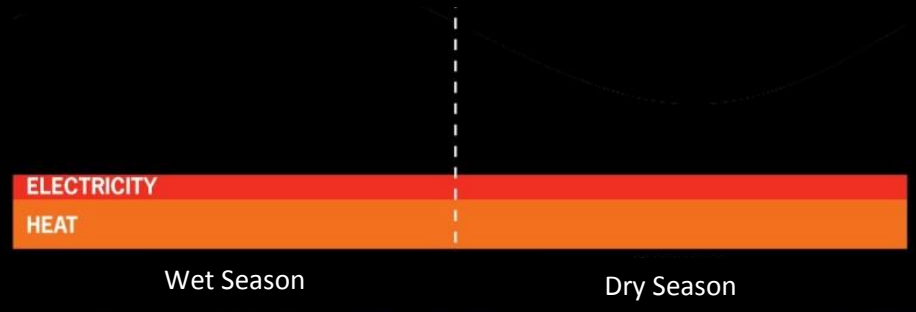
LEGEND
- DHW
- ELEVATOR
- FANS
- PUMPS
- COOLING
- INTERIOR EQUIPMENT
- ELEVATOR
- INTERIOR LIGHTING
- EXTERIOR LIGHTING

High Performance Design

Design Reductions



Geothermal



Geothermal

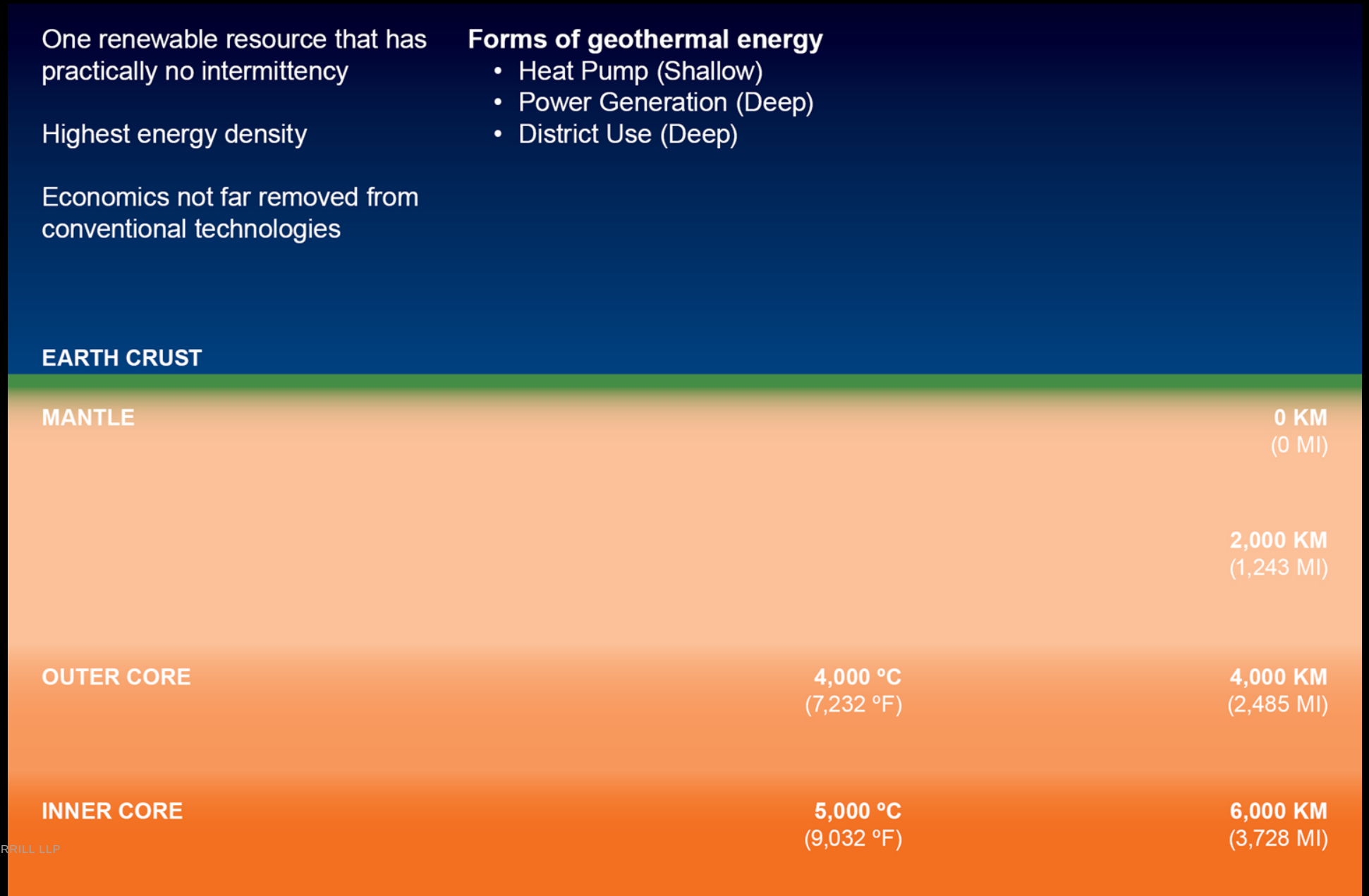
One renewable resource that has practically no intermittency

Highest energy density

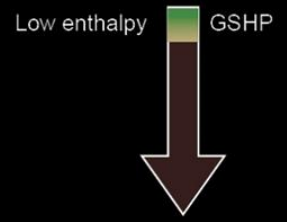
Economics not far removed from conventional technologies

Forms of geothermal energy

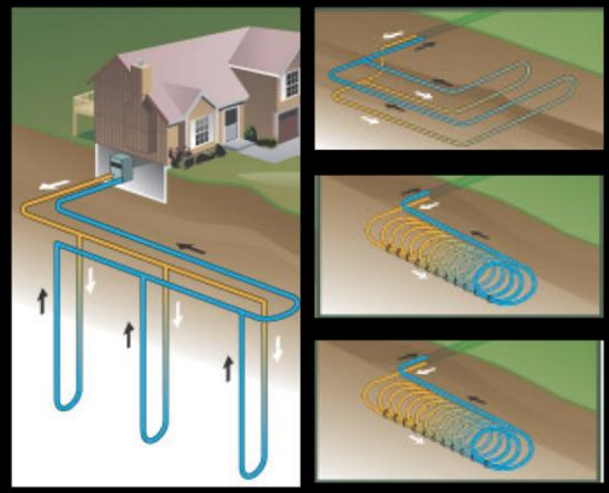
- Heat Pump (Shallow)
- Power Generation (Deep)
- District Use (Deep)



Ground Source Heat Pump



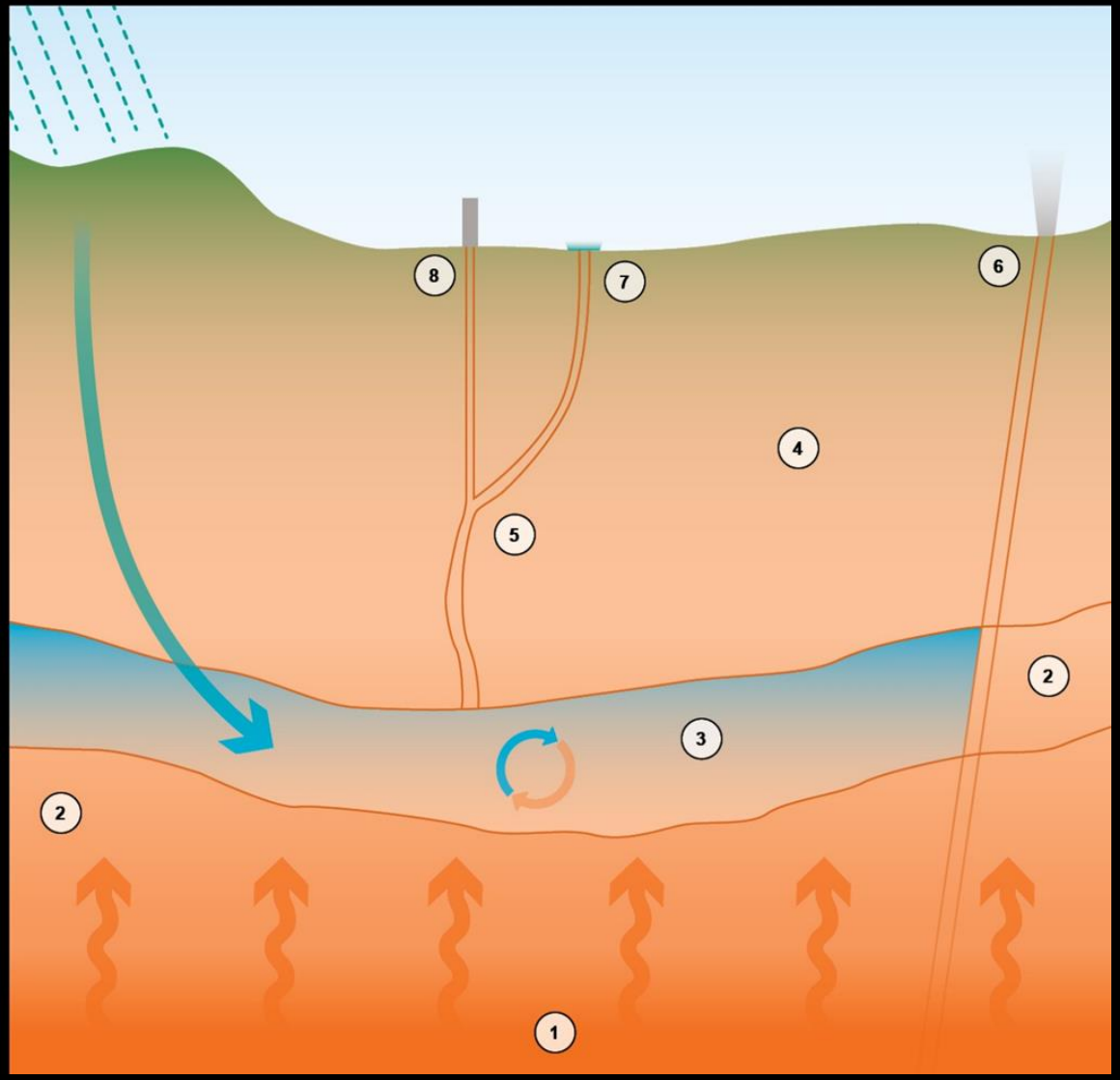
The geothermal field plays the role of a heat exchanger that feeds a heat pump to deliver heating and cooling.



Geothermal Field

Near-surface or shallow geothermal energy - heating and cooling of buildings

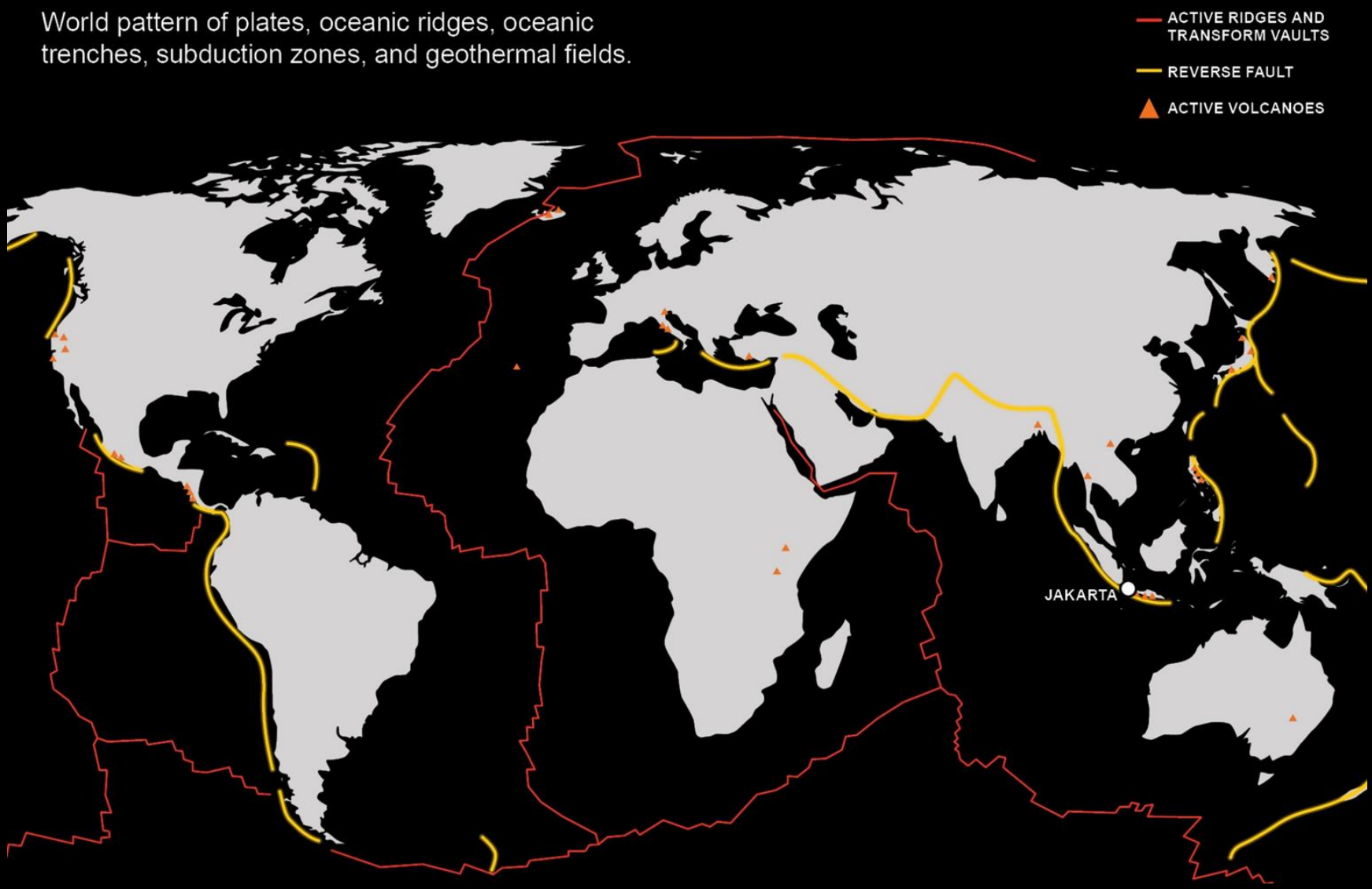
Deep geothermal energy for electricity and heat production



1. MAGMA
2. HOT (FIERY) ROCK
3. PERMEABLE RESERVOIR
4. IMPERMEABLE SOLID ROCK
5. FISSURES (CRACKS)
6. GEYSERS
7. HOT SPRINGS
8. GEOTHERMAL WELL

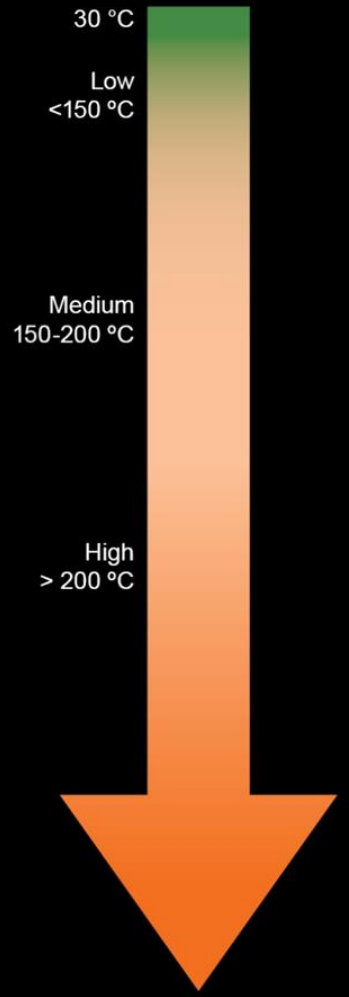
Geothermal Resources

World pattern of plates, oceanic ridges, oceanic trenches, subduction zones, and geothermal fields.



Geothermal Resources

Type and Use of Geothermal Resources



	Application and Technology	Geographical and geological location
Low <150 °C	Thermal energy generation with Ground source heat pump Power generation with binary power plants	Exist in most countries where average temperature gradient is around 30 °C/km
Medium 150-200 °C	Power generation with binary power plants	Globally mainly in sedimentary geology or adjacent to high temperature resources
High > 200 °C	Power generation with conventional steam, flash, double flash, or dry steam technology	Globally around boundaries of tectonic plates, on hot spots and volcanic areas

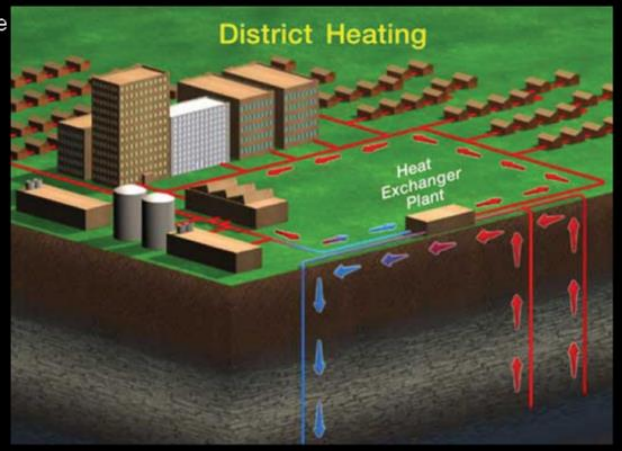
Source: Geothermal handbook: planning and financing power generation, ESMAP 2012

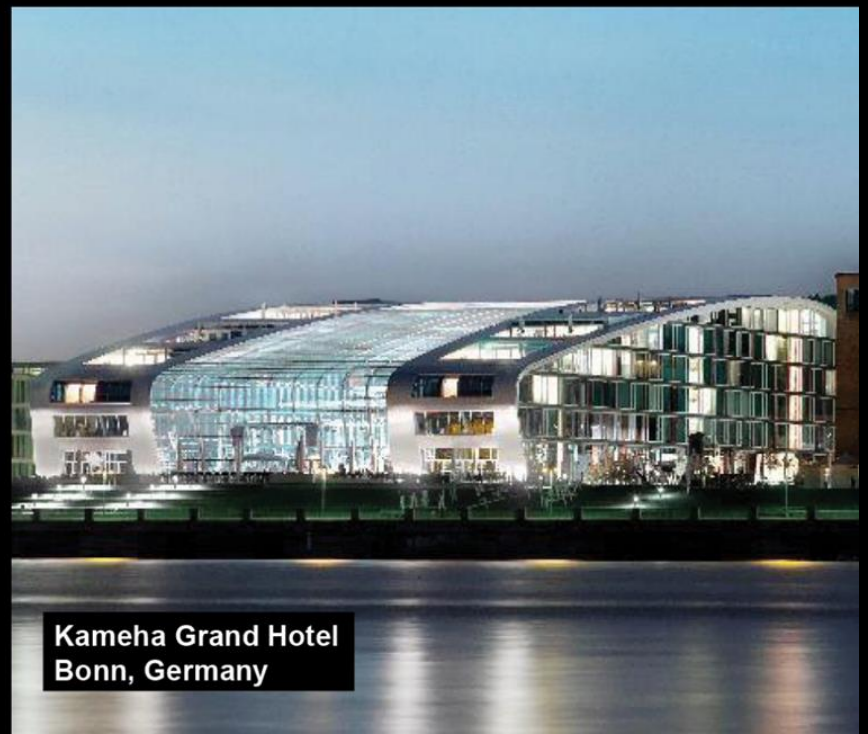
Direct Use

Low enthalpy

Direct Use

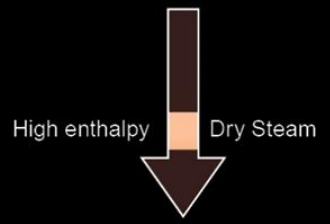
Direct use of underground hot fluid to provide heating or cooling for district or singular building use.

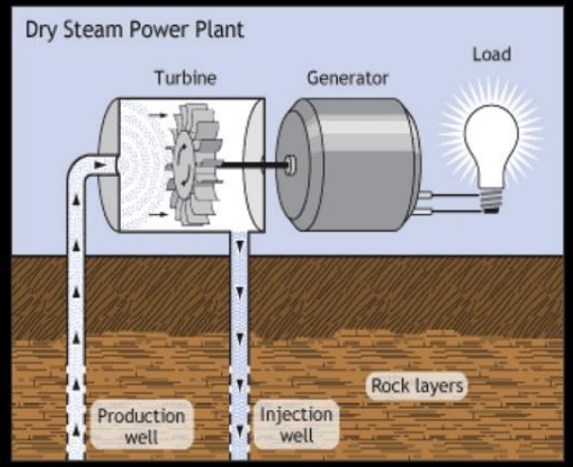




Dry Steam

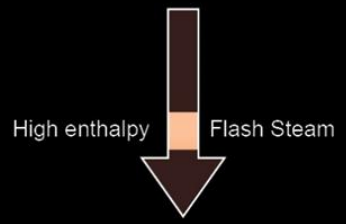
Steam, generaly from geysers, directly feeds the turbine which in turns generates electricity. Dry steam fields are rare.

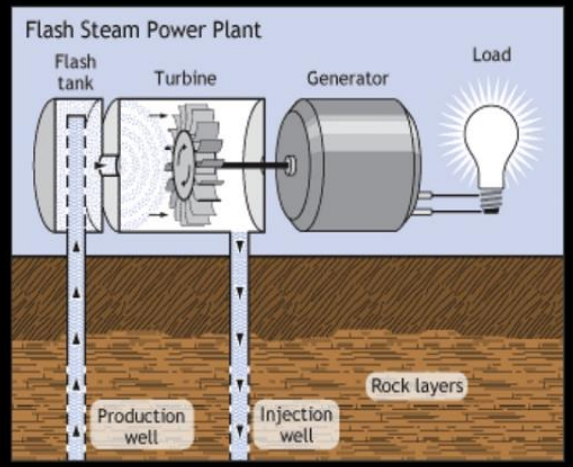




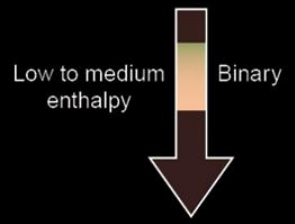
Flash Steam

High pressure and hot water is depressurized or “flashed” into steam that will drive the turbine that will generate electricity.



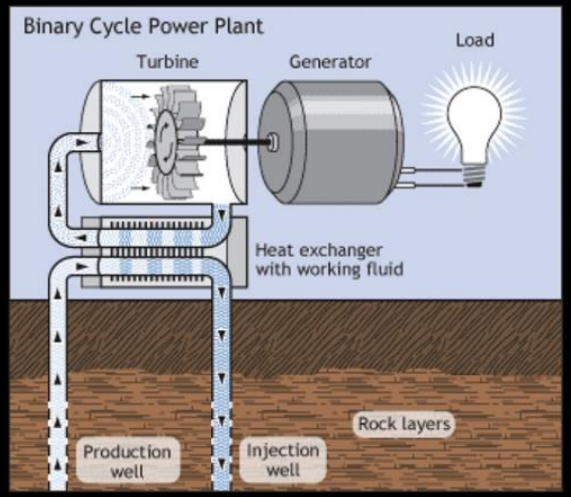


Binary Cycle



Hot water is passed through a heat exchanger, where it heats a second liquid—such as isobutane—in a closed loop.

The isobutane boils at a lower temperature than water, so it is more easily converted into steam to run the turbine.

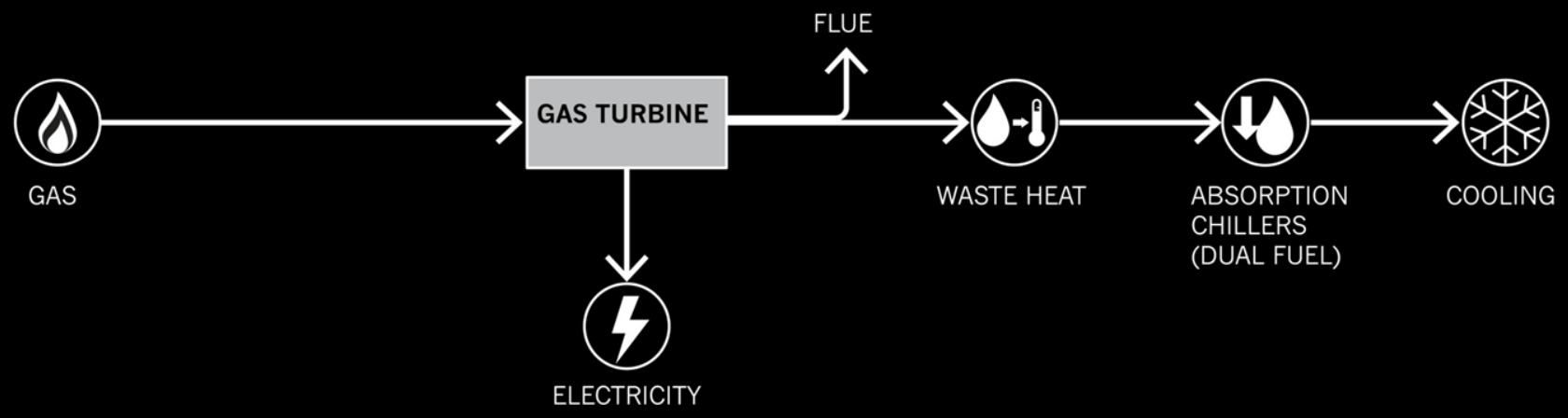


Northeast Iceland

Altheim Austria

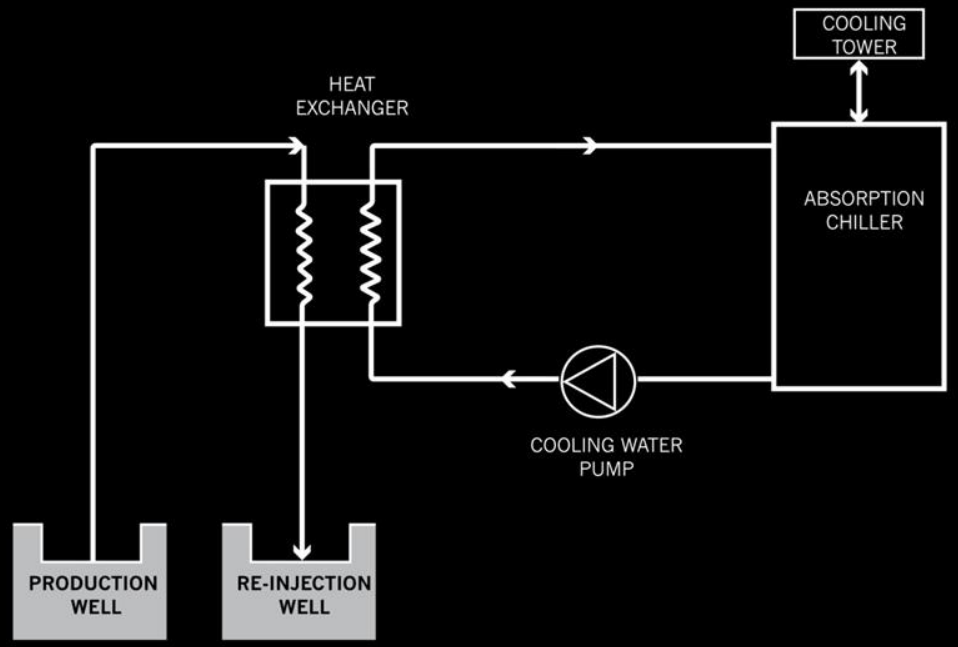
Energy Center

Tri-Generation Scheme



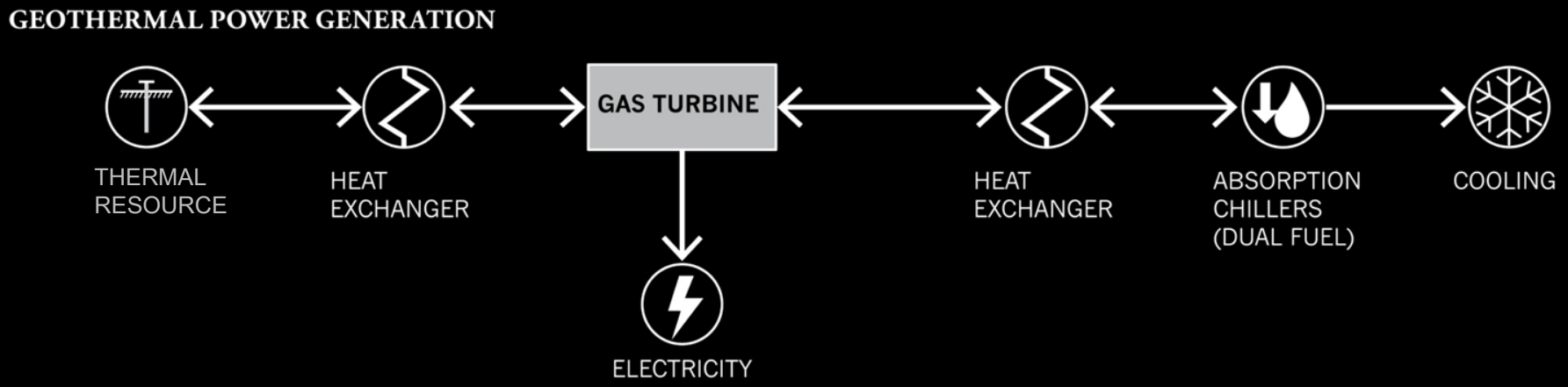
Deep geothermal cooling only

Deep Geothermal Cooling Only

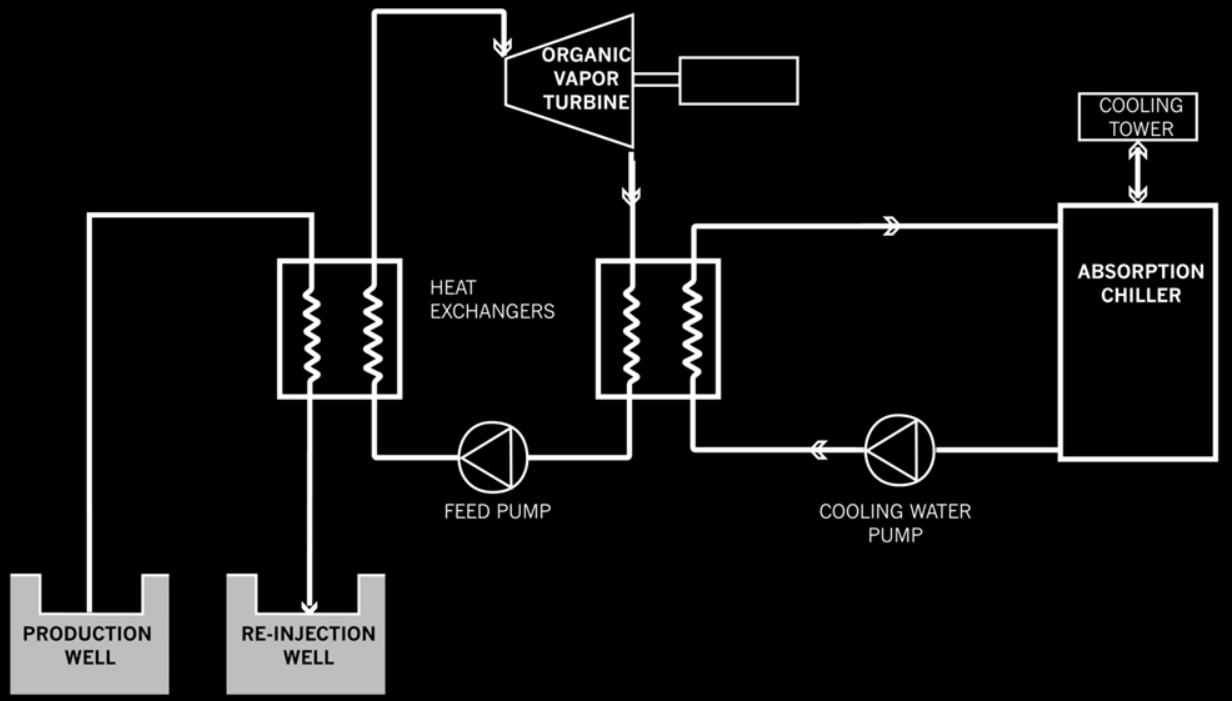


Geothermal cooling plant

Deep Geothermal Tri-Generation



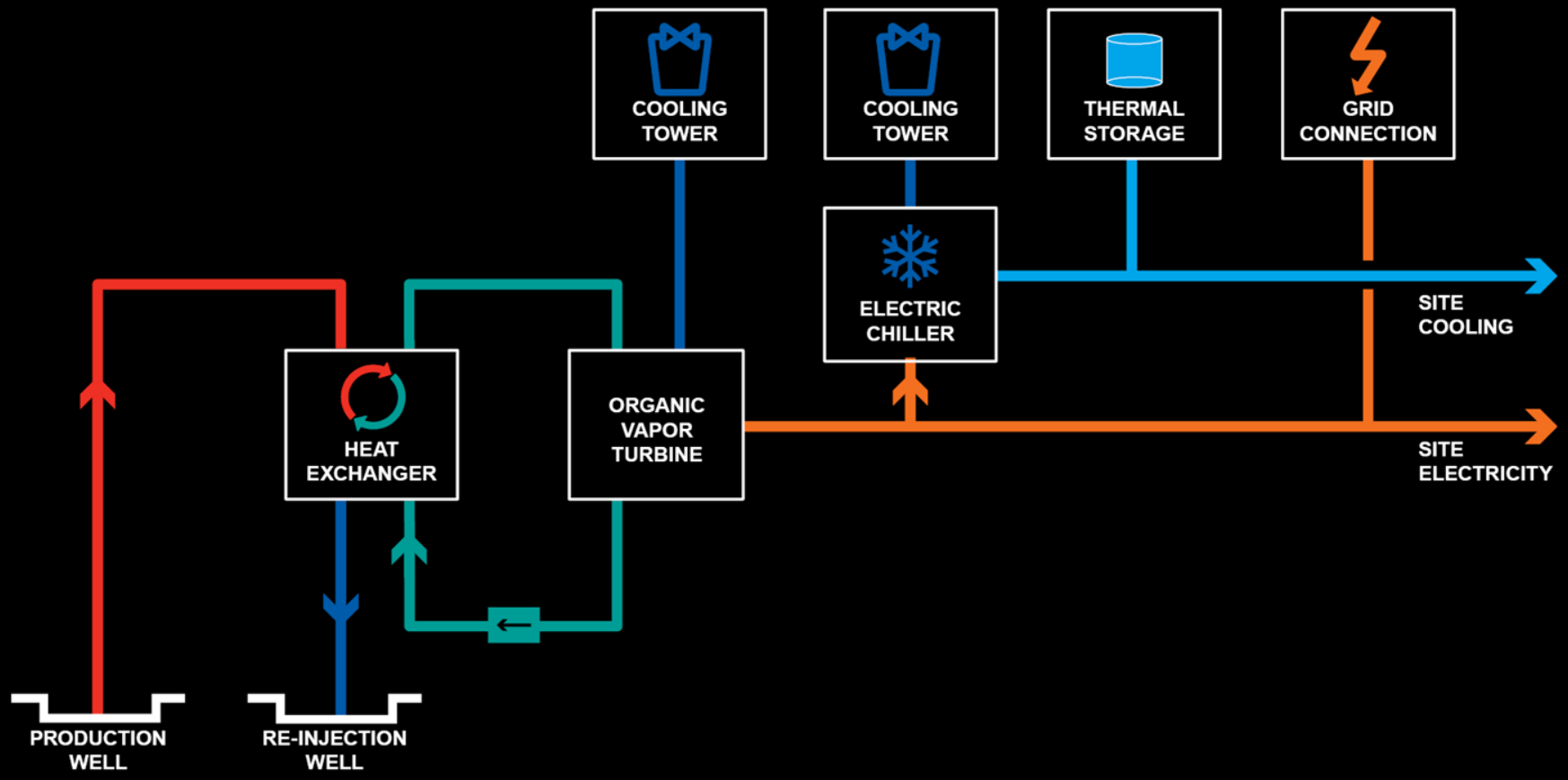
Deep Geothermal Tri-Generation



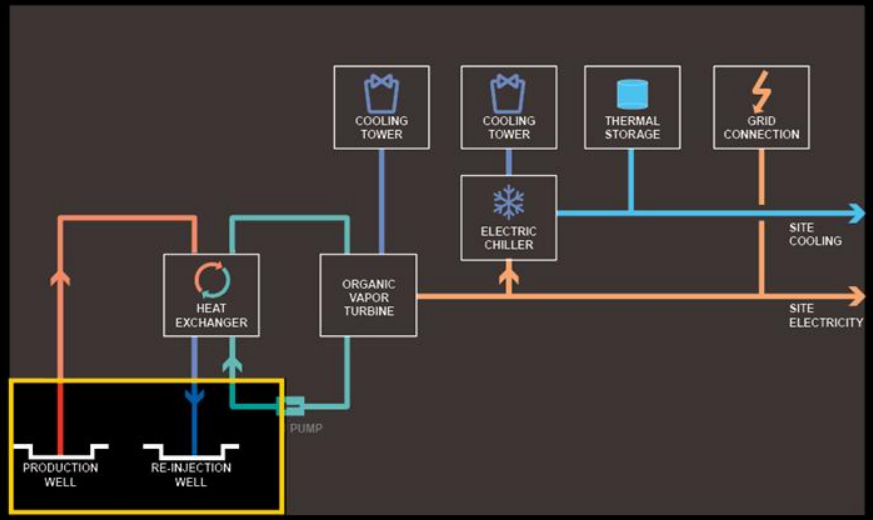
Binary cycle combined heat and power plant

The expected simple payback for this technology (binary cycle) and capital investment is less than 5 years.

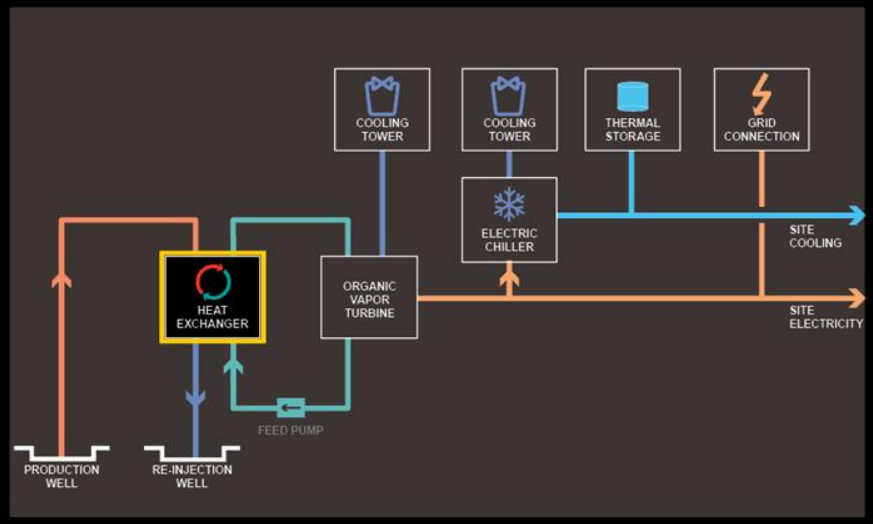
Geothermal Application on Campus



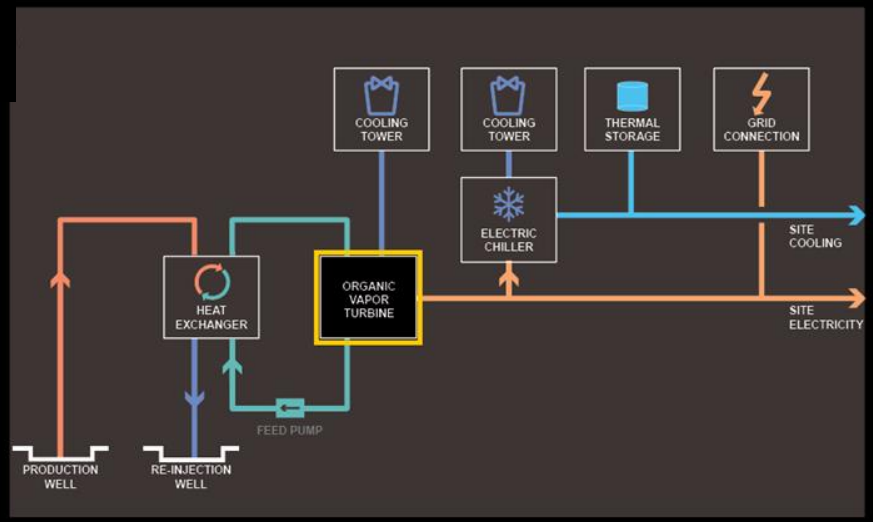
Well Heads


COOLING TOWER
COOLING TOWER
THERMAL STORAGE
GRID CONNECTION
ELECTRIC CHILLER
SITE COOLING
SITE ELECTRICITY
HEAT EXCHANGER
ORGANIC VAPOR TURBINE
PUMP
PRODUCTION WELL
RE-INJECTION WELL

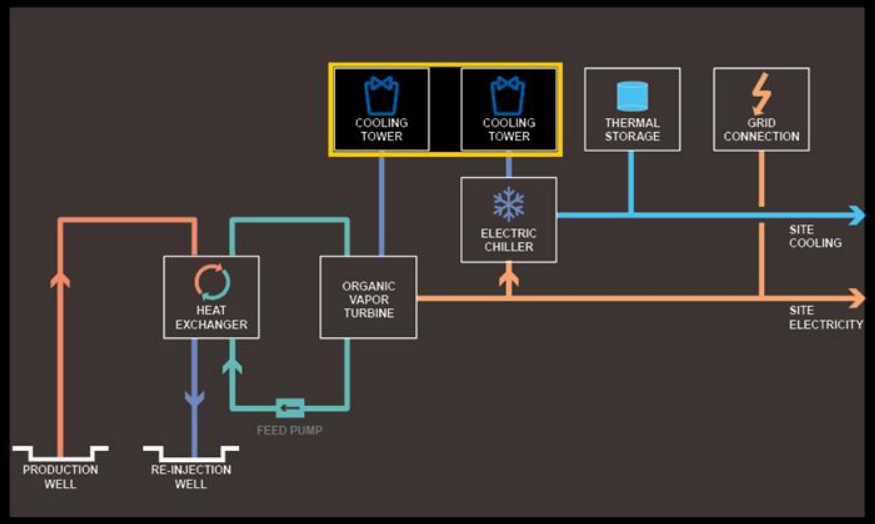
Heat Exchangers



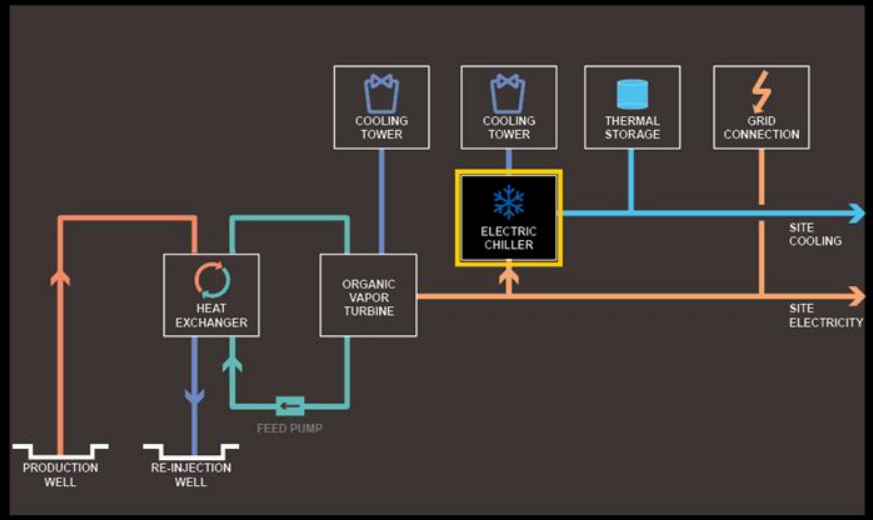
Organic Vapor Turbine



Cooling Towers



Chillers


COOLING TOWER
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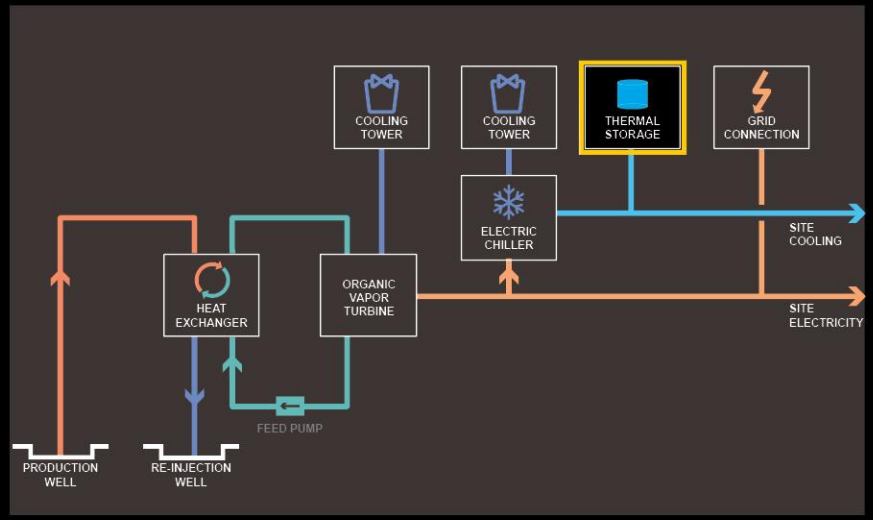
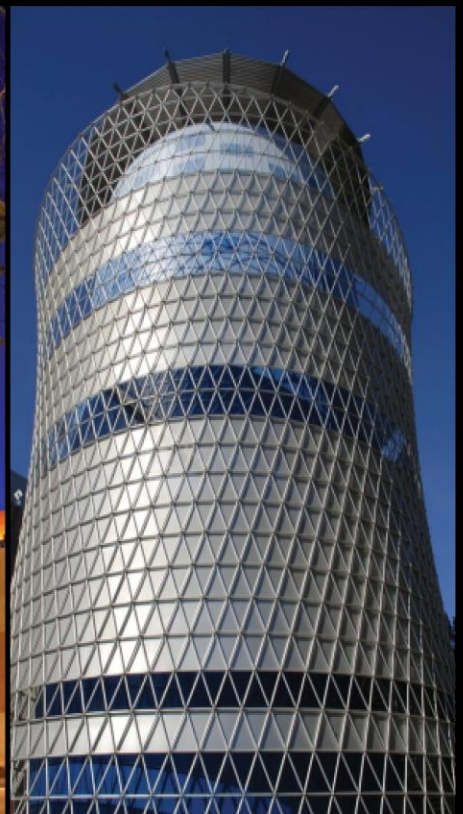
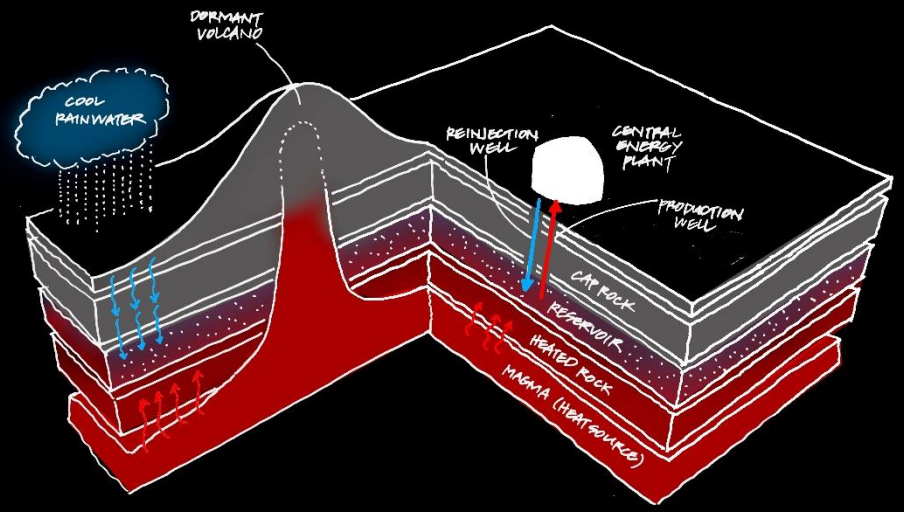
SITE ELECTRICITY
HEAT EXCHANGER
ORGANIC VAPOR TURBINE
FEED PUMP
PRODUCTION WELL
RE-INJECTION WELL

Thermal Energy Storage

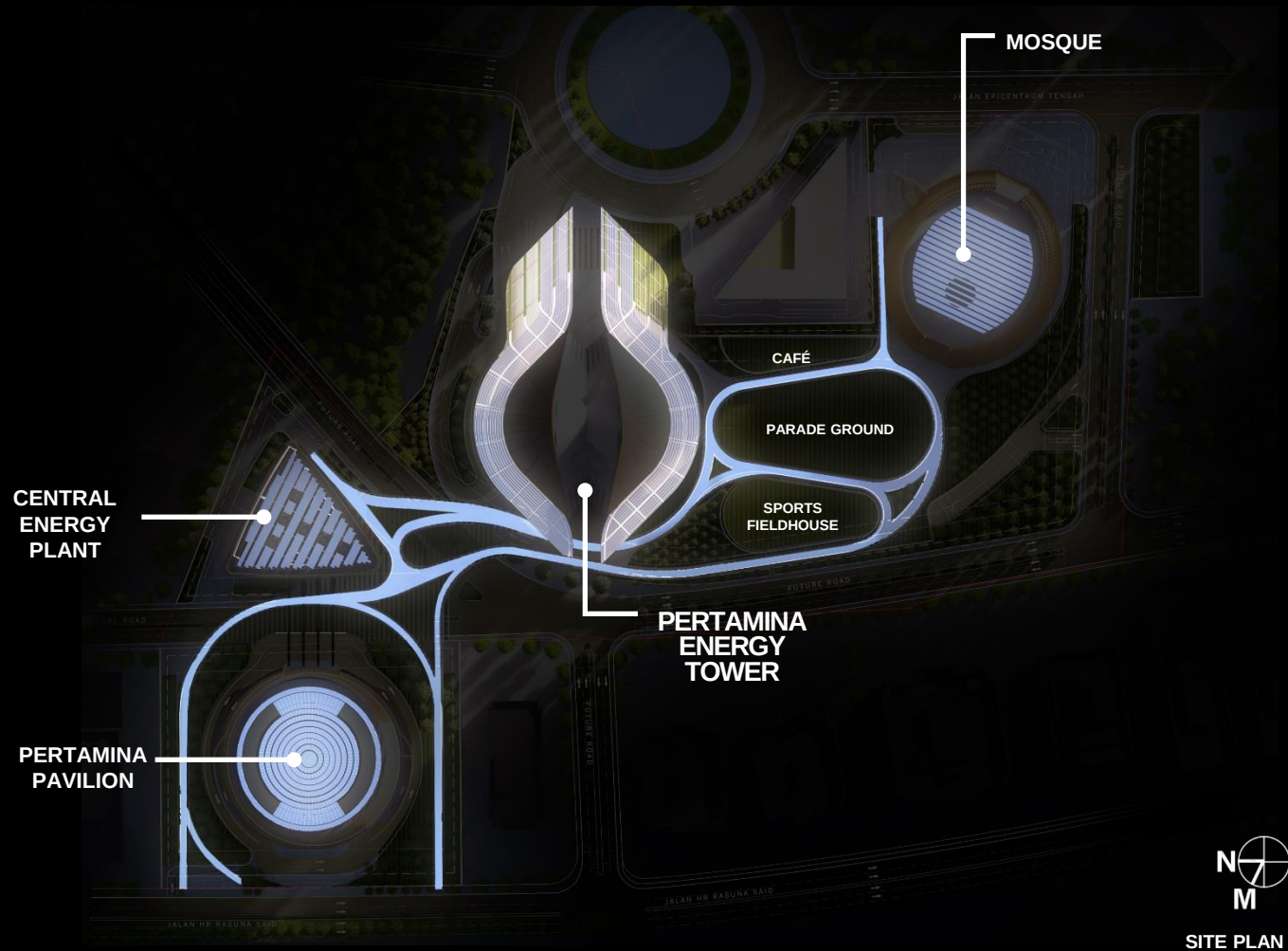




Geothermal Application on Campus



Solar Energy Potential

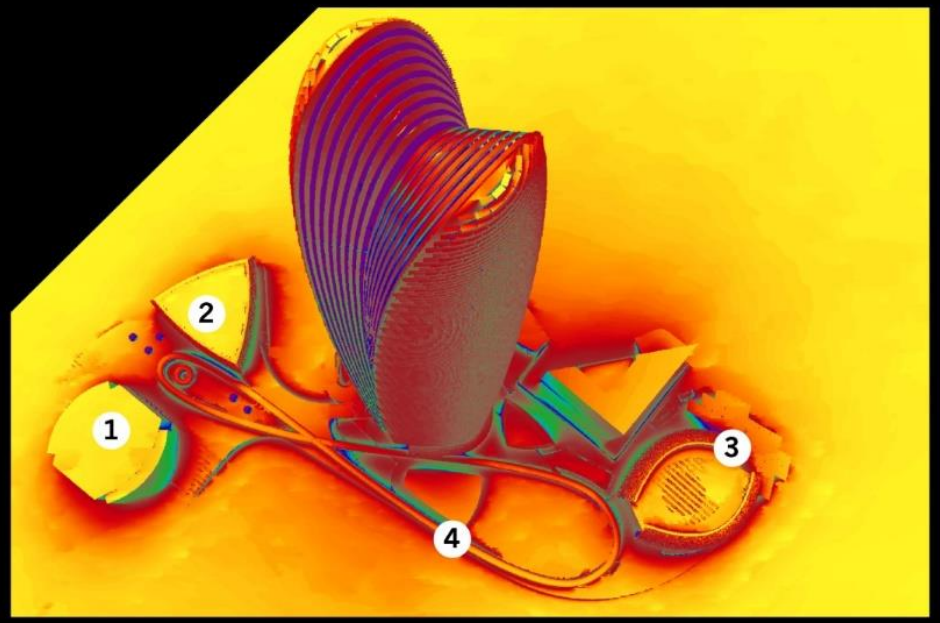


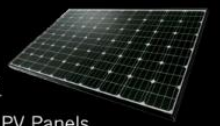
SITE PLAN

Solar Energy Potential

ANNUAL SOLAR INSOLATION (kWh/m²)

1,600
1,300
990
780
610
480
380
300



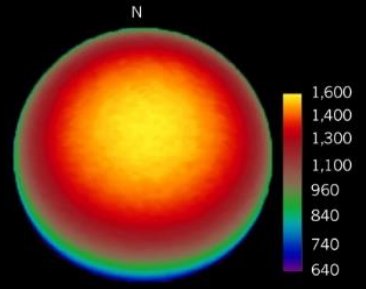


ASSUMPTIONS

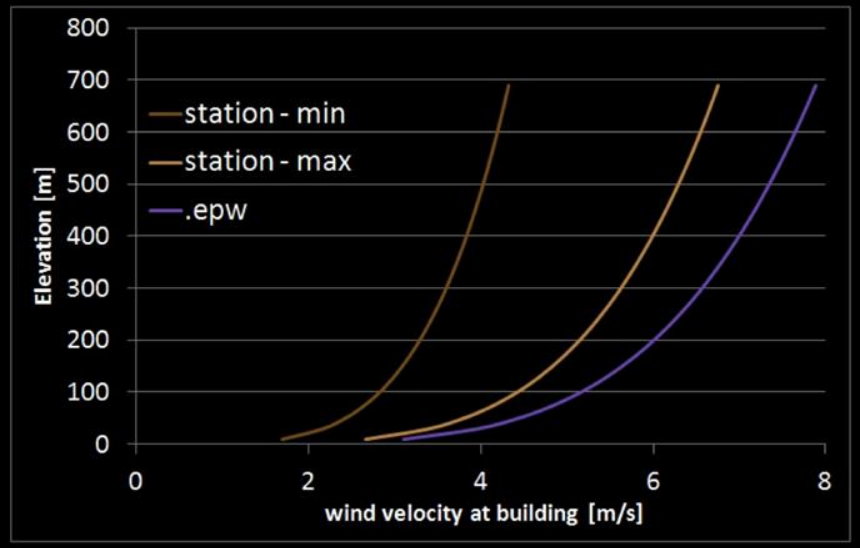
- Monocrystalline PV Panels
- Highest efficiency panels (20%)
- More power in the same amount of space
- Assumed derate factor 0.77
- Assumed PV area coverage to be 80% of total area available for PV
- Estimated energy calculated includes miscellaneous losses

	1 Pavillion	2 CEP	3 Mosque	4 Ribbon
PV area (m²)	1,280	435	2,645	2,500
Estimated annual energy generated (kWh/yr)	314,960	109,023	642,030	605,690
% of Site energy use	1.0	0.4	2.1	2.0

ANNUAL SOLAR INSOLATION POTENTIAL (kWh/m²)



Wind Energy Potential

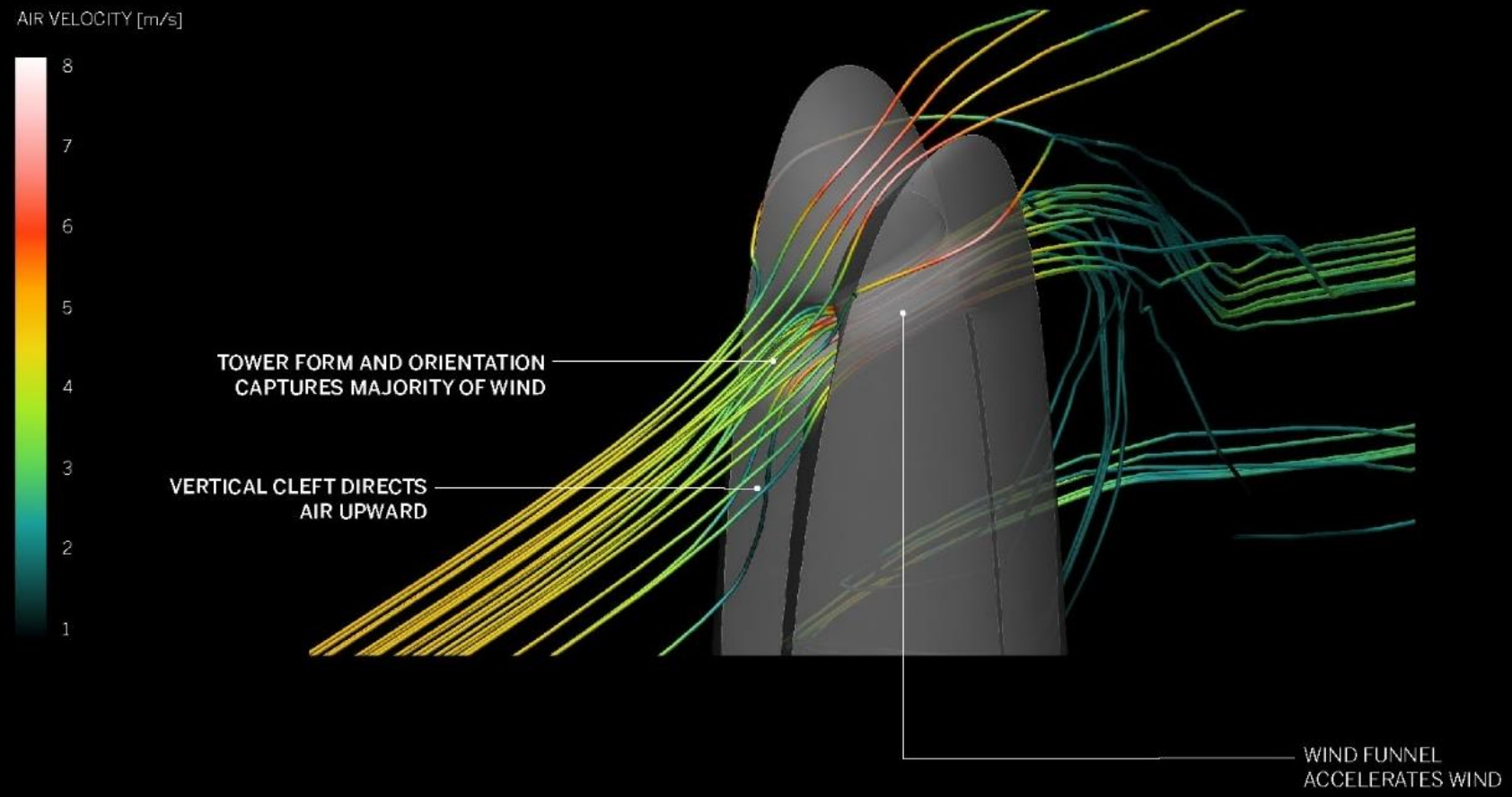


Wind speed changes with height because fewer obstructions disrupt its path at higher elevations.

According to the standard ASHRAE wind correlation, we can expect an average wind speed of 4-6 m/s at the crown using data from actual weather stations.

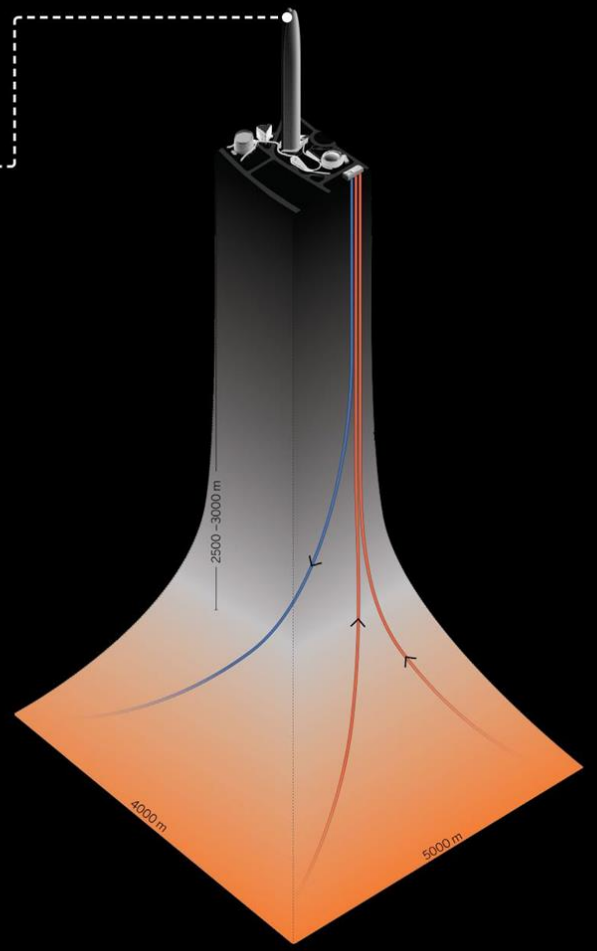
This 4-6 m/s average wind speed is further increased by the optimized crown design.

Wind Energy Potential

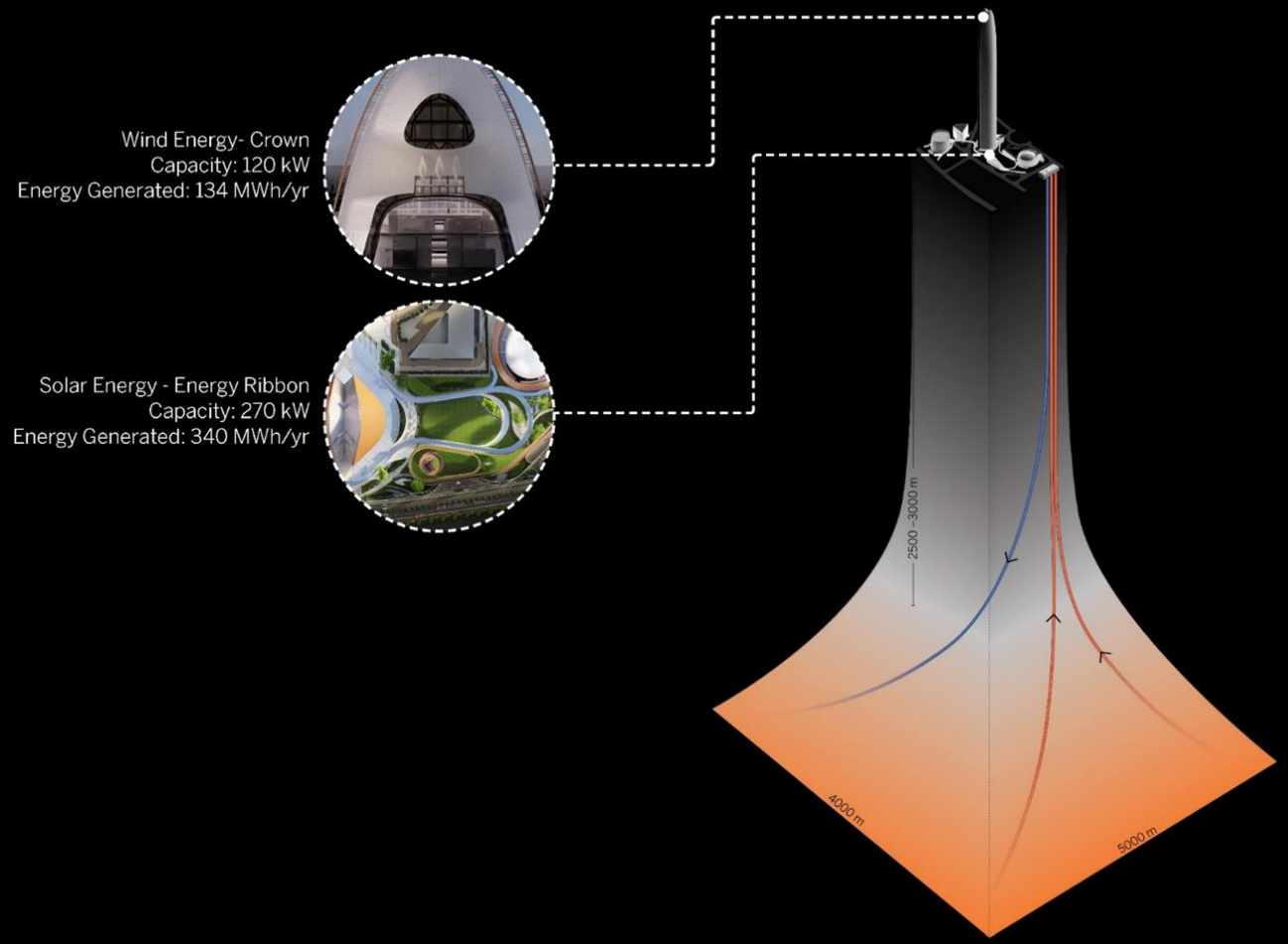


Renewable Energy Supply

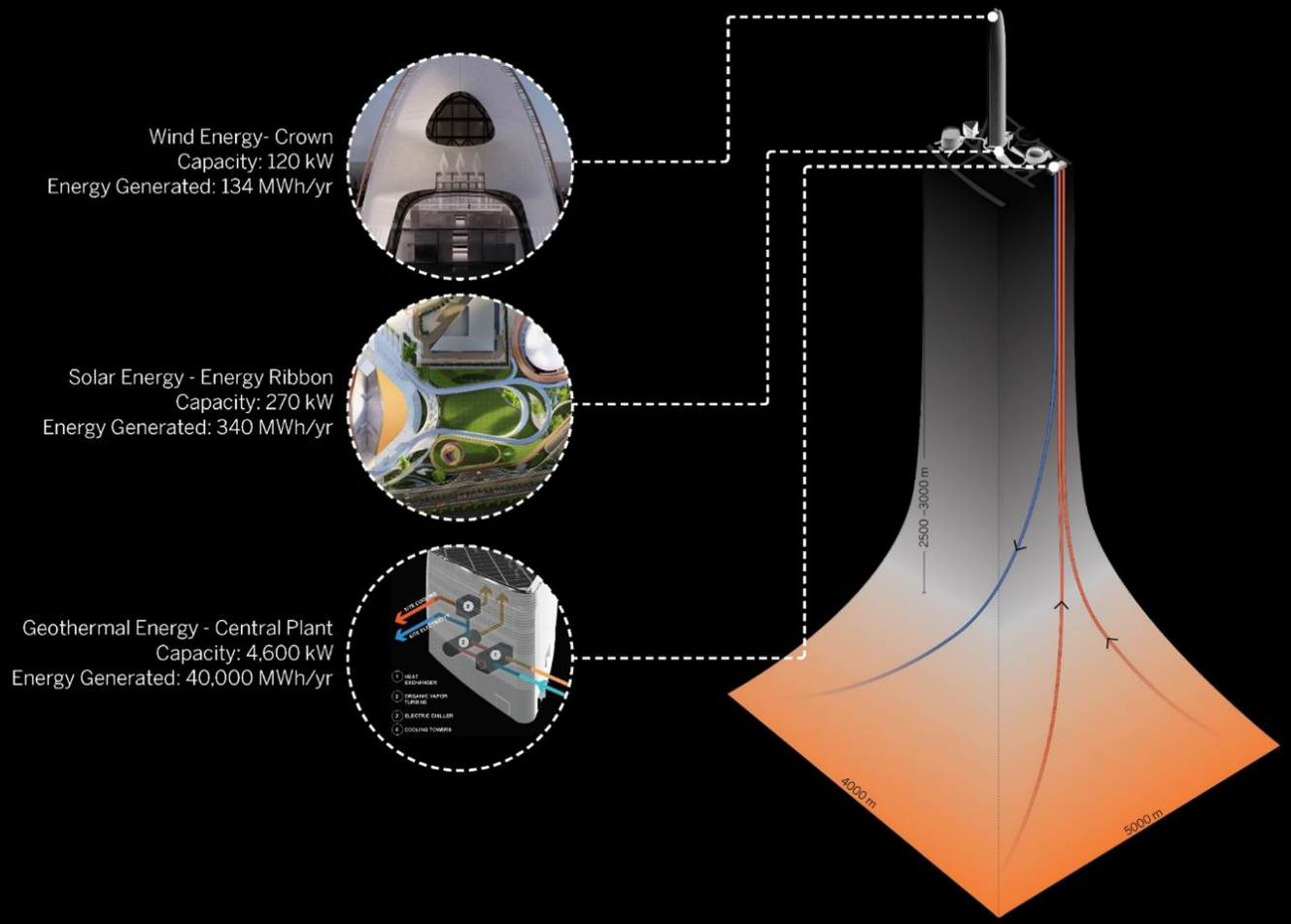
Wind Energy- Crown
Capacity: 120 kW
Energy Generated: 134 MWh/yr



Renewable Energy Supply



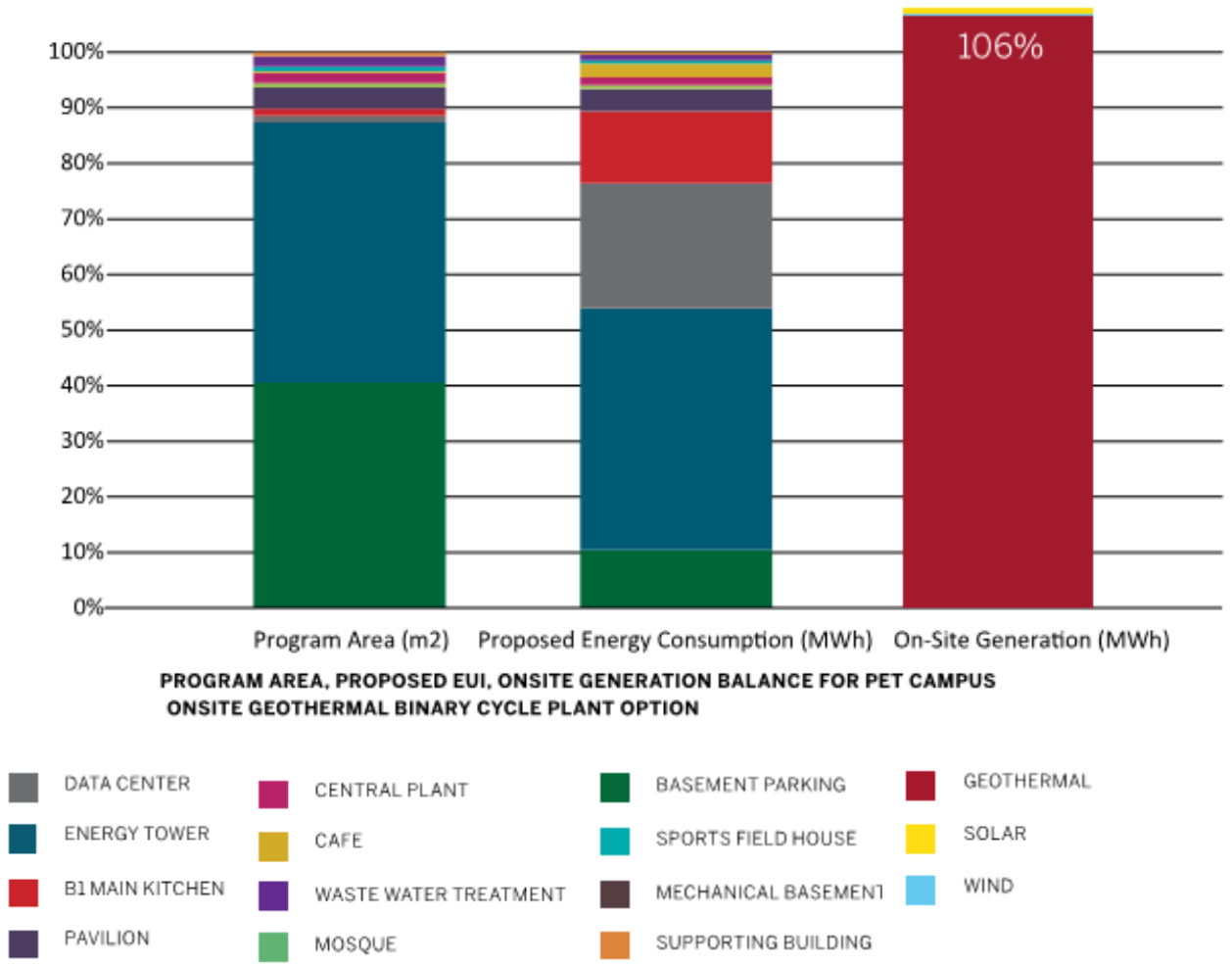
Renewable Energy Supply



Final Design Energy Balance Performance

ENERGY DEMAND VERSUS GENERATION
ONSITE GEOTHERMAL BINARY CYCLE PLANT OPTION

Energy Consumption (MWh/annum)	
Data Center	8,644
Energy Tower	16,722
B1 Main Kitchen	4,977
Pavilion	1,507
Central Plant/Support	542
Cafe	938
Waste Water Treatment	387
Mosque	304
Basement Parking	3,995
Basement Mechanical	178
Visitor Center/Sports	223
TOTAL	**38,417**
On-Site Generation (MWh/Annum)	
Geothermal Power (4.6 MW)	40,296
Solar Power	340
Wind Power	134
TOTAL	**40,770**



PROGRAM AREA, PROPOSED EUI, ONSITE GENERATION BALANCE FOR PET CAMPUS
ONSITE GEOTHERMAL BINARY CYCLE PLANT OPTION

Thank you

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