FLEXIBLE AND ENERGY SELF-SUFFICIENT FLOATING CITIES IN THE NORTH SEA

SUSTAINABLE GRADUATION STUDIO
Building technology track

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WHY BUILDING ON WATER?

NOW

FUTURE

URBANISATION — LACK OF BUILDING GROUND

EXTEND THROUGH WATER

CLIMATE CHANGE — SEA LEVEL RISE AND FLOOD RISK

IMMUNE THROW FLOATING

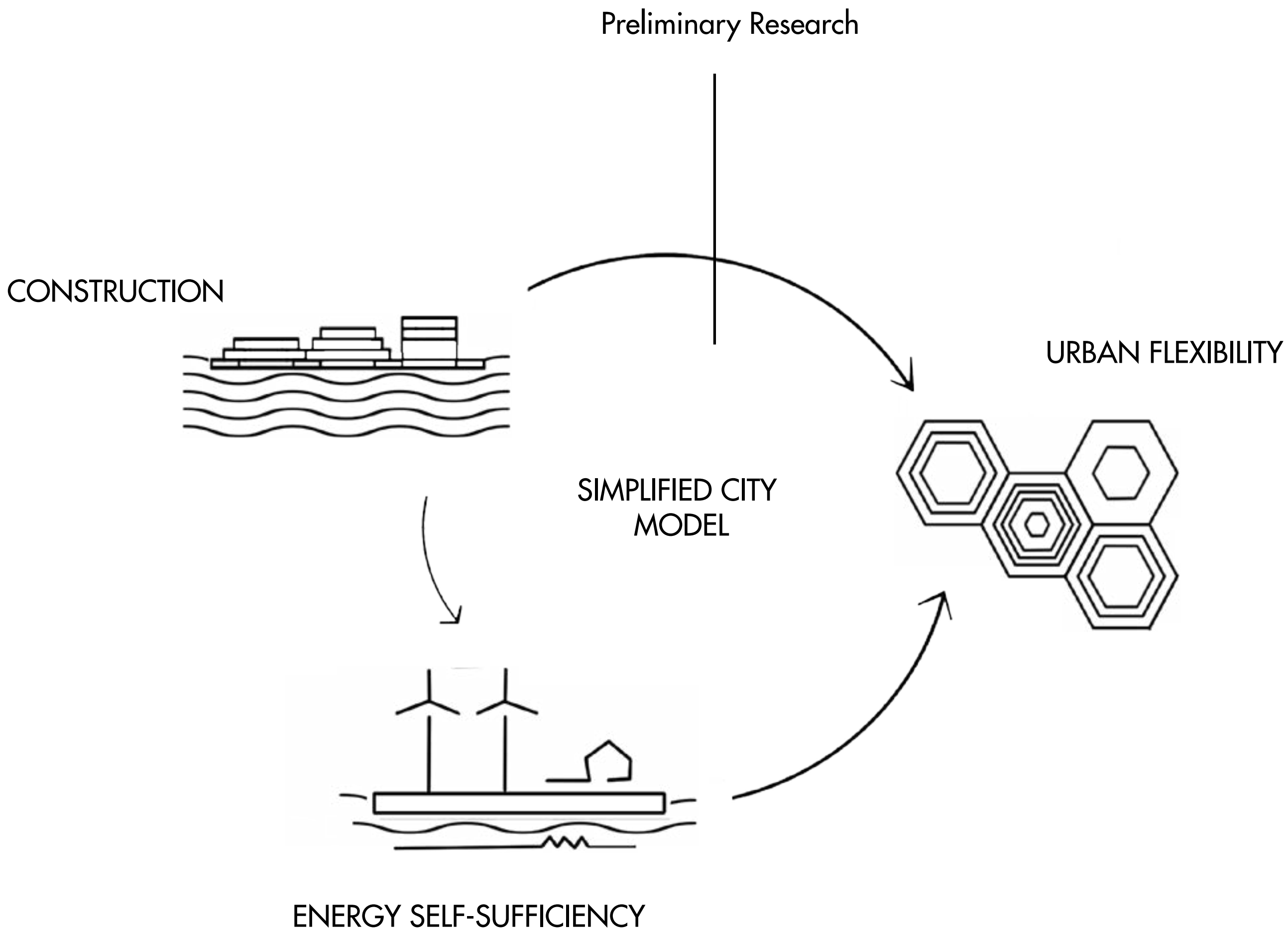
FLEXIBLE URBAN COMPONENTS

Dynamic geography
Fullfill building's technical life

ENERGY AUTONOMOUS SETTLEMENT

Sea energy potential
Renewable resources

Can a floating city be energetically self-sustained and flexible?


Preliminary Research
CONSTRUCTION
URBAN FLEXIBILITY
SIMPLIFIED CITY
MODEL
ENERGY SELF-SUFFICIENCY

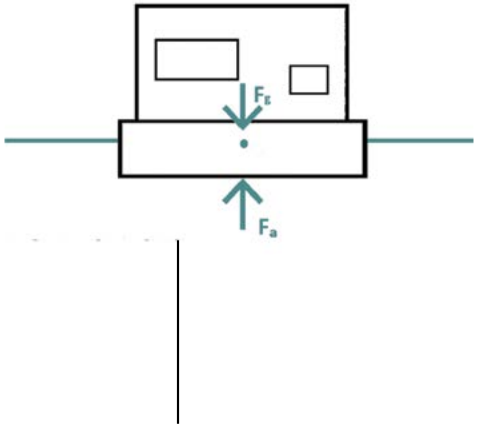
LOCATION

Nasa satellite picture aquired the 18th December 2004

Source : https://visibleearth.nasa.gov/view.php?id=69721

- Population grows throw coast
- City grows from settlement in open sea for other functions, like new floating aeroport or Offshore turbine maintenance
- Option to analyse sea atmosphere

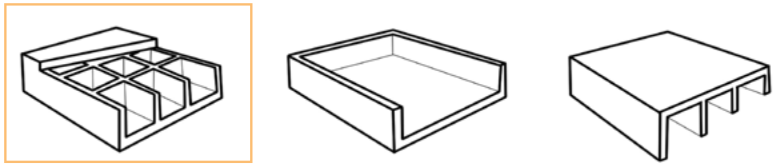
ARCHIMEDE'S LAW



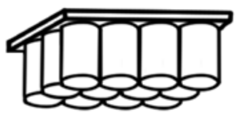
$F_a = F_g$

Any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object.

BUOYANT BODIES

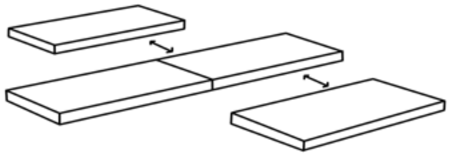


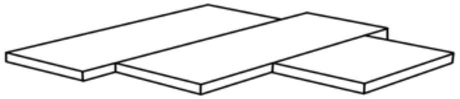
Concrete caissons



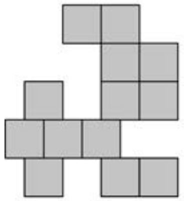
Steel pneumatically stabilized platform

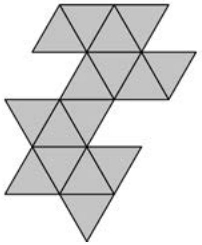
BUOYANT BODIES CONNECTED TO BUILD THE CITY

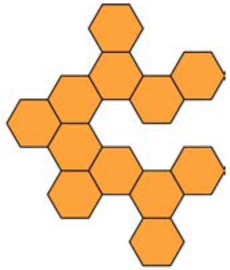


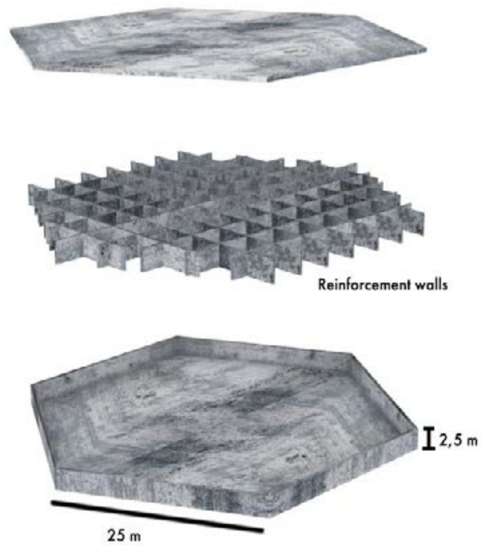


PLATFORM SHAPE

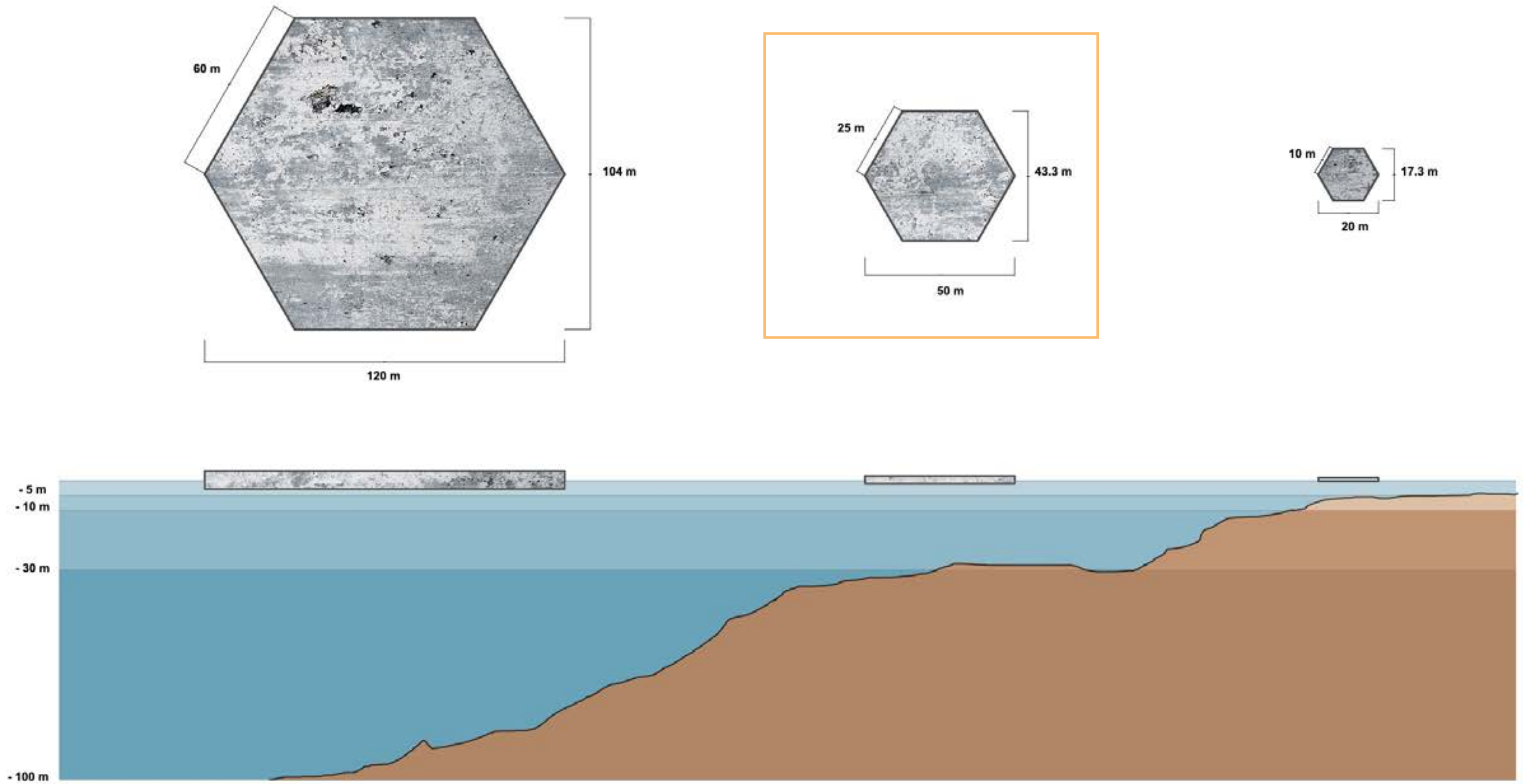




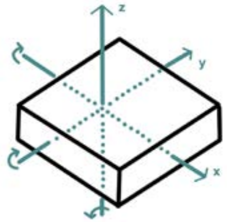




minimum number of connections
stability when connected to form one
possibility to mantain building orientation
possibility to allow light pass throw for
environment preservation

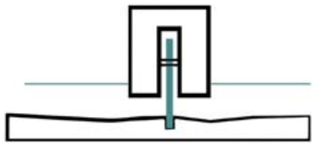

60 m
104 m
120 m
25 m
43.3 m
50 m
10 m
17.3 m
20 m
- 5 m
- 10 m
- 30 m
- 100 m

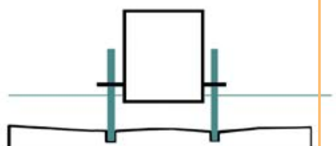
DEGREES OF FREEDOM



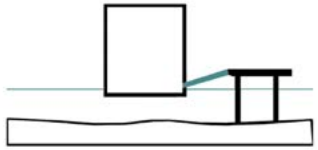
- Allow only vertical movement
- Avoid horizontal translations and rotation

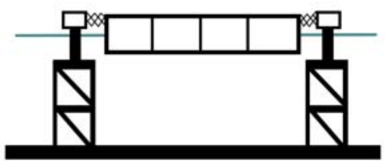
MOORINGS



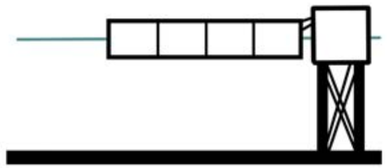


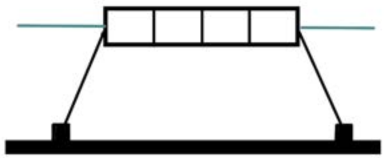
Pile mooring

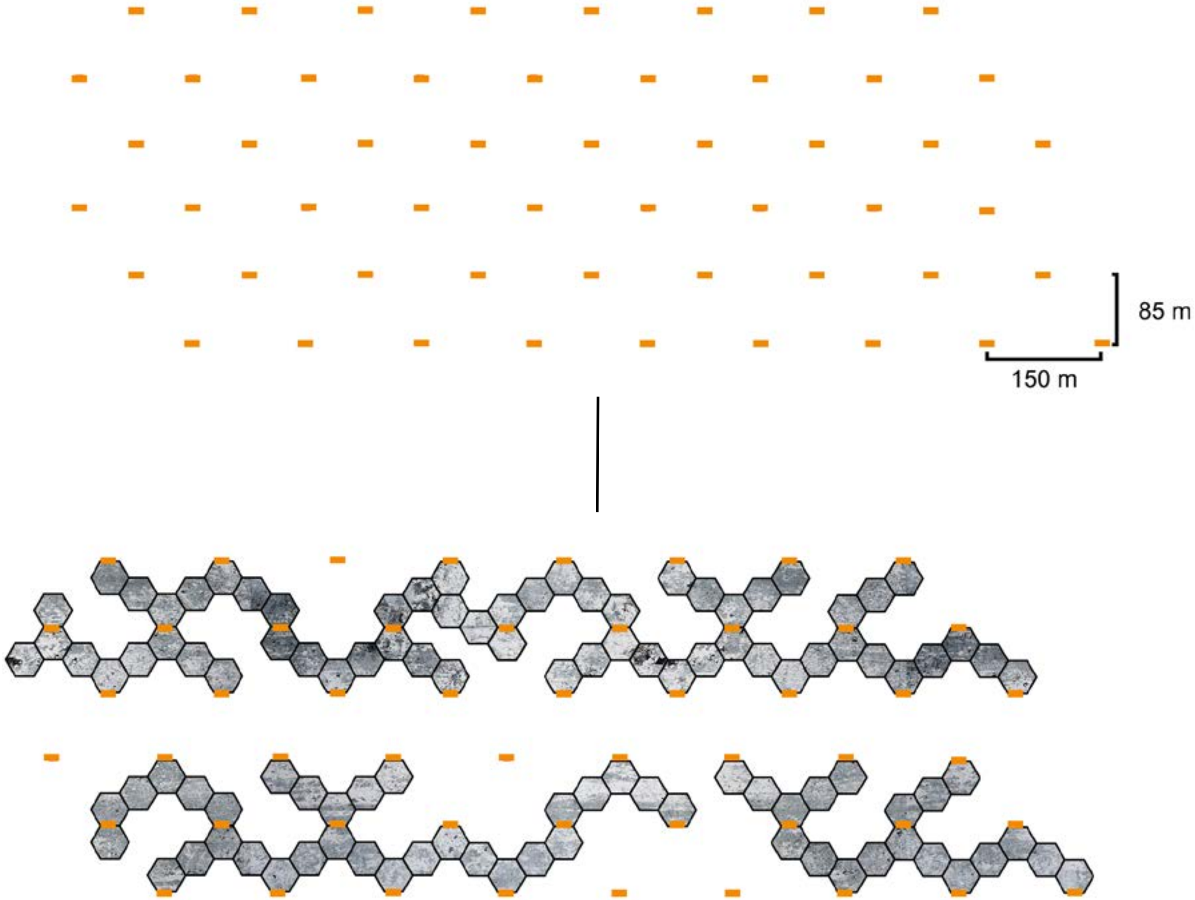




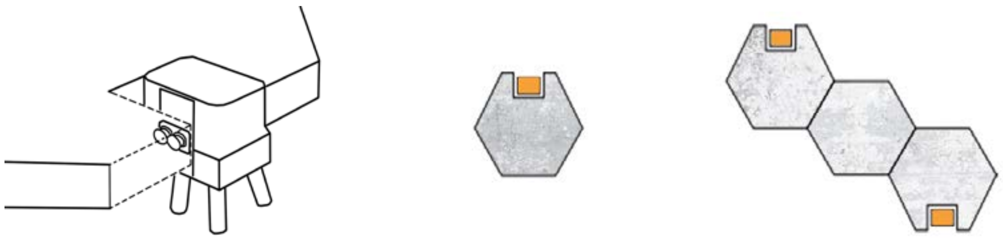
Dolphin



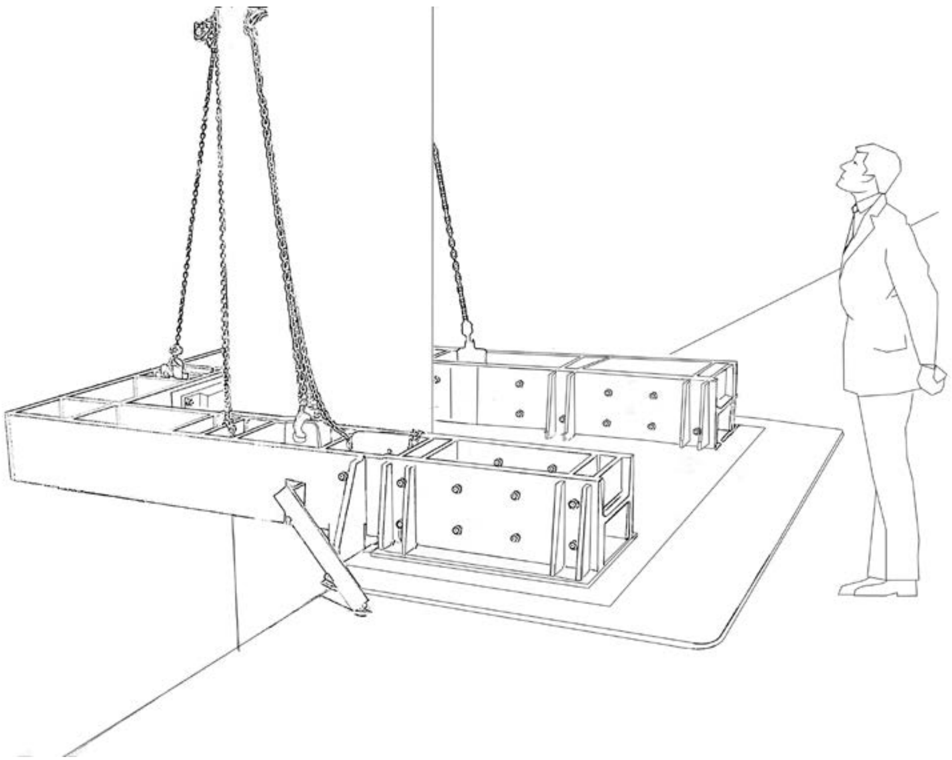


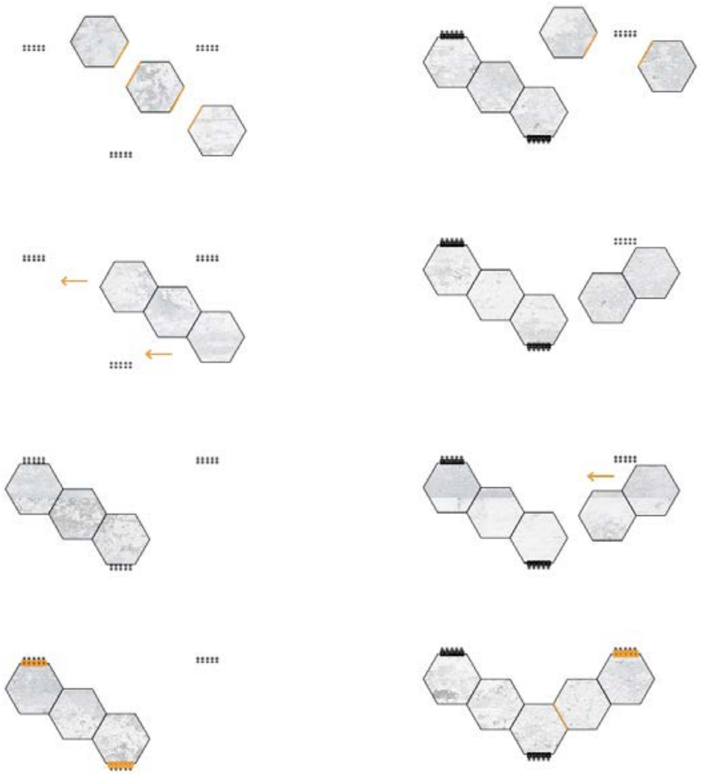

85 m
150 m

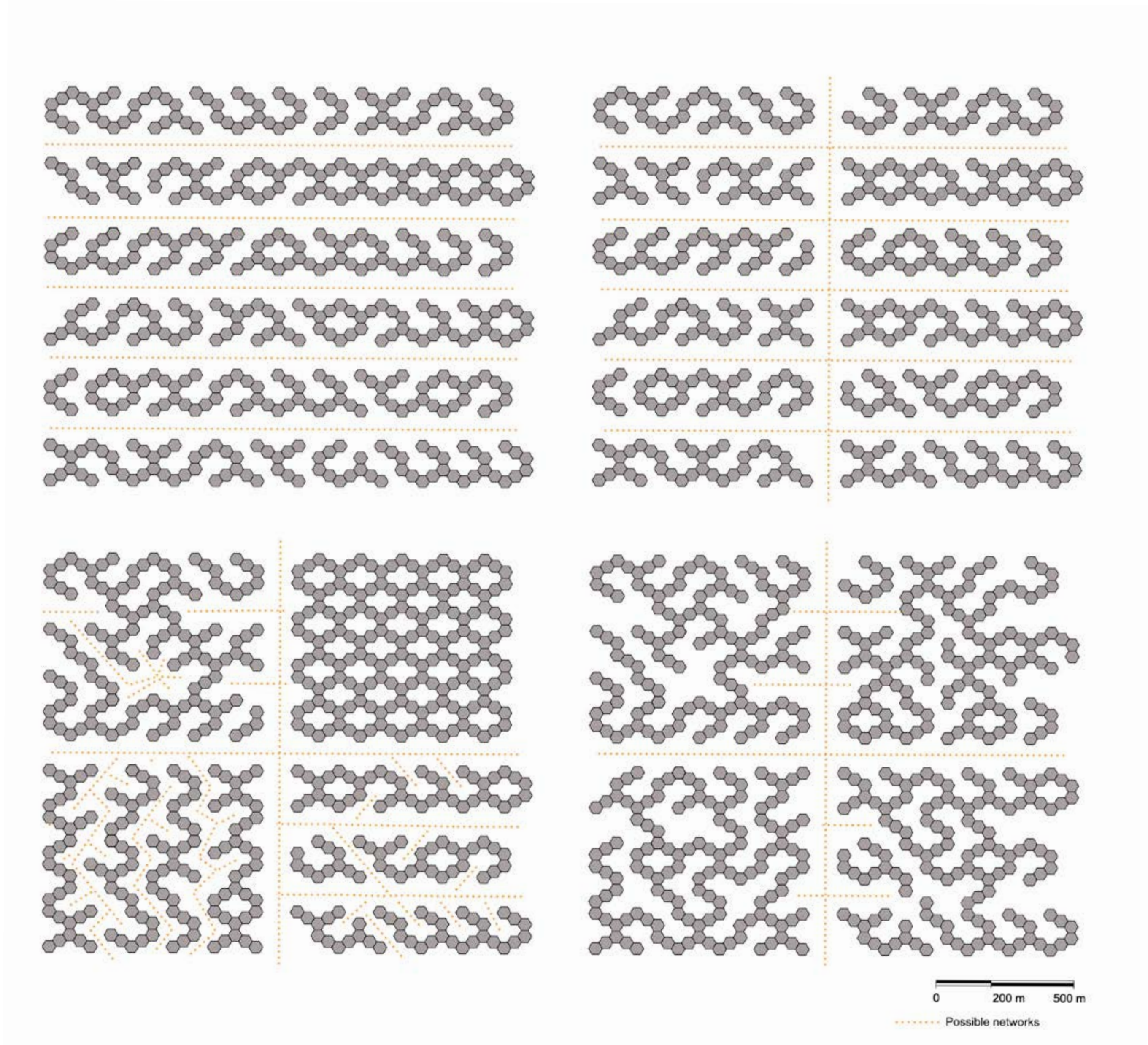
Dolphin mooring

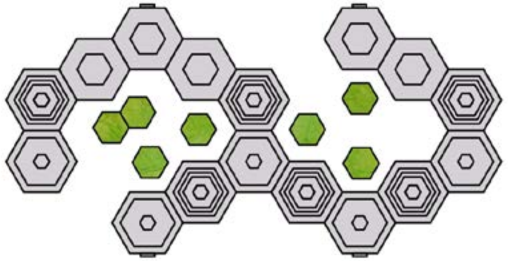


Pile mooring

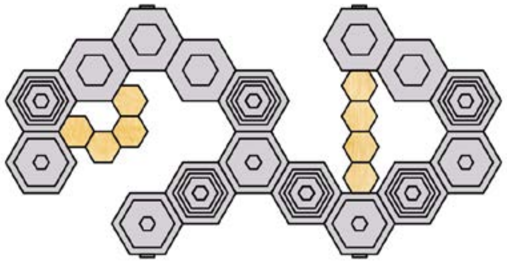




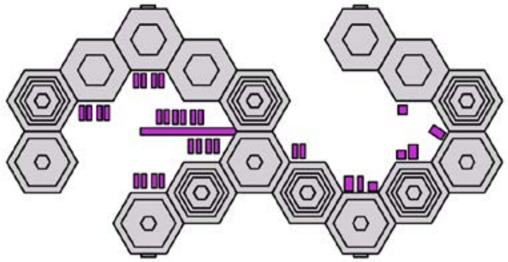

0
200 m
500 m
Possible networks



GREEN

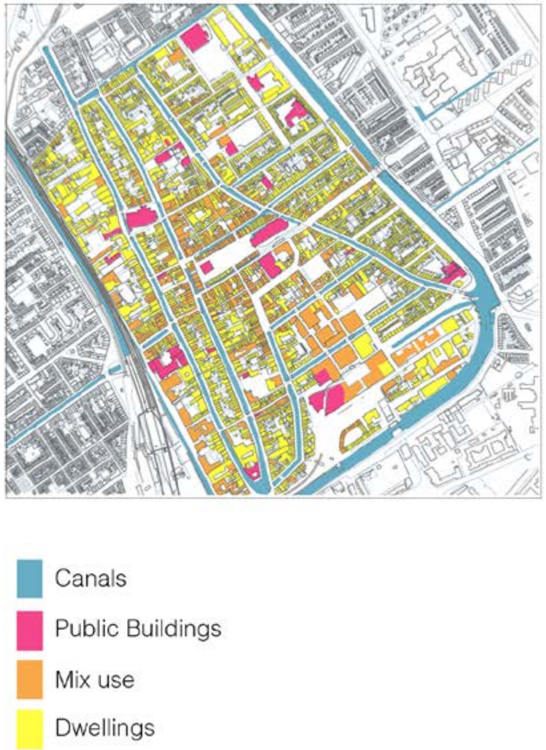


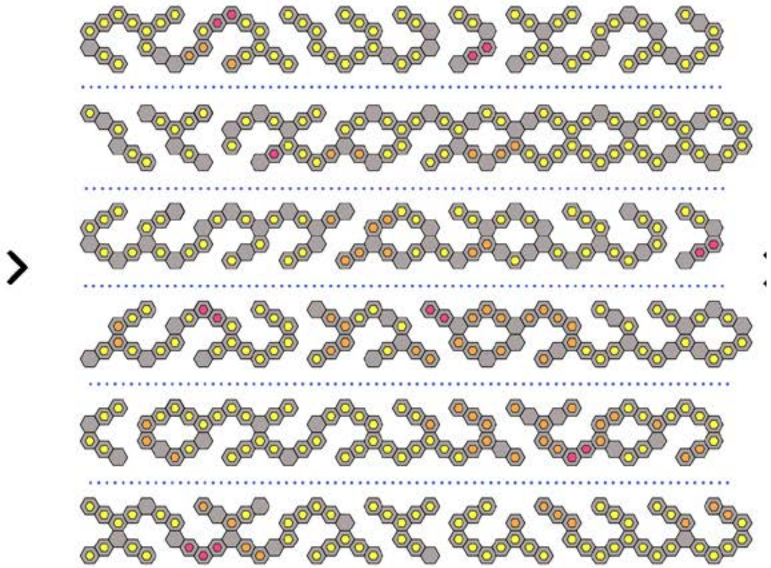
PUBLIC SPACES



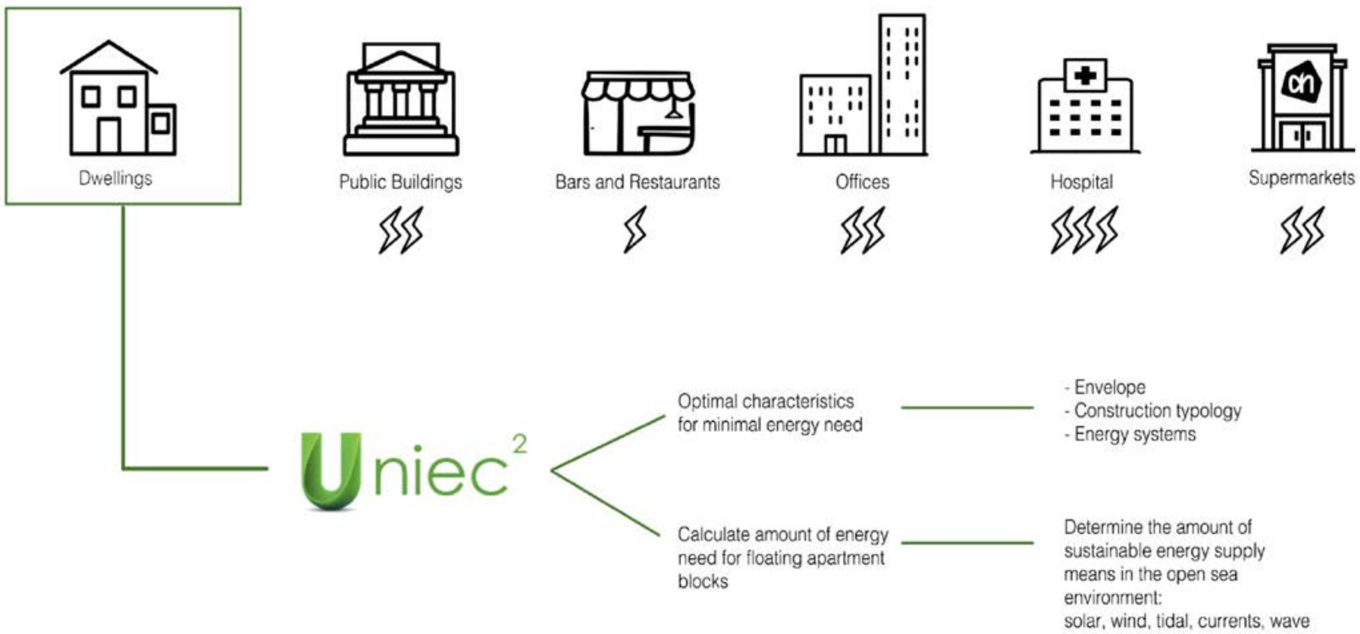
FLOATING DWELLINGS

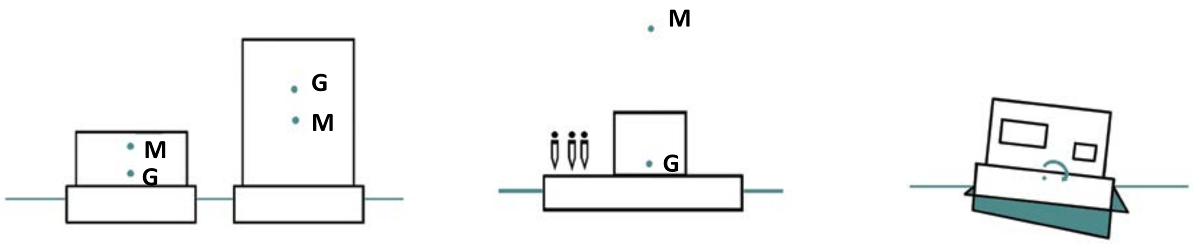
CITY SIZE



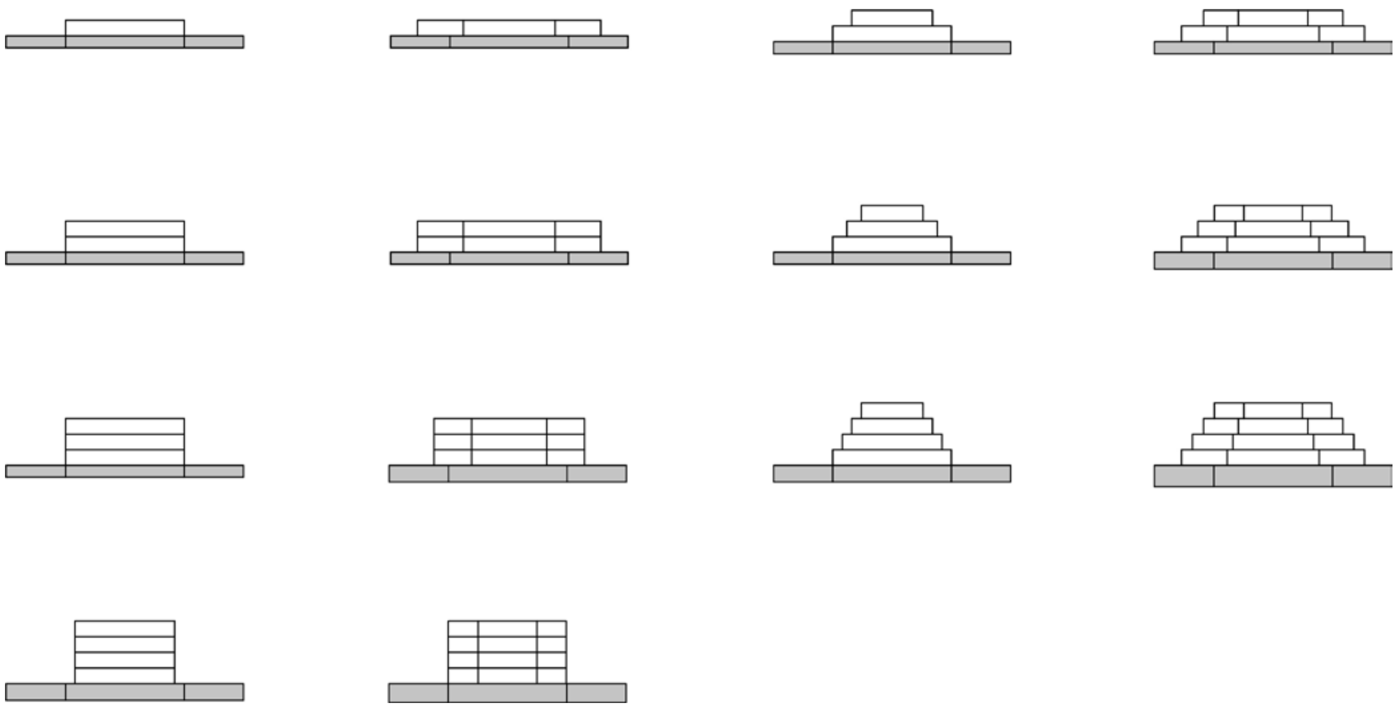


ENERGY STUDY

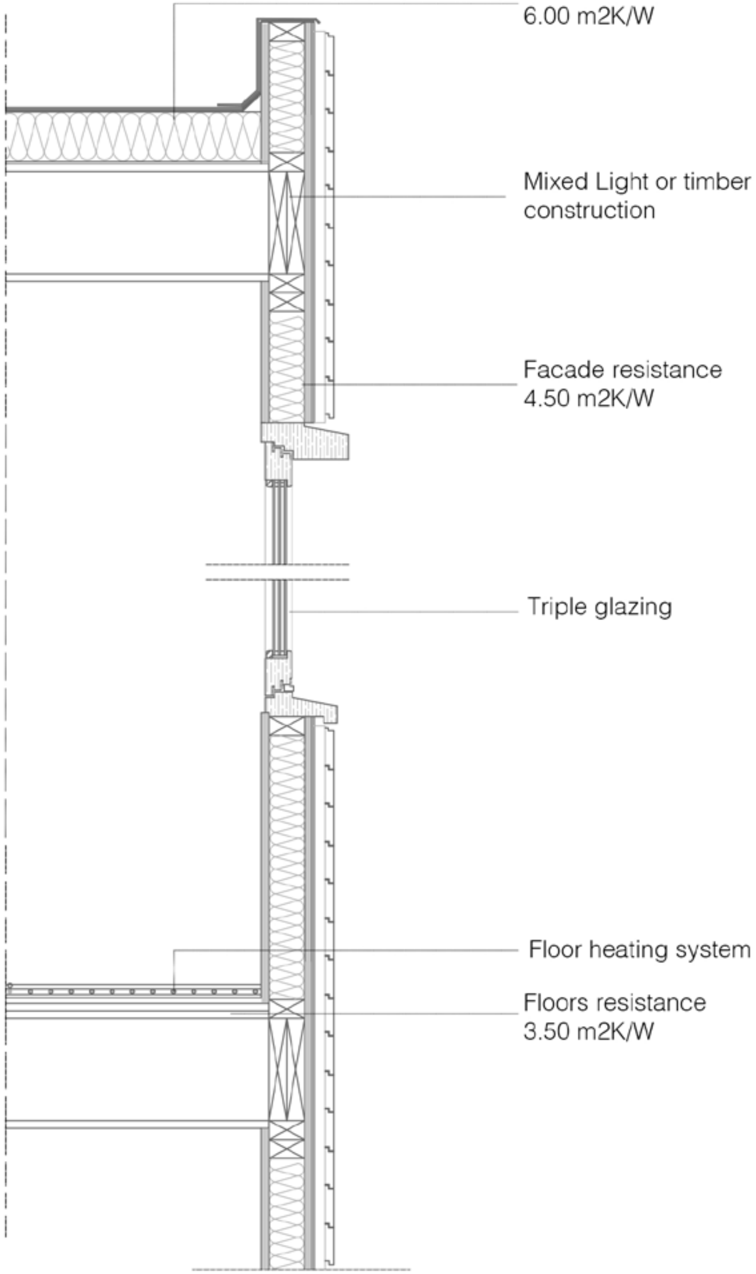




PIXELS' DIMENTIONS

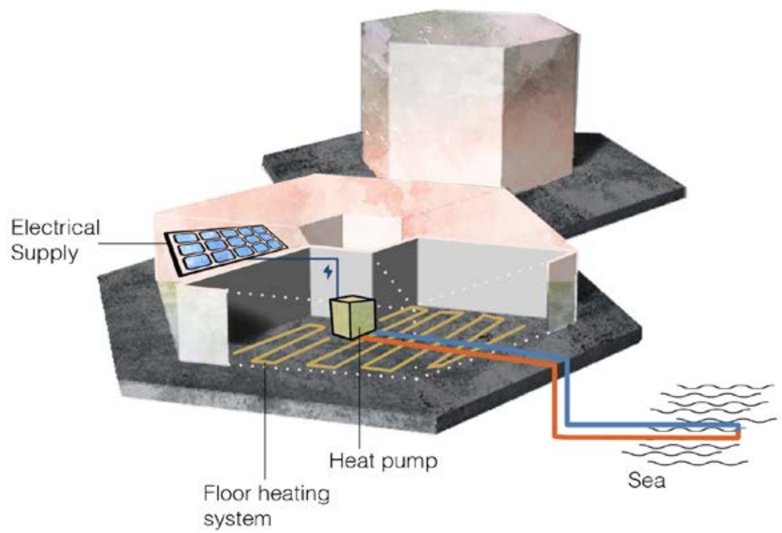


BUILDING CHARACTERISTICS



Electric heat pump

Heat pump boiler



PIXELS' ENERGY NEED

595,4 m2
7 units
26.617 kWh
3802 kWh per unit

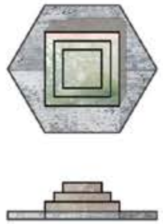
847.2 m2
11 units
40.826 kWh
3711 kWh per unit

863 m2
11 units
42.103 kWh
3827 kWh per unit

1294 m2
17 units
60666 kWh
3568 kWh per unit

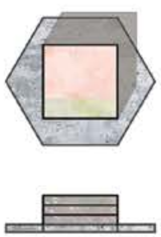
1190.8 m2
15 units
54.474 kWh
3631 kWh per unit

1694 m2
22 units
78.020 kWh
3546 kWh per unit

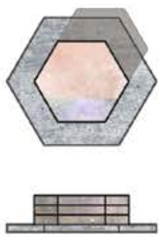


1088.7 m2
14 units
50842 kWh
3631 kWh per unit

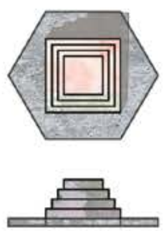
1673 m2
22 units
77763 kWh
3534 kWh per unit



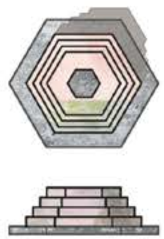
1786 m2
23 units
81.610 kWh
3548 kWh per unit



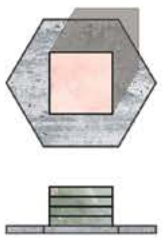
973.8 m2
13 units
46.857 kWh
3604 kWh per unit



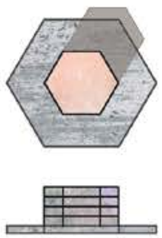
1432 m2
19 units
66.907 kWh
3521 kWh per unit



2216 m2
29 units
102091 kWh
3520 kWh per unit



1664 m2
22 units
76.954 kWh
3498 kWh per unit



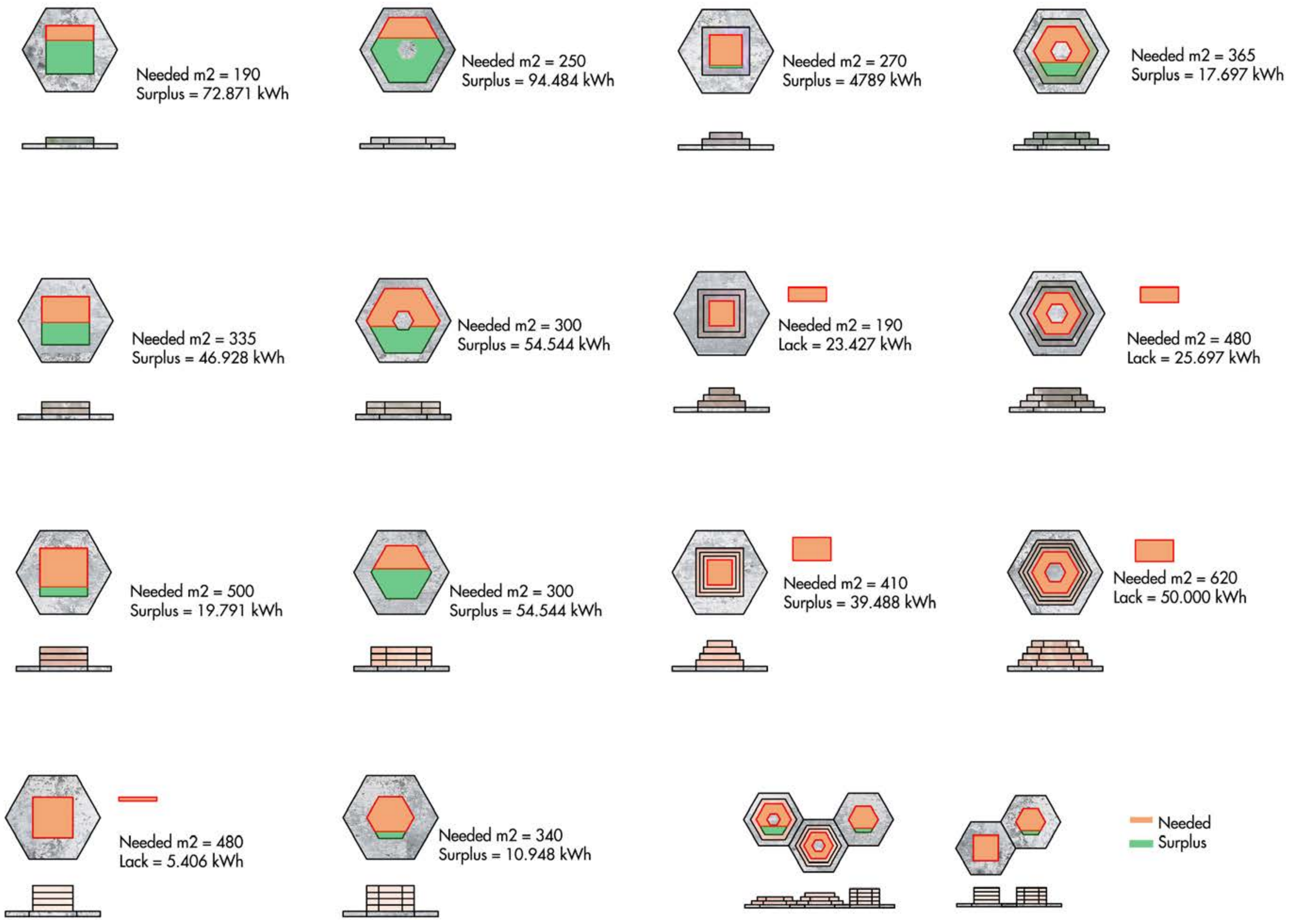
1504 m2
20 units
53.786 kWh
2689 kWh per unit

HOUSING UNITS PER PIXEL: 7- 29

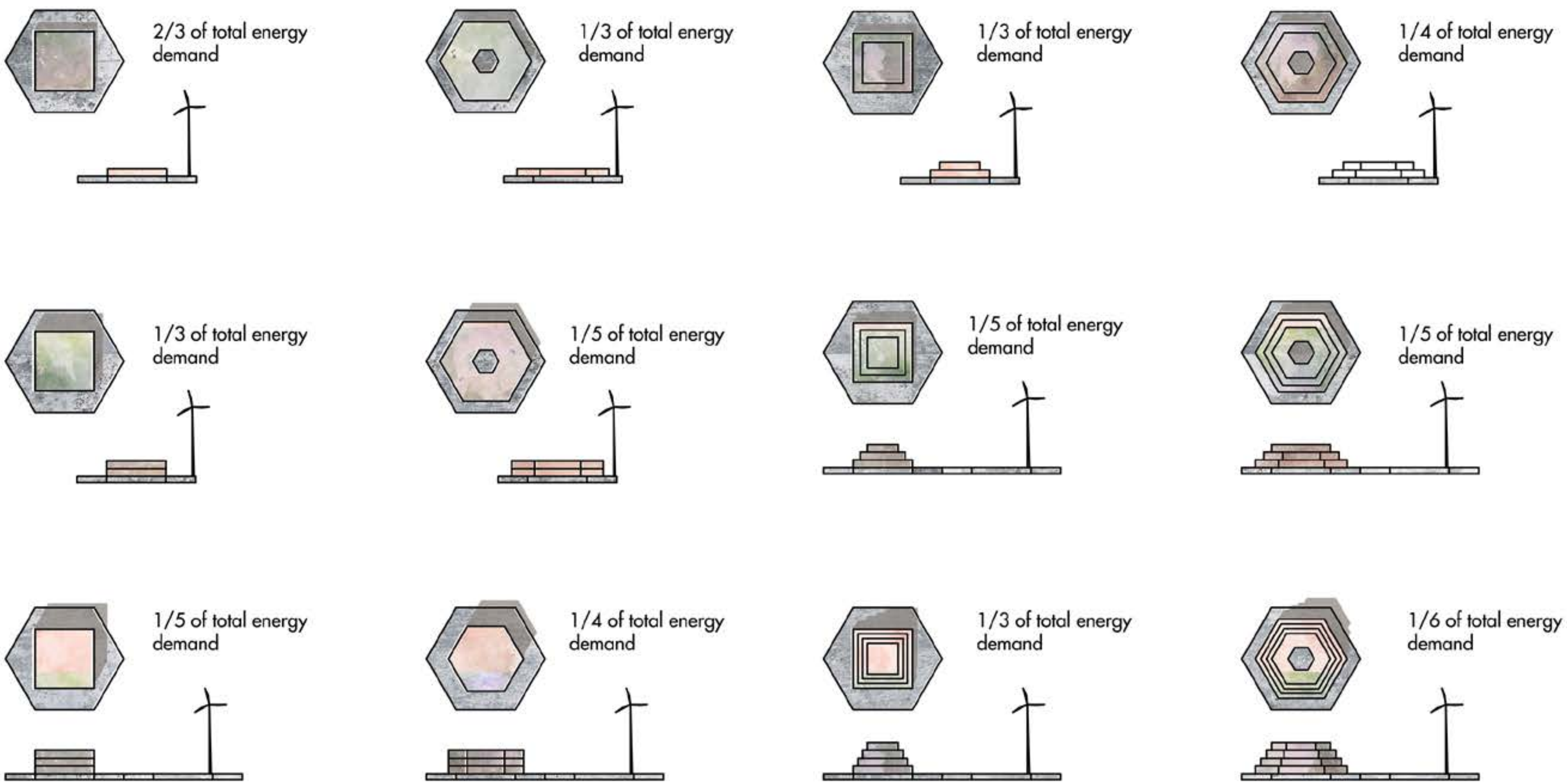
ENERGY NEED PER DAY PER HOUSING UNIT:
7.36-10 KW/h PER DAY = 1/3 OF NORMAL ENERGY DEMAND

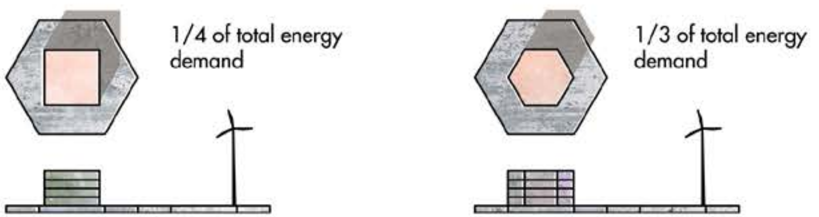
DAILY DIFFERENCE PER HOUSING UNIT ca 2kWh

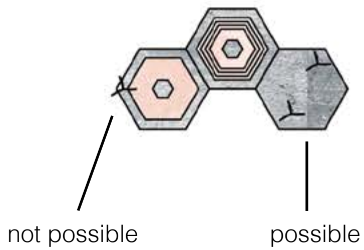
SOLAR => Pixel integration with horizontal PV panels of 200 Wp/m2



WIND (7 to 10 m/s) => Pixel integration with small turbines 10

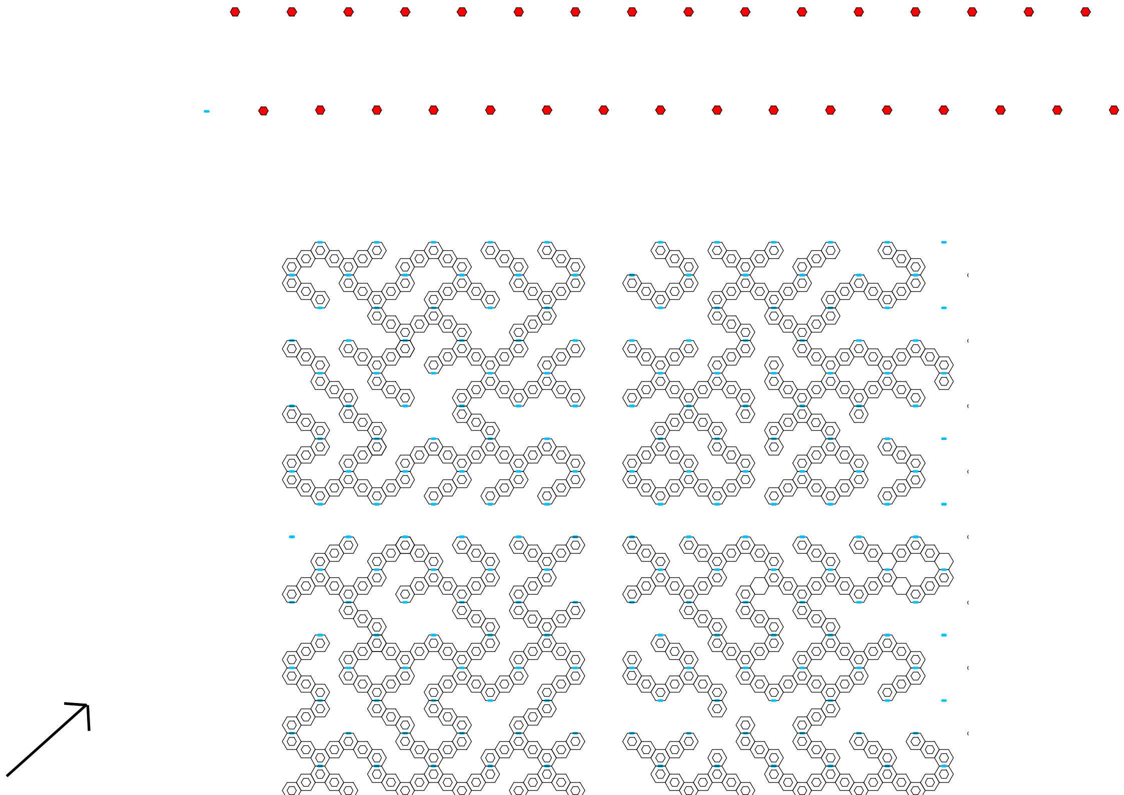






- Small windturbines of 10 to 15 KW
- Average rotor diameter 8 m
- Noise from 35 to 65 dB according to speed
- Minimum distance needed 30 m
- They do not fullfill energy need
- Green can help dissipates the noise
- Water increments the noise

WIND => Wind farm outside the city



Wind direction

0 200 500 m

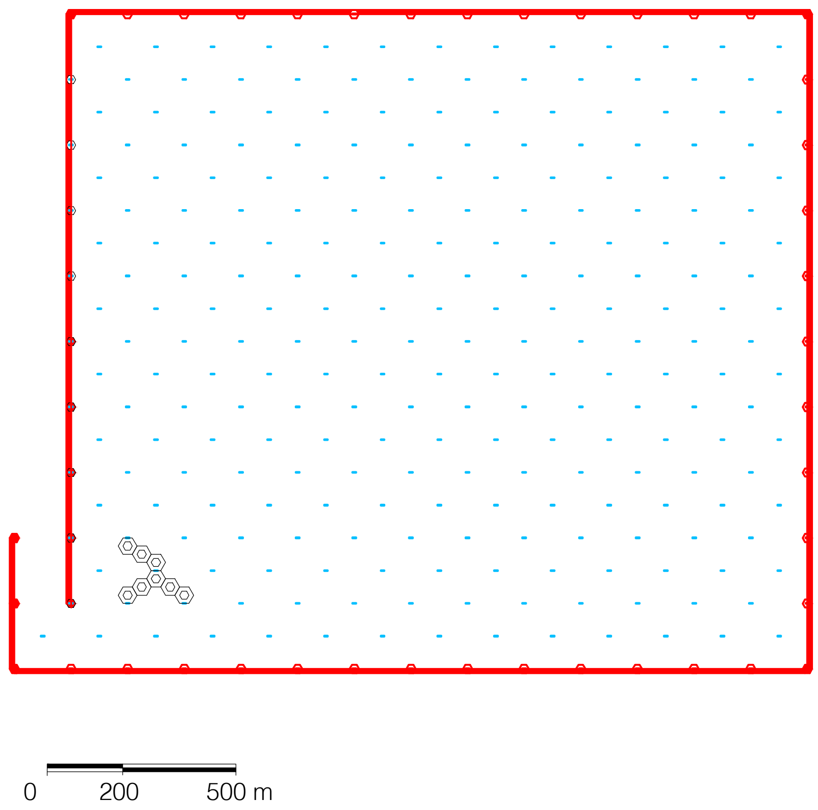
- Bigger turbines will need to be placed at least 300 m from dwelling
- A portion of the city with the energy need of the building pixels will need aproximately 30 - 32 turbines of 800 kW
- The scheme shows the minimal distance required among turbines of this size
- Bigger turbines will decrease their amount for equal energy need but increase the distance required

WATER

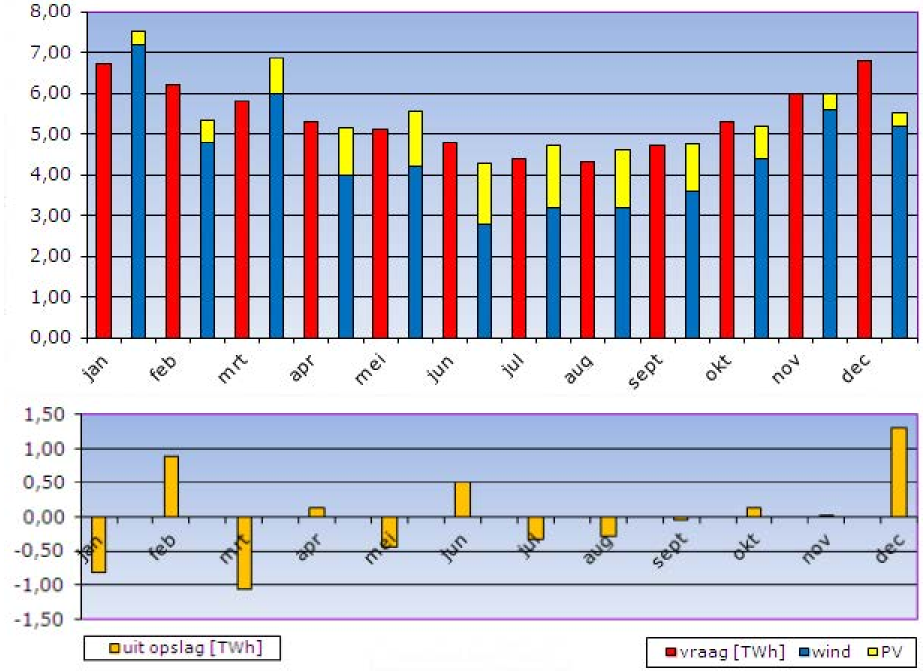
CURRENTS = 1-3 cm/s => Not possible

TIDES = 1.5 -2 m => Not possible

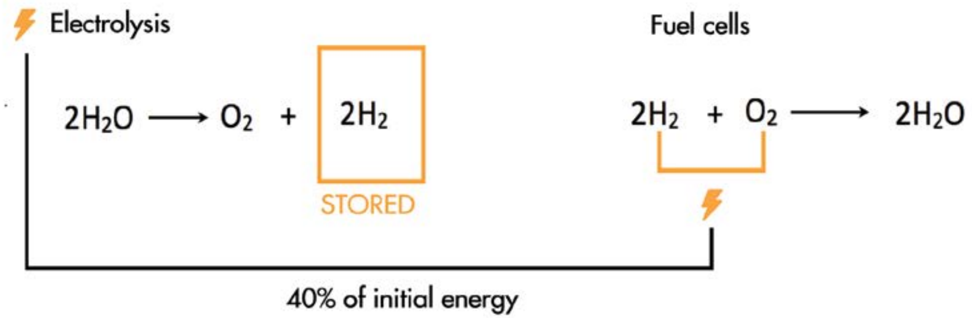
WAVES => 5-8 kW/m

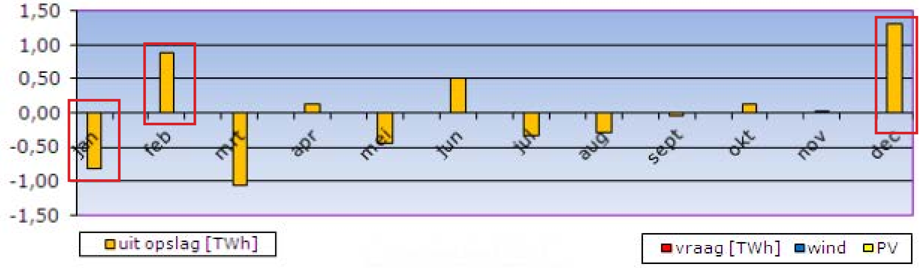


MONTHLY ENERGY SUPPLY



Monthly yields of favorable combination of energy from wind turbines (70%) and PV cells (30%) to cover the annual Dutch electricity demand
Source: Leo Gommans, gebiedsgerichte energetische systeemoptimalisatie, doctoral thesis, 2012, p. 221





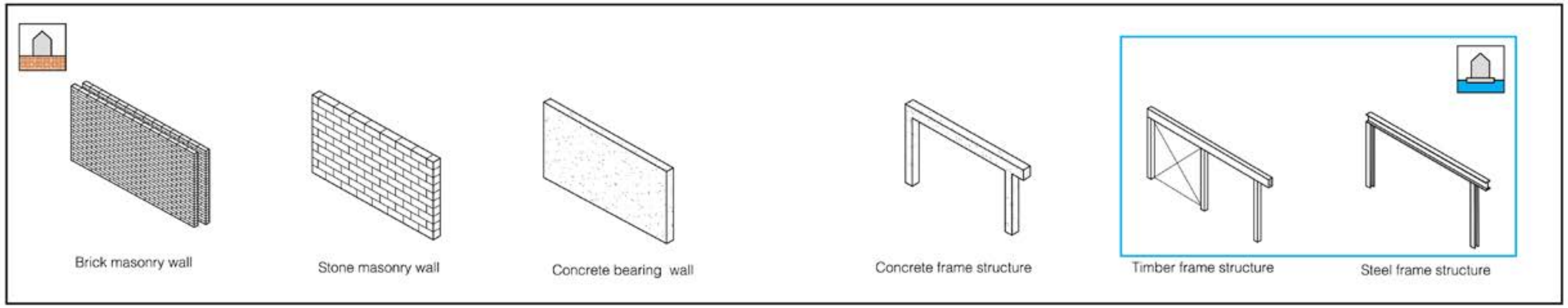
January's stored energy is enough for February and December

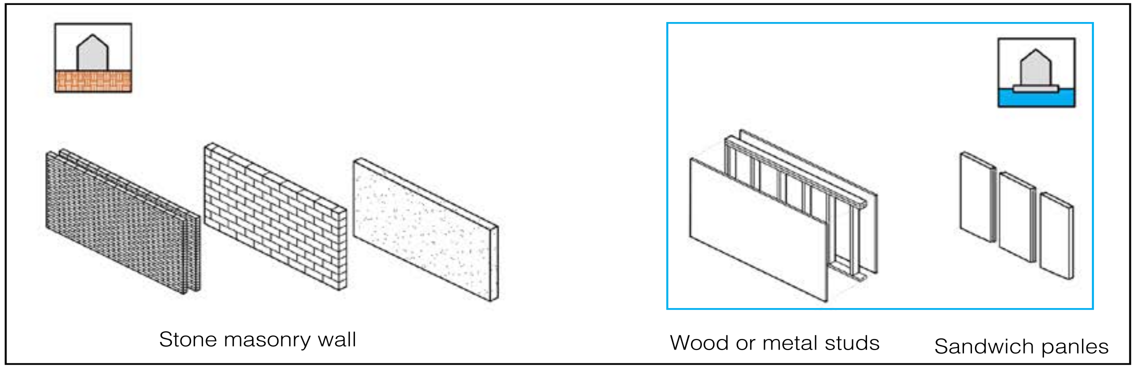
ENERGY POTENTIAL IN THE FURURE

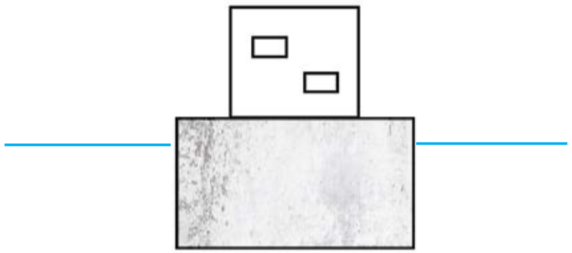
It is expected that by the end of century

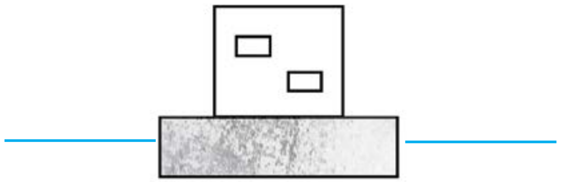
- Radiation will increase by 10% in the Summer
- Radiation will decrease by 10% in the Winter
- Wind speed will increase by 10 % both in warm and cold season

CONSTRUCTION







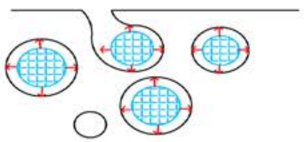


MATERIAL DURABILITY

MATERIAL	DEGRADATION TYPE	EXTERNAL FACTORS							
		Temperature	Condensation	RH	TOW	Bio Agents	Pollution	UV	SALT
METALS	Corrosion	±	±	+	+	no	+	-	±
BRICKS	Weathering/Salt attack	-	±	+	+	-	±	-	+
CONCRETE	Salt attack , freeze/thaw	-	-	-	+	no	+	-	±
STONE	Salt attack, chemical dissolution	-	-	-	±	±	+	-	+
GLASS		+	-	-	-	no	±	±	-
TIMBER	Fungal attack, termits, defi-bration	-	-	±	+	+	-	±	-
TIMBER COMPOSITES	Adhesive failure	+	-	+	+	-	-	-	no
PLASTICS	Photo - oxidation	+	-	-	±	?	+	+	-
POLYESTER RESINS	Yellowing	+	-	-	±	?	no	+	-

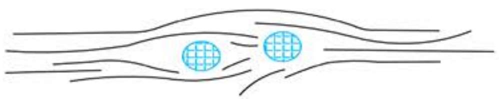
SALT ATTACK

Porous materials



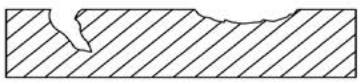
Micropressure by salt crystals when hydrated in wet and dry cycles

Wood



Defibration by salt crystallisation

Metals



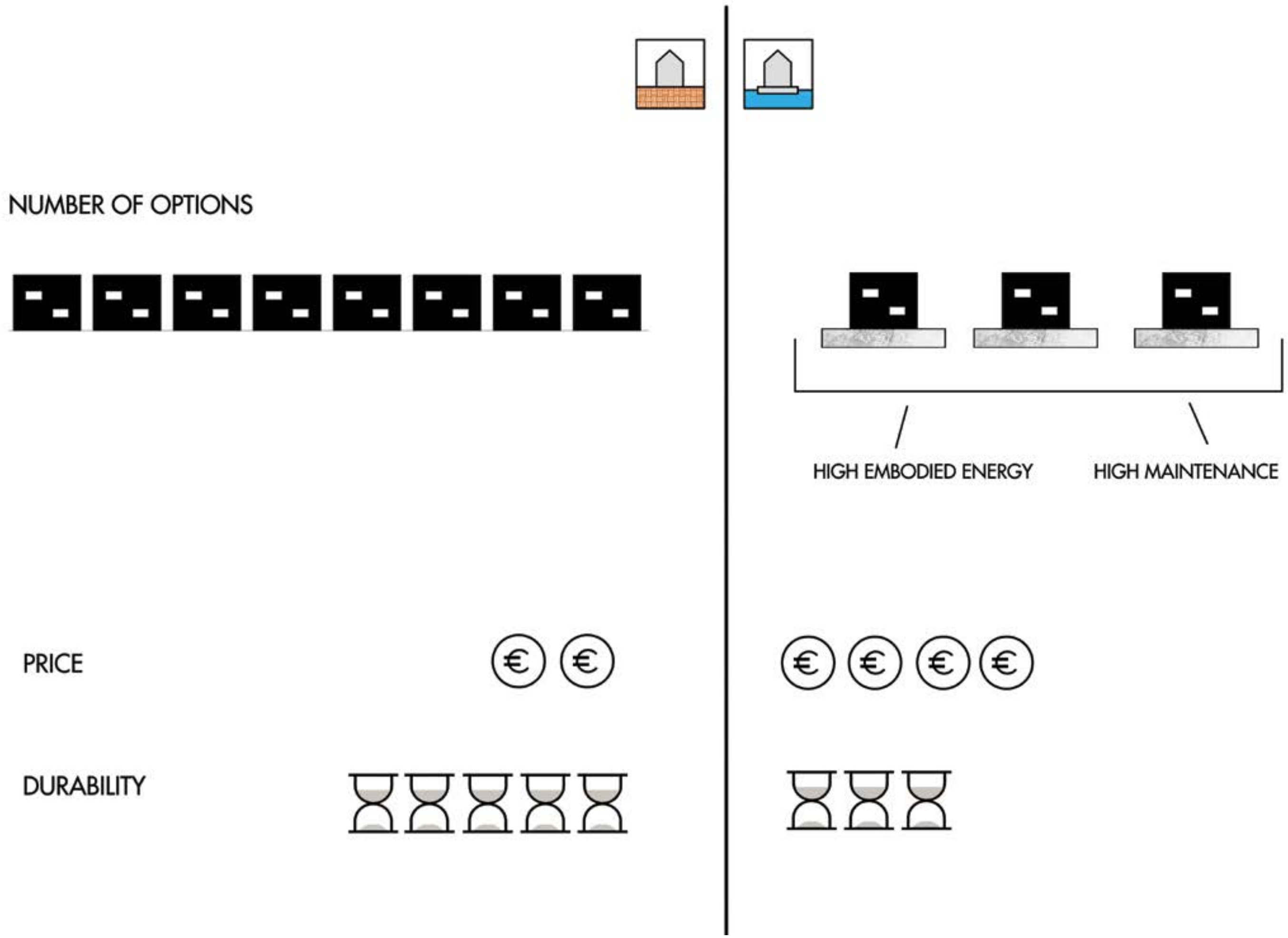
Pitting and crevice corrosion

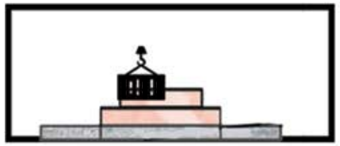
METALS	Weathering Steel	Titanium	Copper	Aluminium	Zinc
Weight (kg/dm3)	7.8-7.9	4.5	8.93	2.7-2.75	7.1
Life span (years)	30-100	100+	60-100	25-50	100
Life span marine environment	30-80	90	>10	15-25	50
Mantainance	minimal	minimal	minimal	minimal	minimal
Embodied energy	***	***	***	***	***
λ value [W/mK]	50.2	22	385	205	116
Recyclable	Yes	Yes	Yes	Yes	Yes
Coating	Yes	yes	no	yes	no
Price	***	***	***	***	**
Other uses	Supporting structures	Aerospace, mediacal implants, construc-tions etc..	Electrical equipment roofing, cookware	Cars, kitch-enware, computers ...	Automo-

POLYMERS	GRP	Polycarbonate	PVC-u
Weight (kg/m3)	3.9	ca	ca
Life span	50	5-15	10-50
Life span marine environment	40-50	2-10	40
Mantainance	minimal	yes	minimal
Embodied energy	***	***	**
λ value [W/(mK)]	0.04	0.19	0.19
Coating	yes	yes	yes
Recyclable	yes	yes	yes
Price	***	**	**
Other uses	Aeroplanes, electronic components, automotives, sporting equip-ment....	Glass substitute when higher resistance re-quired, lenses, facade	Pipes, window frames

MASONRY	Bricks	Concrete	Limestone
Weight (kg/m3)	1922	2400-3000	1760
Life span	100+	100+	50-100
Life span marine environment	80 or less	100+ (with the right mixture)	40-80 or less
Mantainance	no	50	no
Embodied energy	*	****	*
λ value [W/(mK)]	0.6/0.11	0.8	1.26/1.23
Coating	no	no	no
Recyclable	Depends	Depends	depends
Price	*	**	**
Other uses	building material	building material	building material

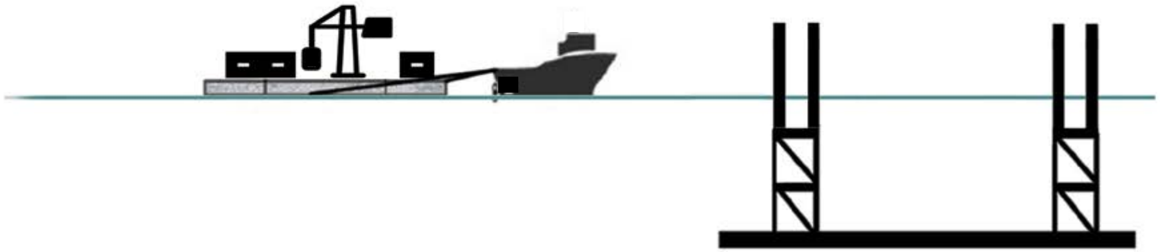
WOOD	White Oak	Old grown Cypress	Plywood
Weight (kg/m3)	730	510	600
Life span	40-50	40-50	25 ca
Life span marine environment	40-50	40-50	25 ca
Mantainance (years)	1-2	1-2	no
Embodied energy	*	*	*
Coating	yes	yes	yes
λ value [W/(mK)]	0.17		0.13
Recyclable	depends	depends	yes
Price	*/**	*/**	
Other Uses	Various	various	various


NUMBER OF OPTIONS
HIGH EMBODIED ENERGY
HIGH MAINTENANCE
PRICE
DURABILITY



Fast and protected construction

Only one transportation



High amount of resources and energy
outside the pixel

Can a floating city be energetically self-sustained and flexible?

URBAN FLEXIBILITY DEPENDS ON

- Mooring system and typology
- Density and networks
- Platform dimensions and shape

FLEXIBILITY IS LINKED TO DURABILITY
OF THE PIXEL

FOR FLEXIBLE CITIES URBAN COMPONENTS
NEED TO LAST MORE THAN ON LAND

ENERGY SUPPLY

- Water cannot yet be considered to make the city selft sustained
- Wind and solar energy can be considered enouth to garantee the
- self-sufficiency of the city
- Only solar can be integrated to the movability of the building pixels
- Calculations only refers to buildings. More energy will be needed for other activities, e.g. water desalinisation, street furniture elements etc.

RELIABILITY OF THE MODEL

- Calculations of energy need are made for inland settlements on water
- In open Sea changes in temperature and RH are more drastic, therefore the model cannot be considerd 100% reliable

PROOF THERE ARE ENOUGH RESOURSES TO MAKE THE CITY ENERGETICALLY SELFT SUFFICIENT

THE RESOURSES TO BUILD THE CITY ARE HIGHER THAN THE NEED TO BUILD NEAR THE ENERGY SOURCES

QUESTIONS?