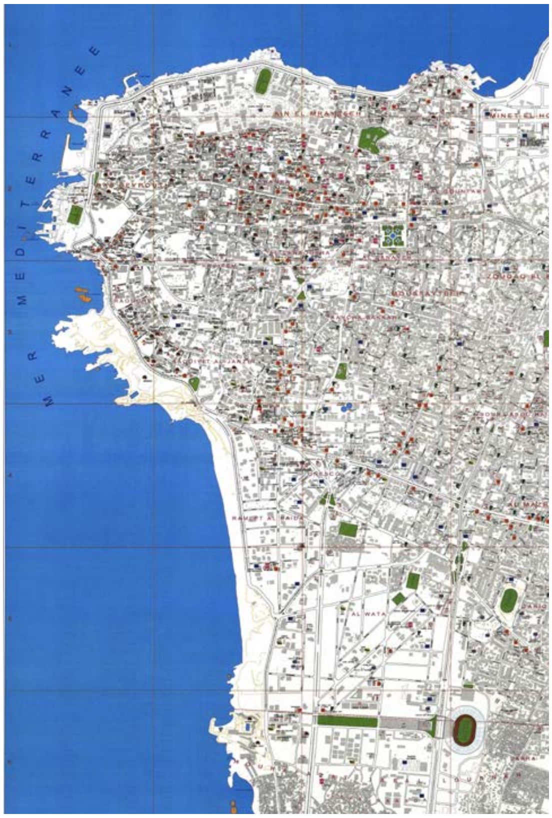
The Earth shell

Sheltering the City in Green

The lack of green space in the city and the lack of space to create green spaces render a gloomy city.

"A verdant roof may form part of an effective strategy for both cooling buildings and helping combat climate change" according to new research published inProceedings of the American National Academy of Sciences (PNAS) on February 11 2014.

"The Earth Shell" shall be adaptive in form and use, easy to assemble and disassemble, modular, light-weight and compact, making it feasible as a do-it-yourself project for any building resident and applied on any roof



Contents

The Gloomy City

Beirut as a Case Study

In Beirut, installing green roofs on the majority of old buildings is a very complex venture. Roofs usually are not waterproof; pipes , private water tanks for the apartments, electricity wires, and other permanent roof fixtures renders preparing a roof for greenery a difficult task. The proposal is to design a lightweight super-roof " the Earth shell" to be implemented on roof tops over existing roof top installations, making use of the dead roof space. The Earth Shell would bridge over the permanent roof fixtures to create a new shell covering the old roof and, at the same time, not affect the old roof's arrangement or its ongoing use.

The Context

Location : the city verses the village

The city: Beirut

The situation inside Beirut can be summarized by couple of points:

- Inside the City, the lack of green spaces
- Power supplied by local diesel generators
- No outdoor spaces
- High levels of air pollution
- A concrete jungle
- Polluted water resources
- Most people live their whole life inside this area
- People need a sustainable village shelter for break outside the city

The village

the situation in the rural areas:

- Good water resources collected on roof tops for all year house-hold use
- Sustainability through self dependency farming
- minimal use of electric power

the village and rural area are still a big contrast to what is happening in the city , but this situation is changing in a fast rate to follow.

Climate

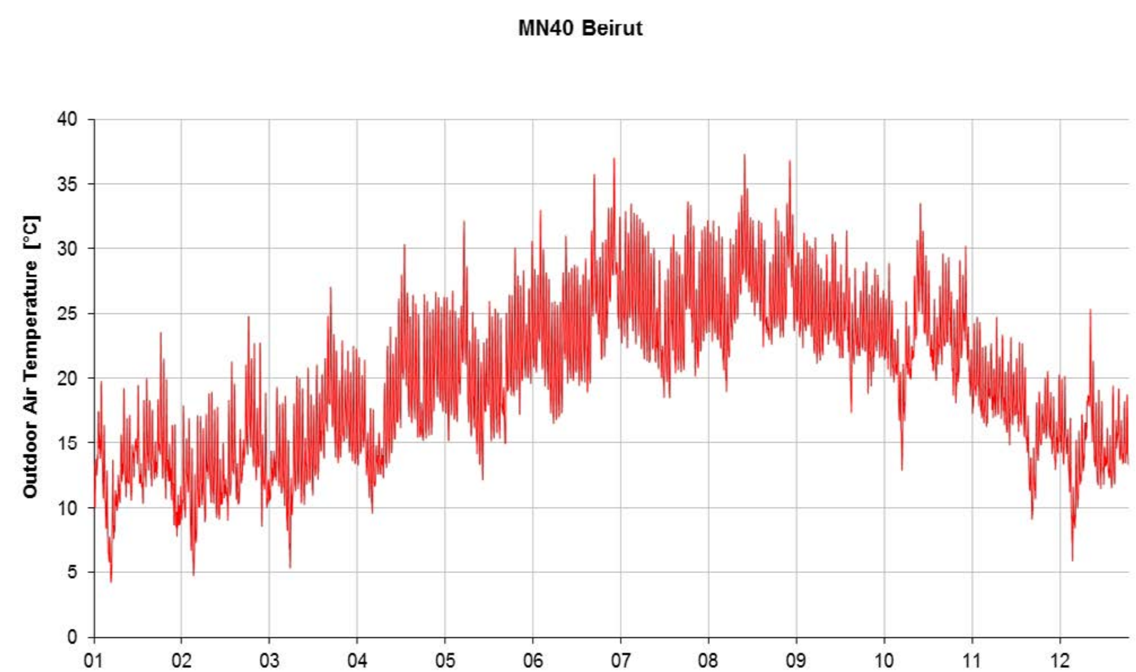
This report describes the typical weather at the Beirut Air Base/Rafic Hariri International Airport (Beirut International) (Beirut, Lebanon) weather station over the course of an average year.

It is based on the historical records from 1992 to 2012. Earlier records are either unavailable or unreliable.

Beirut has a mediterranean climate with dry hot summers and mild winters. The area within 40 km of this station is covered by oceans and seas (54%), croplands (27%), and grasslands (17%)

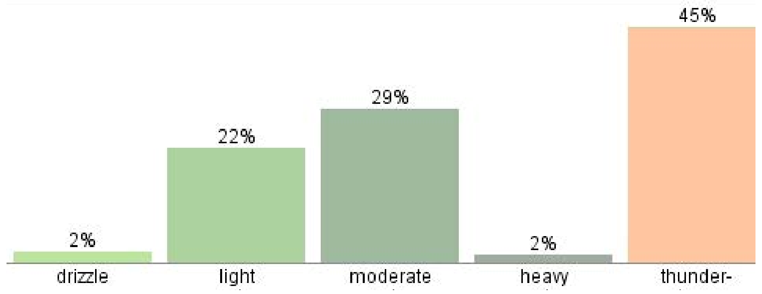
High and low tempreture

The warm season lasts from June 15 to October 12 with an average daily high temperature above 28°C. The hottest day of the year is August 9, with an average high of 31°C and low of 25°C. The cold season lasts from December 10 to March 23 with an average daily high temperature below 19°C. The coldest day of the year is January 29, with an average low of 11°C and high of 17°C



Rain and percipitation

The probability that precipitation will be observed at this location varies throughout the year. Precipitation is most likely around January 11, occurring in 55% of days. Precipitation is least likely around July 14, occurring in 1% of days. Over the entire year, the most common forms of precipitation are thunderstorms, moderate rain, and light rain.



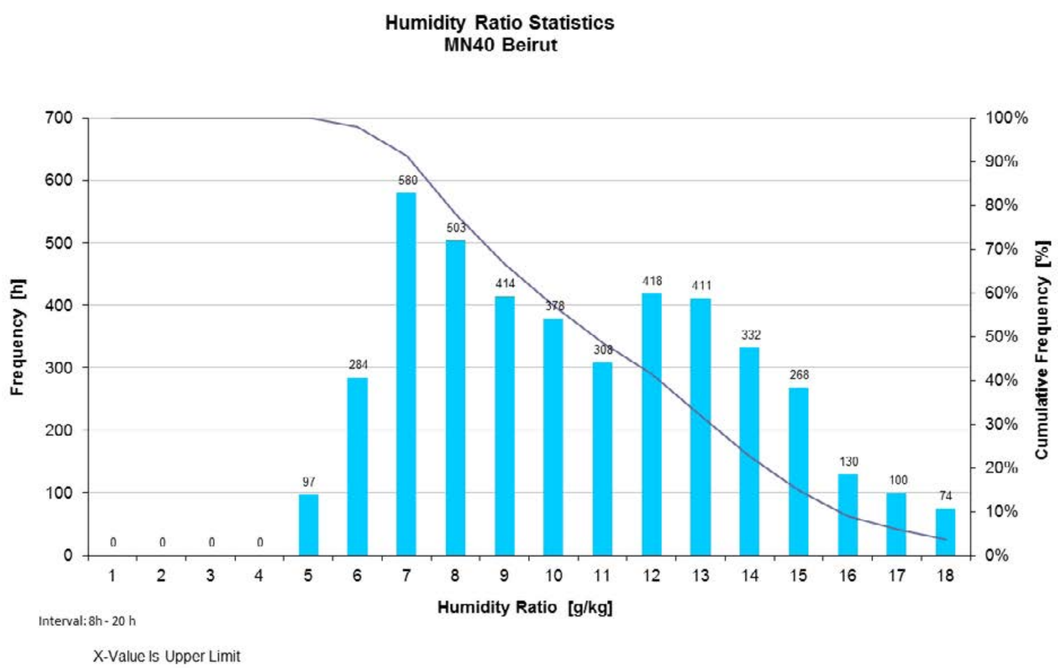
Thunderstorms are the most severe precipitation observed during 45% of those days with precipitation. They are most likely around January 5, when it is observed during 26% of all days. Moderate rain is the most severe precipitation observed during 29% of those days with precipitation. It is most likely around January 20, when it is observed during 17% of all days. Light rain is the most severe precipitation observed during 22% of those days with precipitation. It is most likely around February 6, when it is observed during 11% of all days.

During the warm season, which lasts from June 15 to October 12, there is a 5% average chance that precipitation will be observed at some point during a given day. When precipitation does occur it is most often in the form of thunderstorms (38% of days with precipitation have at worst thunderstorms), light rain (29%), and moderate rain (27%).

During the cold season, which lasts from December 10 to March 23, there is a 50% average chance that precipitation will be observed at some point during a given day. When precipitation does occur it is most often in the form of thunderstorms (46% of days with precipitation have at worst thunderstorms),

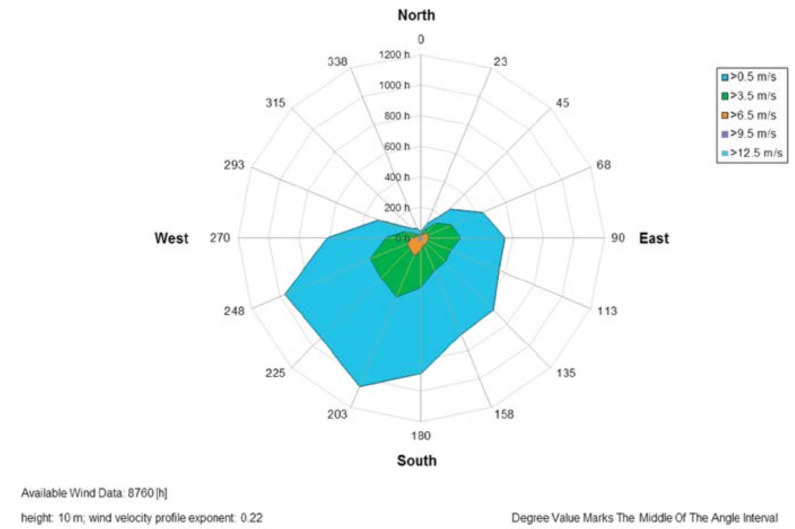
Humidity

The relative humidity typically ranges from 42% (comfortable) to 84% (humid) over the course of the year, rarely dropping below 25% (dry) and reaching as high as 95% (very humid). The air is driest around November 10, at which time the relative humidity drops below 51% (mildly humid) three days out of four; it is most humid around May 12, exceeding 78% (humid) three days out of four.



Wind

Over the course of the year typical wind speeds vary from 0 m/s to 6 m/s (light air to moderate breeze), rarely exceeding 12 m/s (strong breeze). The highest average wind speed of 4 m/s (gentle breeze) occurs around July 15, at which time the average daily maximum wind speed is 6 m/s (moderate breeze). The lowest average wind speed of 3 m/s (light breeze) occurs around October 16, at which time the average daily maximum wind speed is 5 m/s (gentle breeze). Wind Speed The wind

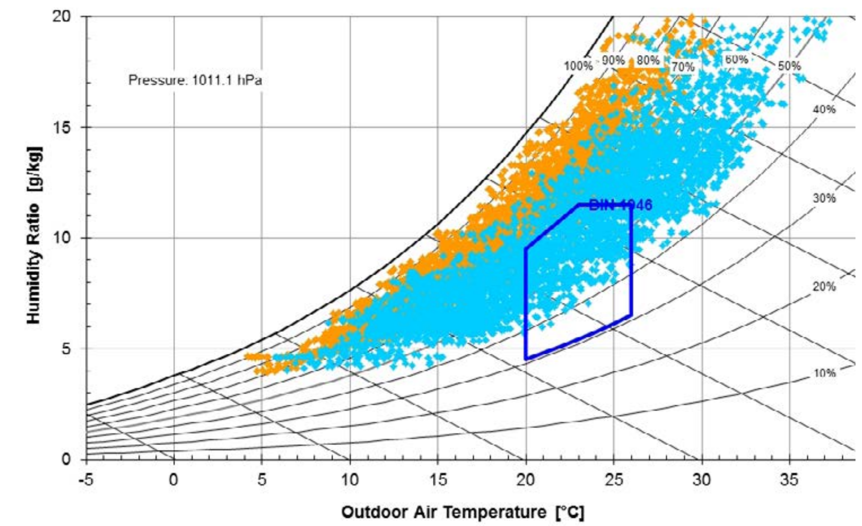


Psychometric chart

The least humid month of the last 12 months was October with an average daily low humidity of 37%, and the most humid month was August with an average daily low humidity of 58%.

But it is important to keep in mind that humidity does not tell the whole picture and the dew point is often a better measure of how comfortable a personwill find a given set of weather conditions.

Dew point is the temperature below which water vapor will condense into liquid water. It is therefore also related to the rate of evaporation of liquid water. Since the evaporation of sweat is an important cooling mechanism for the human body, the dew point is an important measurement for understanding how dry, comfortable, or humid a given set of weather conditions will feel.



Generally speaking, dew points below 10°C will feel a bit dry to some people, but comfortable to people accustomed to dry conditions; dew points from 10°C to 20°C are fairly comfortable to most people, and dew points above 20°C are increasingly uncomfortable, becoming oppressive around 25°C.

History and Tradition

The old techniques of timber earth roofs and the cross vaults in traditional architecture was widely spread, but with modern building practices these techniques were lost.

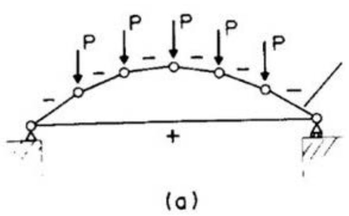
Vision and the future

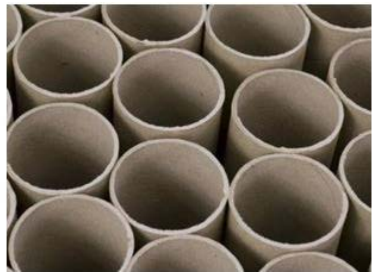
A Hybrid

- Adaptive in scale, form and use
- Do It Your self project
- Easy assembly- disassembly
- Modular in design
- Light weight
- Compact

Implementing on roof tops to bridge over existing roof top installation

making use of roof space, in same time planting vegetation.
without preparing existing roofs for the regular green roof plantation,
the shell is implemented as an add-on to the roof.





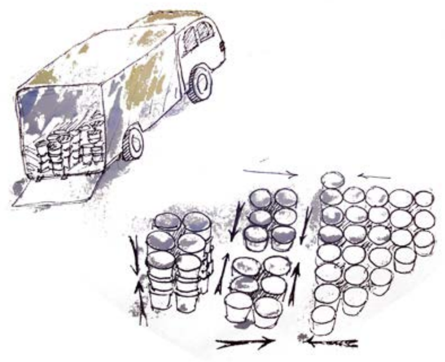
Uses and scope

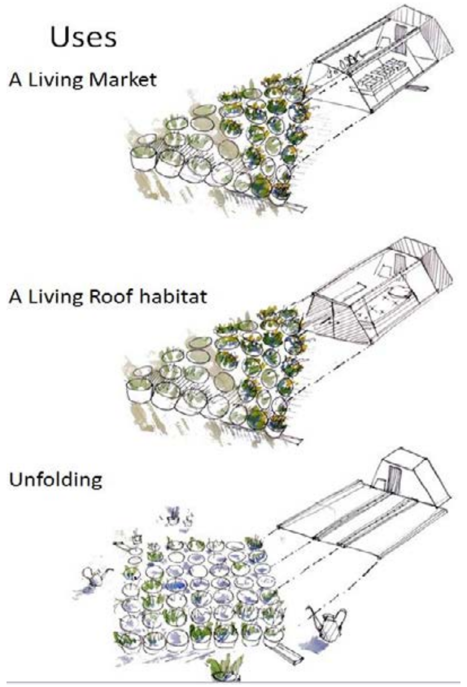
Landscaping

The configuration for the Shell is adaptive to the scale, the site and the use. Mainly it could include three units: for plantation and vegetation, for collecting rain water or kept open for ventilation and sunlight in long configurations. One site Can be landscape or park use or just backyard use.

Living Market

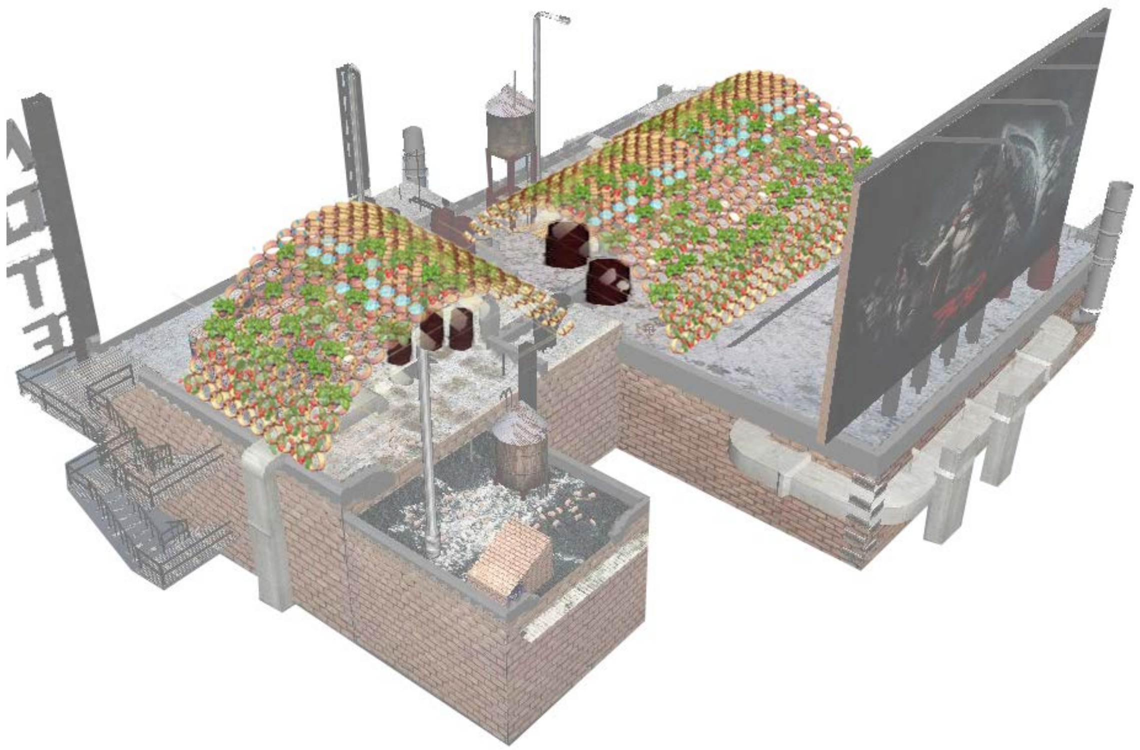
Dynamic use of shelter becomes a living market, to be assembled and dissassembled, and underneath becomes a space for the vendor. It acts as a living market set up in piazzas can be unfolded to become a horizental surface for maintanace and transportation





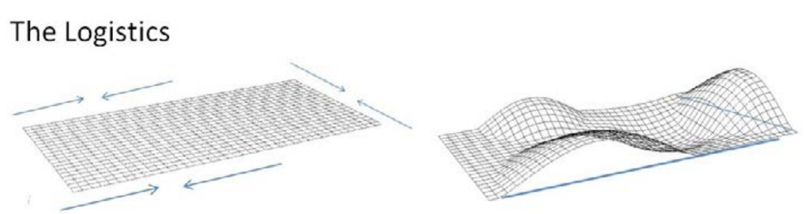
Roof Tops

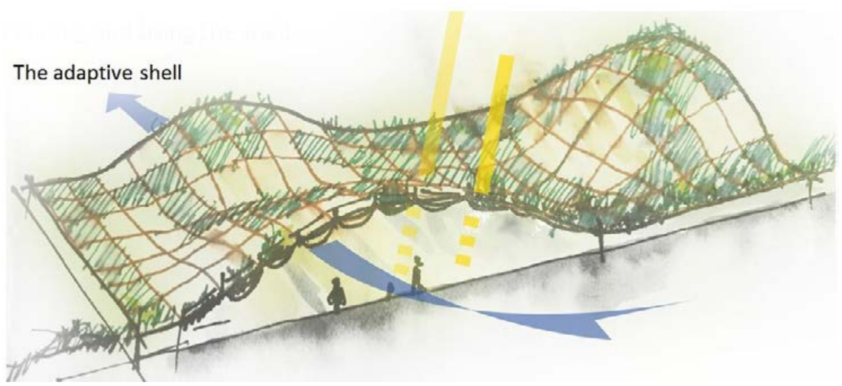
After the shell is assembled, it is lifted to create the space underneath and then filled with earth.



The Urban

The vision takes the scale to the urban configuration. piazzas and public space, markets and camping





Study and research

Material

The aim for the selected material is to fulfill a cheap, recyclable and high strength material. different materials are examined for different aspects.
Most important for our study via priority is: Price ; Availability; recyclable; strength; light weight

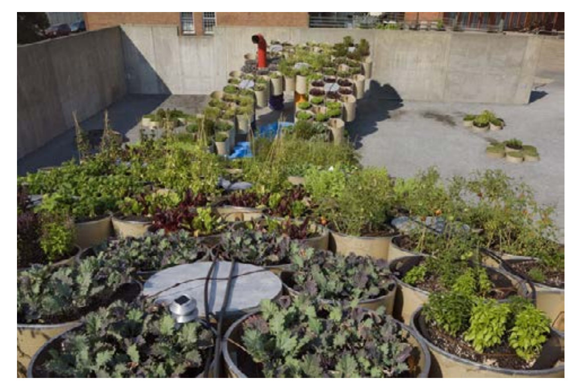
Cardboard Tubes	Clay/Ceramic Tubes	Fiberglass Tubes	Plastic/PVC Tubes
			
Recyclable from paper material. biodegradable	Recyclable from earth material. biodegradable	advanced level of production	Needs more energy in production
easily produced for different sizes	needs special production and treatment	high tech fabrication	easily produced for different sizes
cheap, 2 dollar per module	costly , 25 dollar per module	too costly, 70 dollar per module	cheap relatively, 6 dollar per module
Can be thickened for high compresion strenght	induces sudden failure after certain amount of pressure	perfect structural characteristics	available for different thickness
Should be treated for water proofing	waterproof	weather and climate proof	weather and climate proof
lasts up to 2 years , depending on locution and treatment	can last up to 15 years up to maintenance	no life-time limit	can last up to 15 years up to maintenance

Cardboard Tubes

Possibility of strengthening the structure of the paper-board core, improving the compressive strength according to the type of support and the components used in the manufacture. Perfect dimensional stability of the tube due to the use of adhesives (dextrins of plant origin with high solid content) in the manufacture. Card-board Tubes Clay/Ceramic Tubes Fiberglass Tubes Plastic/PVC Tubes

Cardboard Tubes provide a cheap, locally recyclable material. Life span is short but this can be solved by casting clay inside or epoxy resin if the structure is intended for long time duration. Thus the tubes will be serving as form-work for casting local clay, and thus transforming it from temporary to permanent.

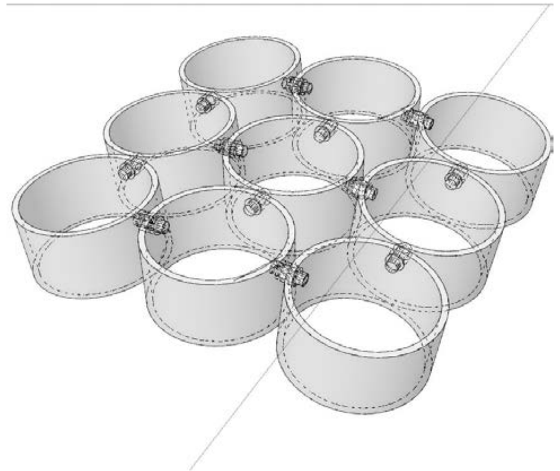
Card board material has its disadvantages in disassembly where it has a high risk of damaging the shell components and thus cant be assembled again.

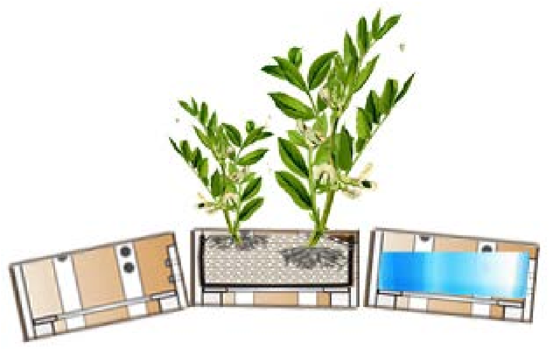


PVC Tubes

PVC has high hardness and mechanical properties. The mechanical properties enhance with the molecular weight increasing, but decrease with the temperature increasing. The mechanical properties of rigid PVC (uPVC) is very good, the elastic modulus can reach to 1500-3,000 MPa.

The soft PVC (Flexible PVC) elastic is 1.5-15 MPa. However, elongation at break is up to 200% -450%. PVC friction is ordinary, the static friction factor is 0.4-0.5, the dynamic friction factor is 0.23.





Conclusion
PVC pipes were shosen for the urban context for its long life span, light weigth, thin properties.

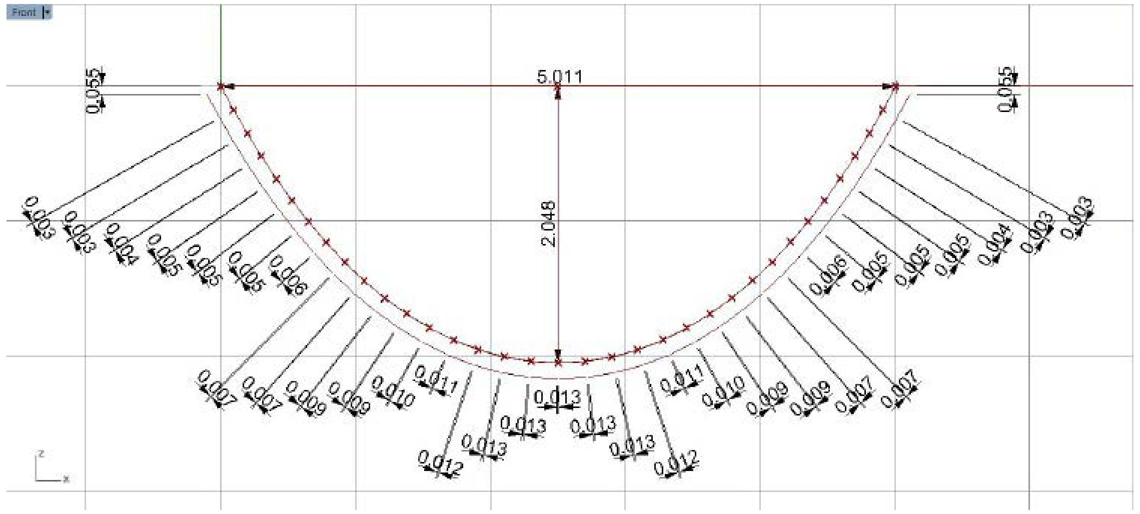
Pavilion can be dissassembled and reassembled without damaging the structure.

On the other hand for a landscape context where the project site is permentant and no need to disassemble, the pavilion with waxed cardboard tubes fits better.

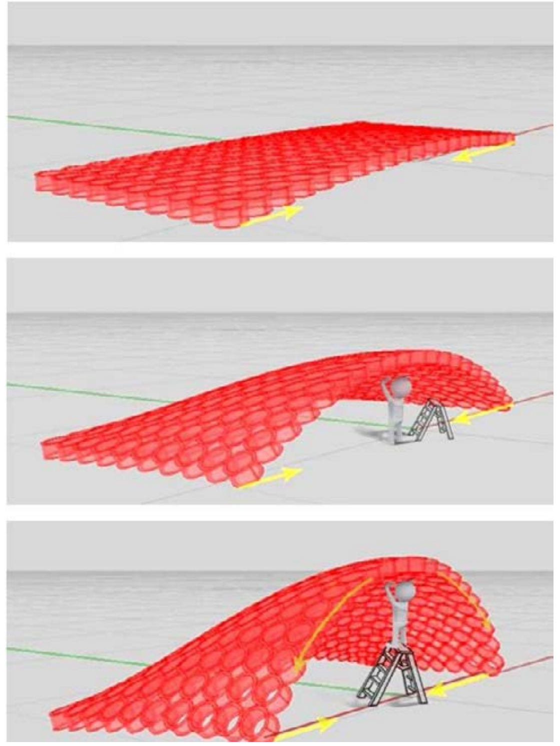
The cardboard biodegrade leaving just the compacted earth and roots.

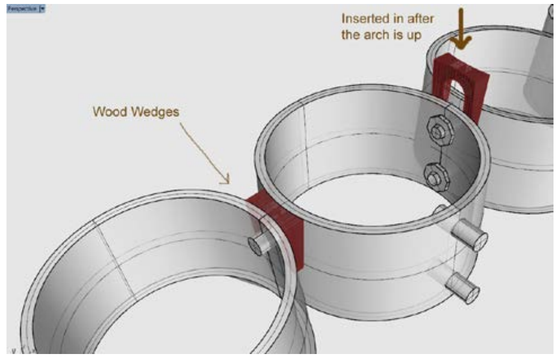
Structural analysis

Form Finding
Comparison of two configuration and form finding for the structure

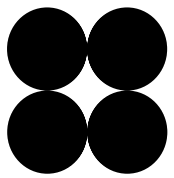
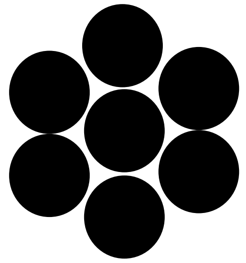


Structural form finding for the pavilion arch was made using grasshopper to figure out the distances and spacers needed for the structure optimum form.



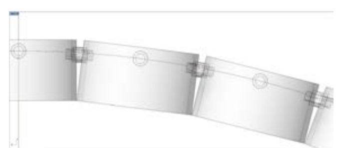


Modeling
Comparison of two configurations and form finding for the structure

Config.	Quad	Hexa
Geometry		
Dead weight	55 kg per unit	20 kg per unit
# per arch	20 units	30 units
Diameter	44 cm	26 cm
Depth	30 cm	20 cm
Thickness	0.5 cm	0.5 cm
decrees weight on stressed area		

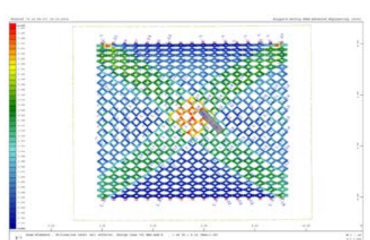
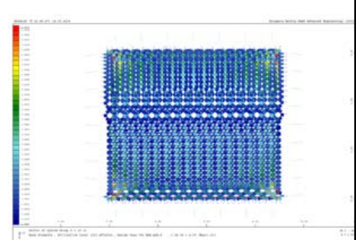
Quad

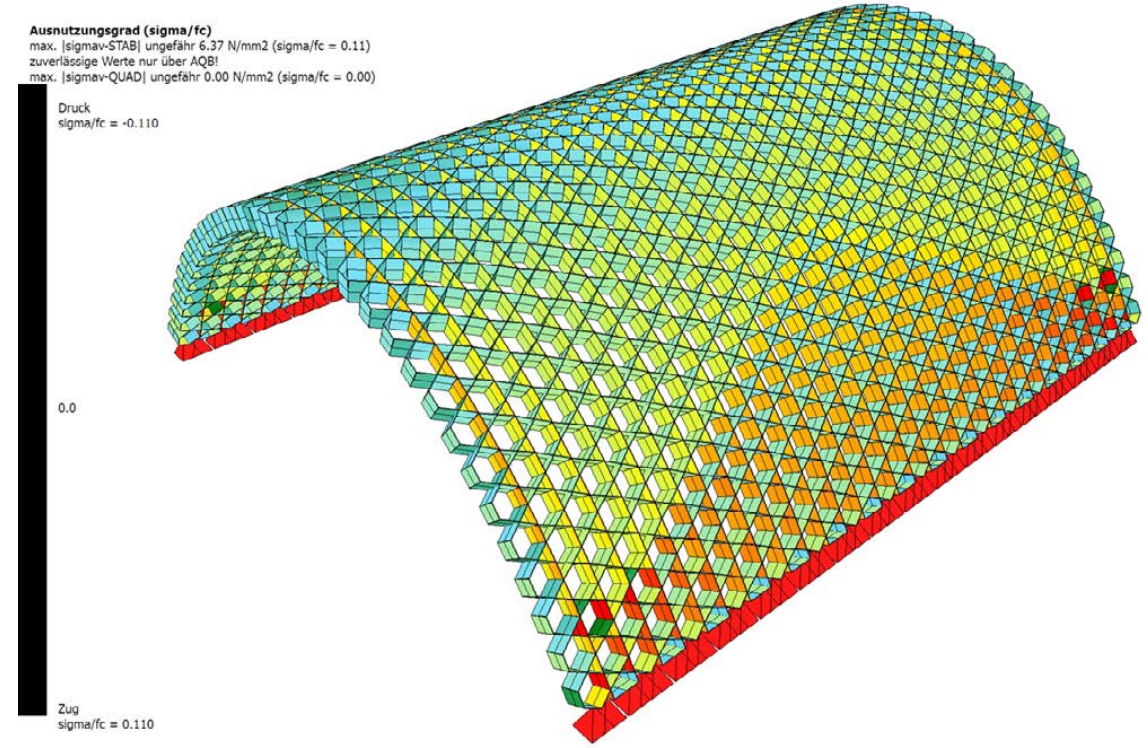
Area = 707 cm^2
loading: 55 kg per unit -------> p = 0.55 KN/0.0707 m^2 = 7.78 KN/m^2
22 kg per unit-->= 2.53 KN/m^2
10 kg per unit-->= 1.42 KN/m^2



Hexa

Area = 417 cm^2
loading: 20 kg per unit -------> p = 0.2 KN/0.0417 m^2 = 4.8 KN/m^2

Config.	Quad	Hexa
Geometry		

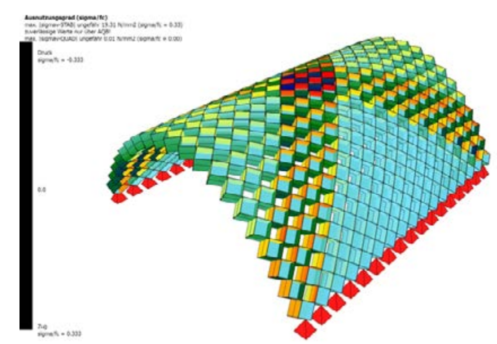


Hexagon structural utilization analysis

Conclusion

The hexagon configuration structurly outfiits the quadratic one, as shown in the analysis the quadratic configuration takes the loads mainly on the lond diagonal arch and imposes incoherent stresses through out the structure , while the hexagon configuration distributes the load uniformly and on the short span of the arches.

thus a hexagon configuration with ground support will be the optimized solution for the structure configuration.

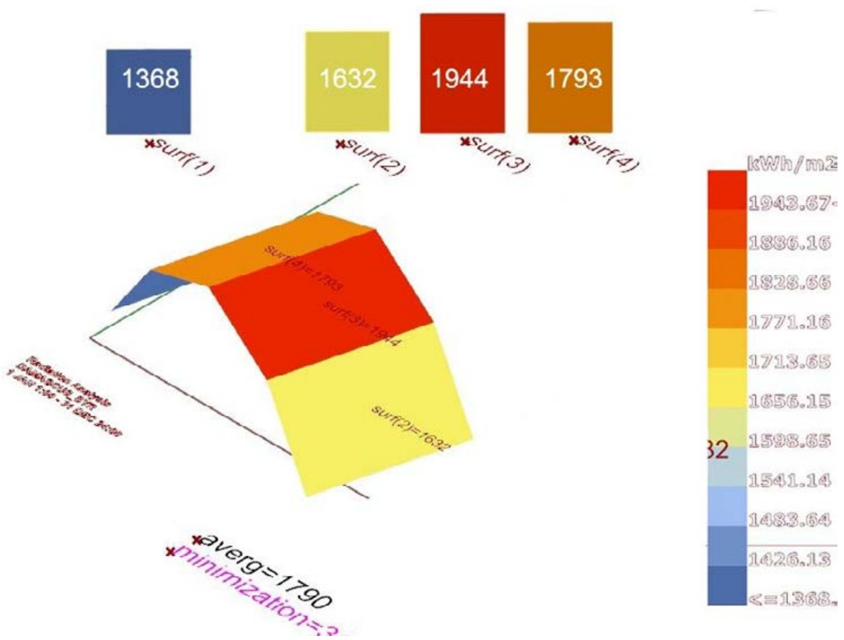


Quadratic structural utilization analysis

Solar Radiation

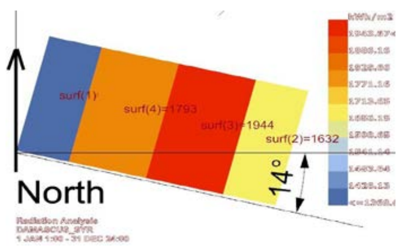
Aim

the aim here is to minimize radiation differences on the different surfaces of the pavilion, by getting the best orientation



Surf (2), Surf (3) and surf (4) has almost similar radiation while surf(1) is left out as a surface for special plants that doesn't need much of radiation

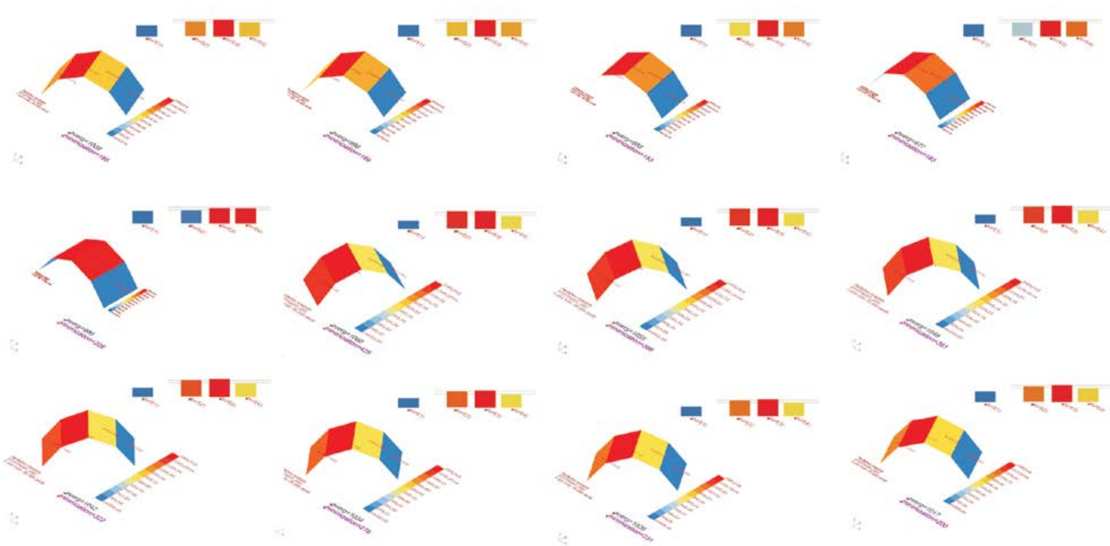
Solar radiation analysis



Angle for intended radiation

Conclusion

An orientation of 14 degrees will acheive coherent radiation on 3 qaurters of the pavilions for planting.
the last qaurter is used for a less needy plants or the oppenings.



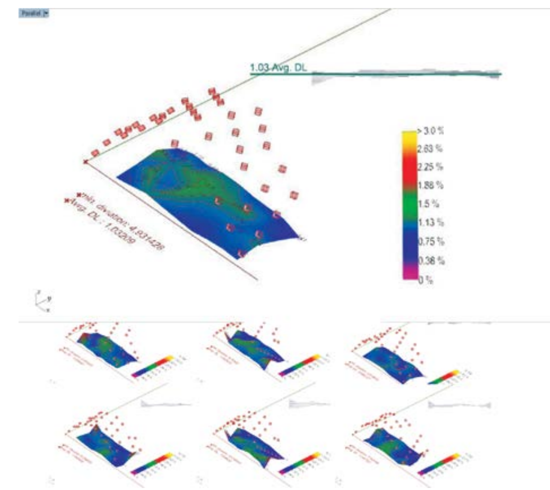
Orientation radiation iteration

Daylight Analysis

Using Day-sim in lizard and minimizing equations

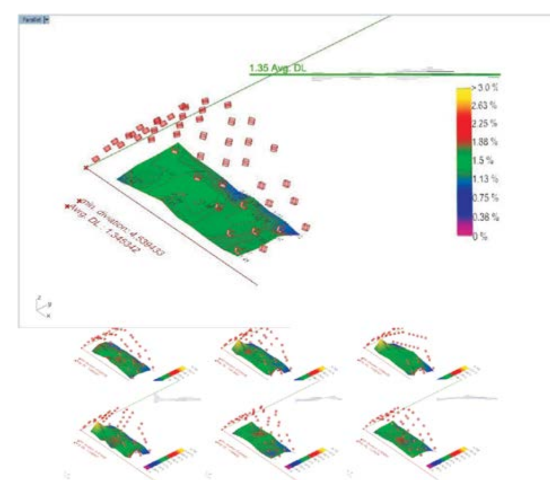
Aim

The aim is to reach the best arrangement of the empty modules in different cases to achieve coherent and good daylight inside the pavilion



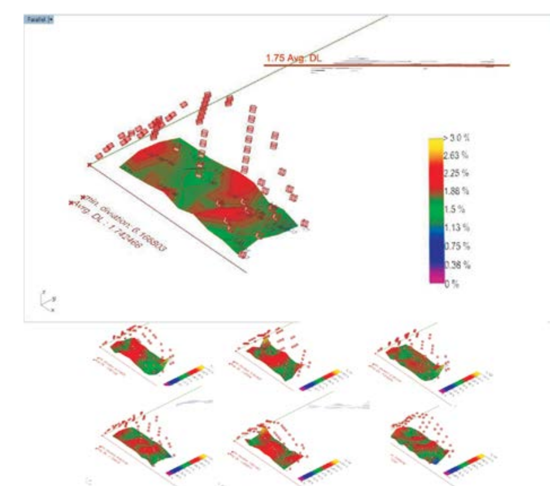
36 openings

Resultant daylight average is 1 percent
506 combinations of runs were done
fig.b 1 shows the optimized arrangement
to get minimum deviation of daylight levels inside the pavilion



48 openings

Resultant daylight average is 1.4 percent 506 combinations of runs were done fig.b 2 shows the optimized arrangement
to get minimum deviation of daylight levels inside the pavilion for 48 openings



60 openings

Resultant daylight average is 1.8 percent 506 combinations of runs were done
fig. b 3 shows the optimized arrangement
to get minimum deviation of daylight levels inside the pavilion for 60 openings

Conclusion

For the totally closed pavilion transperent pods arrangment and number is imprtant to acheive adeqaute and coherent daylight level inside.

Comfort Analysis

Model setup

Using UTCI and EEs tool

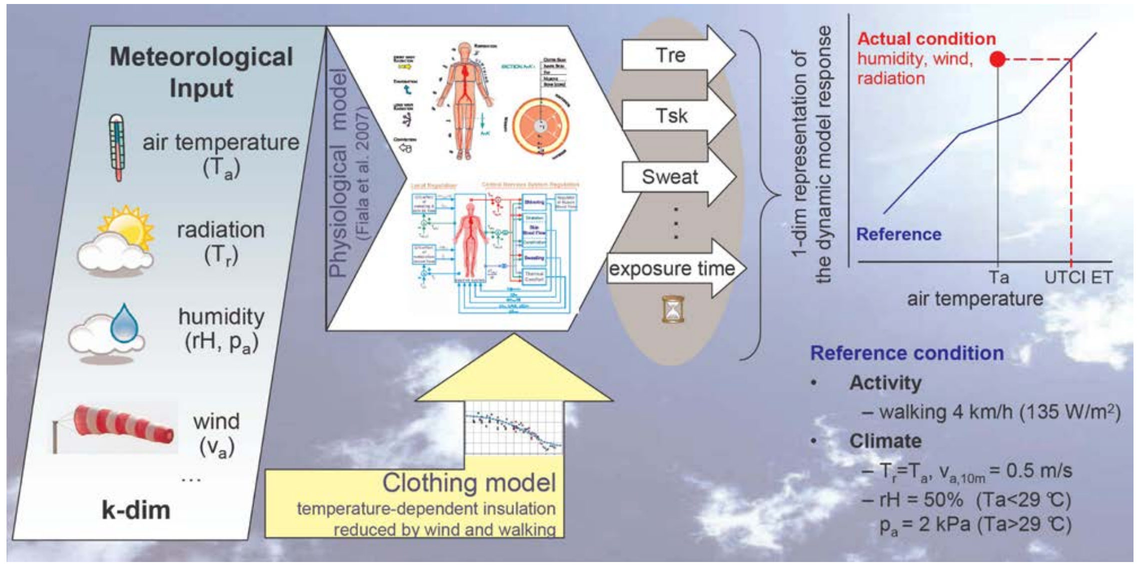
The aim is to reach best comfort strategies during both cold and hot halfs of the year using outdoor comfort analysis tool.

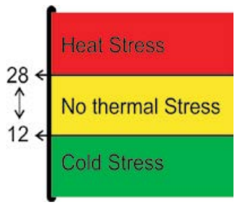
BODEN	spec. Heat capacity of soil	C		0.00100	[MJ/(kgK)]
	density soil	rho		2400.00	[kg/m³]
	thermal conductivity of soil	k		0.00720	[MJ/(h*m*K)]
	Type WU coeff ground top?	Switch_WÜ	0 / 1	1	[-]
	const coeff wu ground top	h1_c		0.010800	[MJ/(h*m²*K)]
	Temperature boundery condition at bottom underside	Bound_Ground	0 / 1	0	[-]
	const soil temp at bottom underside	T_soil		18.0	[°C]
	const coeff wu ground base	h0_c		0.003456	[MJ/(h*m²*K)]
	IR emissivity of soil	e_top	0..1	0.96	[-]
	sol absorption coefficient floor	esol_top	0..1	0.90	[-]
	Layer thickness (per layer)	dx		0.10	[m]
	Number of time steps per hour	N_Time	10..30	20	
	Cooling capacity in the soil	q_cool_layer2		0.00	[W/m²]
	Early hour floor cooling in	begin_hfc_of_year	0..8759	0	[h]
	Final hour floor cooling in	end_hfc_of_year	0..8759	8759	[h]
	Early hour floor cooling day	begin_fc	0..23	0	[h]
	Floor cooling final hour a day	end_fc	0..23	23	[h]
LUFT	Reduction of wind speed	fac_w_g_red	0..1	0.10	[-]
	Setting whether wind of weather data or constant	Switch_wv	0/1	0.00	[-]
	Wind speed at a constant wind	wind_vel	0...	0.10	[m/s]
	Switch air conditioning	ac_on	0 / 1	0	[-]
	First start of ac	begin_ac_forenoon	0..23	8	[h]
	1	end_ac_forenoon	0..23	13	[h]
	Second start of ac	begin_ac_afternoon	0..23	16	[h]
	Second end of ac	end_ac_afternoon	0..23	23	[h]
	limit temp	UTCI_ac_on		32.0	[°C]
	limit moisture	x_limit		0.0130	[kg/kg]
		T_cool		18.0000	[°C]
	Height to the membrane	area_height		3.00	[m]
	Ventilation by means of ac	air_change_cool		1.00	[1/h]
	Air exchange with outside	air_change_amb		2.00	(1/h]
	spec. heat capacity of air	cp_air		0.001005	[MJ/(kgK)]
MEMBRAN	membrane status	Switch_Mem	0 / 1 / 2	0	[-]
	control membrane	Contr_Mem	0 / 1	0	[-]
	Beginning of shading	start_day	0..23	0	[h]
	end of shading	end_day	0..23	23	[h]
	IR emissivity membrane below	e_mem_in		0.90	[-]
	IR emissivity membrane above	e_mem_out		0.90	[-]
	sol absorbtion coefficient membrane below	esol_mem_in		0.80	[-]
	sol absorbtion coefficient membrane above	esol_mem_out		0.80	[-]
	sol transmittance membrane	tsol_mem_in		0.10	[-]
HIMMEL	sol absorption coefficient sky	esol_sky	[-]	1.00	[-]
ADIABATIC COOLING	Adiabatic cooling	adia_cl_on	0/1	0	[-]
	efficiency humidifier	eta_adiabatic	0..1	0.80	[-]
	PT is cooled adiabatically from the	UTCI_adia_on		32	[°C]

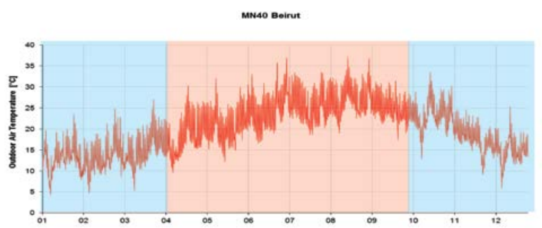
Base Case 1

the base case is set to simulate an average urban site context with the following quantitative inputs:

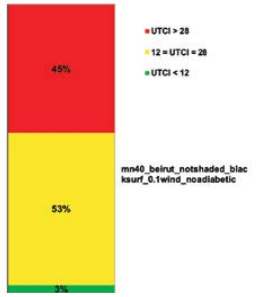
0.9 coefficient of solar absorptions (black ground)
0.1 wind factor (almost no wind)
no membrane
no adiabatic cooling



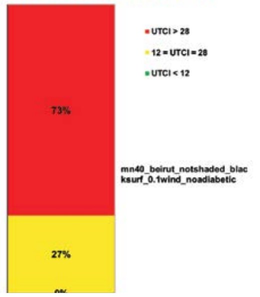




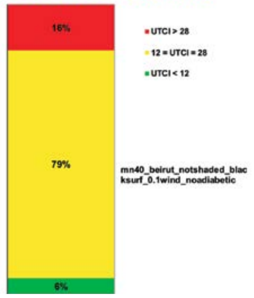
Base Case
Annual assessment

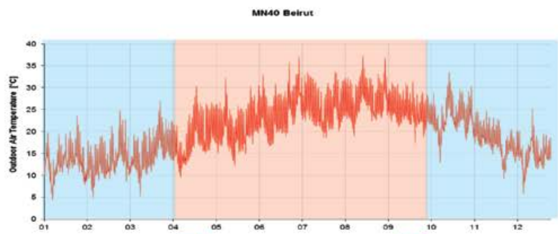


Base Case
Hot Half assessment



Base Case
Cold Half assessment



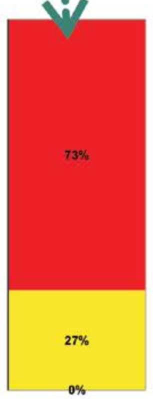


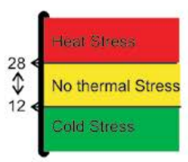
Analysis for the **Hot Section**

April till Sept

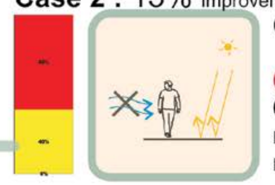
Base Case 1

0.9 coefficient of solar absorption (black ground)
0.1 wind factor (almost no wind)
no membrane
no adiabatic cooling





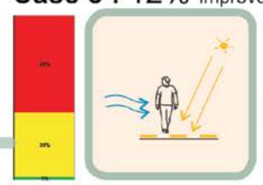
Case 2 : 13% improvement



Case 2

0.2 coefficient of solar absorptions (white ground)
0.1 wind factor (almost no wind)
no membrane
no adiabatic cooling

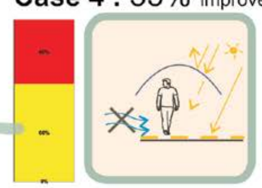
Case 3 : 12% improvement



Case 3

0.9 coefficient of solar absorptions (black ground)
0.7 wind factor (normal wind)
no membrane
no adiabatic cooling

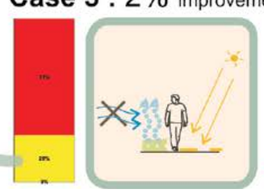
Case 4 : 33% improvement



Case 4

0.9 coefficient of solar absorptions (black ground)
0.1 wind factor (almost no wind)
with membrane (in shade)
no adiabatic cooling

Case 5 : 2% improvement



Case 5

0.9 coefficient of solar absorptions (black ground)
0.1 wind factor (almost no wind)
no membrane
adiabatic cooling on(plants of 0.25 humidity on 26

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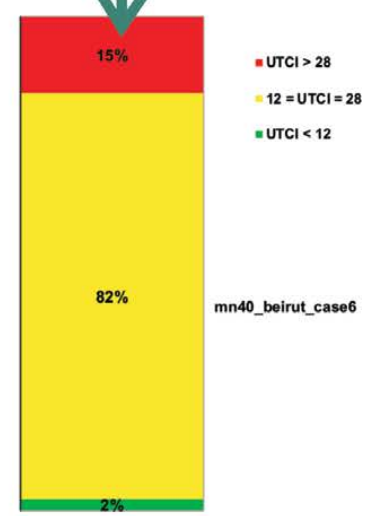
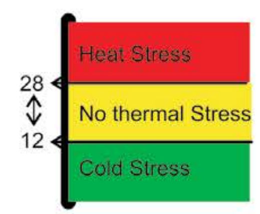
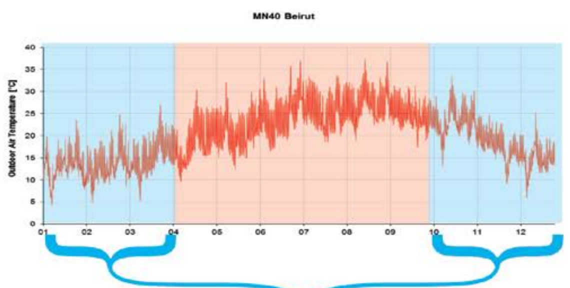
Case 6 : 55% improvement

Case 6 all

0.2 coefficient of solar absorptions (white ground)
0.7 wind factor (with wind)
with membrane (shaded)
adiabatic cooling on(plants of 0.25 humidity on 26 degrees on)

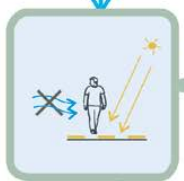






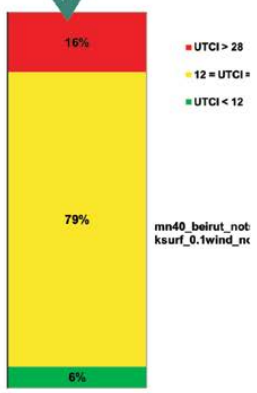
Analysis for the **Cold Section**

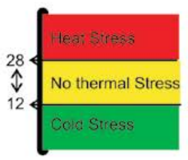
Oct till March



Base Case 1

0.9 coefficient of SA (black ground)
0.1 wind factor (almost no wind)
no membrane
no adiabatic cooling



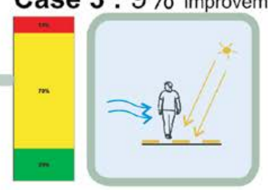


Case 2 : 1 % decrease

Case 2

0.2 coefficient of solar absorptions (white ground)
0.1 wind factor (almost no wind)
no membrane
no adiabatic cooling

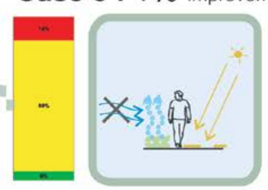
Case 3 : 9% improvement



Case 3

0.9 coefficient of solar absorptions (black ground)
0.7 wind factor (normal wind)
no membrane
no adiabatic cooling

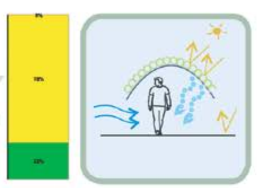
Case 5 : 1% improvement



Case 5

0.9 coefficient of solar absorptions (black ground)
0.1 wind factor (almost no wind)
no membrane
adiabatic cooling on(plants of 0.25 humidity on 26

Case 6 : 1% decrease



Case 6 all

0.2 coefficient of solar absorptions (white ground)
0.7 wind factor (with wind)
with membrane (shaded)
adiabatic cooling on(plants of 0.25 humidity on 26

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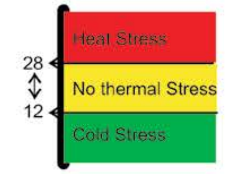
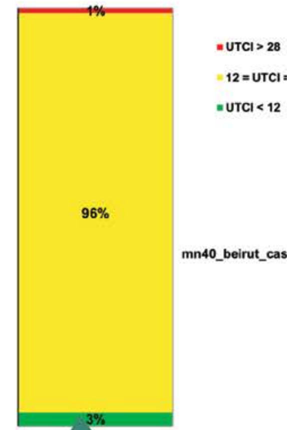
Case 4 : 17% improvement

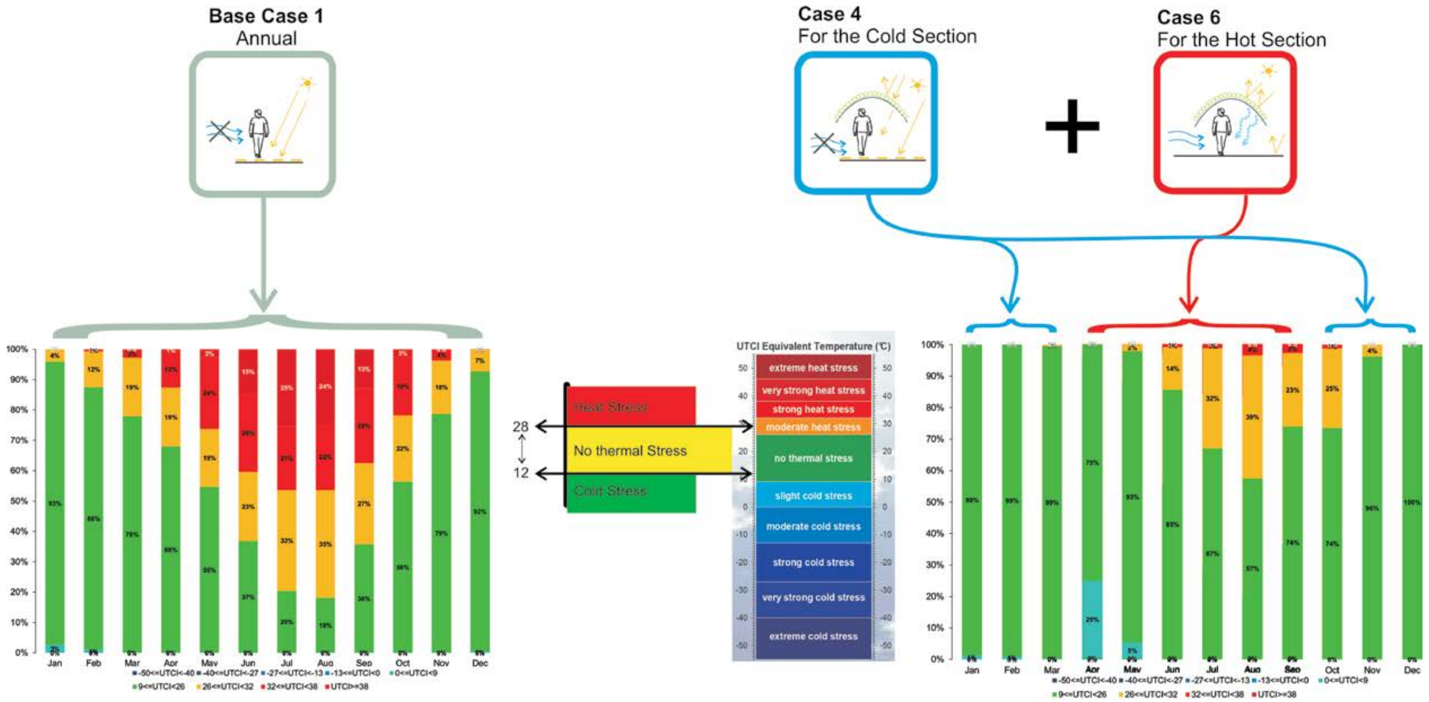
Case 4

0.9 coefficient of solar absorptions (black ground)
0.1 wind factor (almost no wind)
with membrane (in shade)
no adiabatic cooling



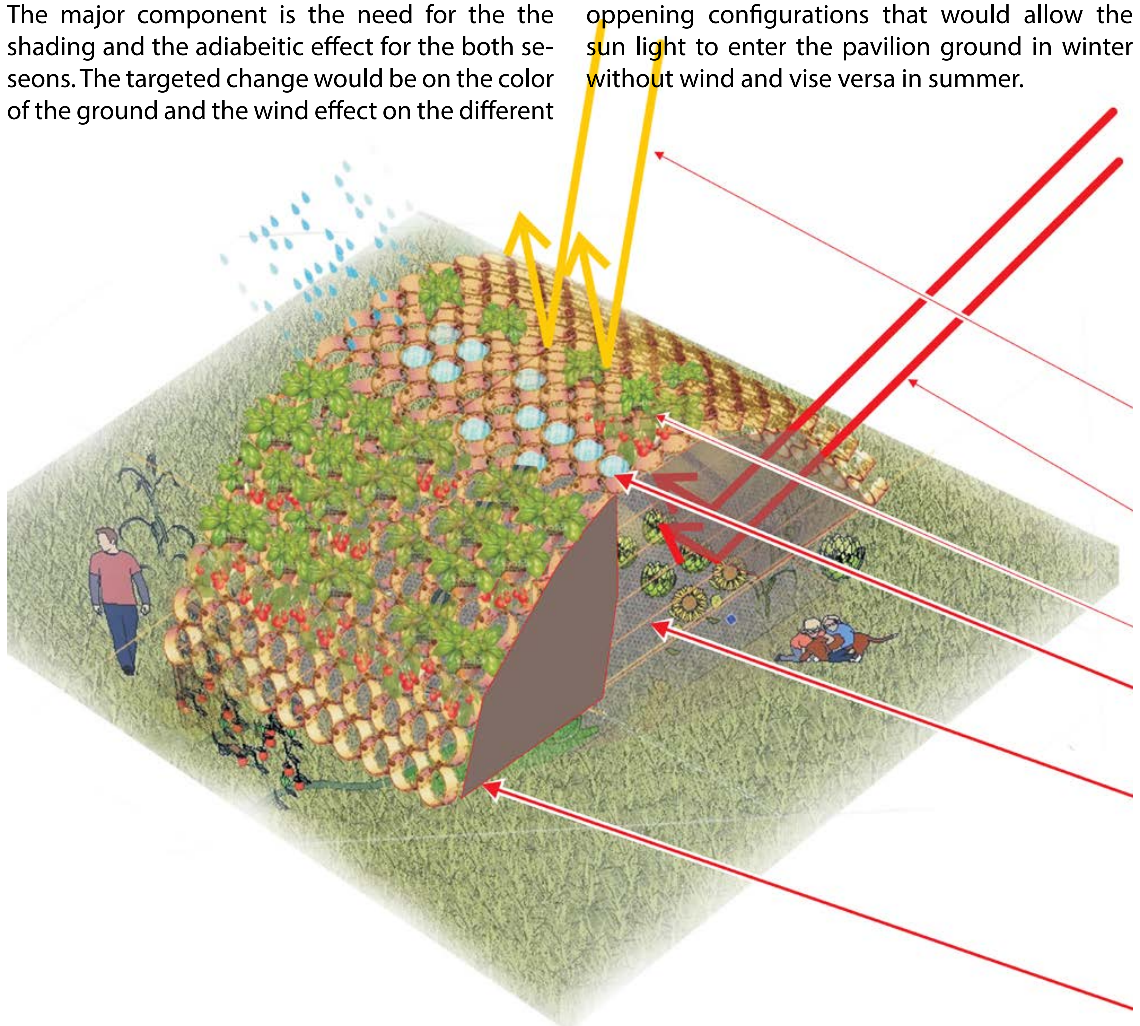


Combined analysis



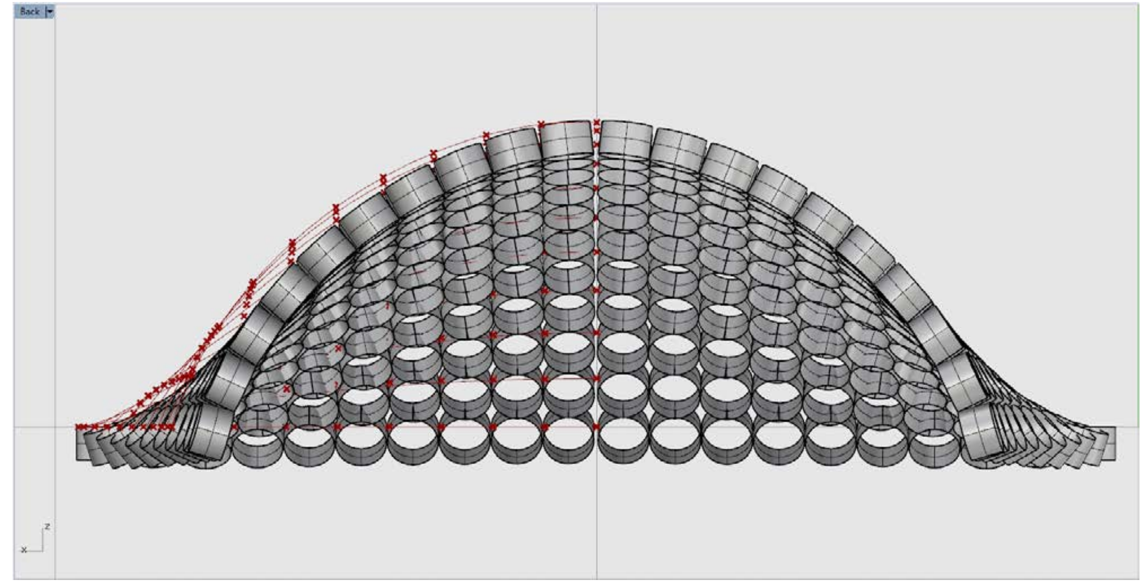
Conclusion

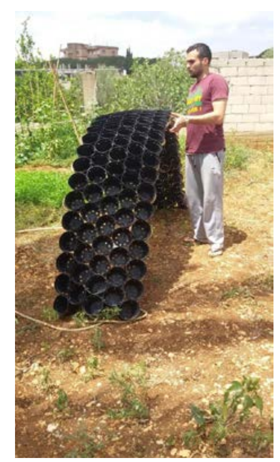
The major component is the need for the the shading and the adiabeitic effect for the both se-seons. The targeted change would be on the color of the ground and the wind effect on the different seasons, this would be acheived by the design of oppening configurations that would allow the sun light to enter the pavilion ground in winter without wind and vise versa in summer.



Building It

Scaled Model Trial





1/1 Model


fig.a


fig.b


fig.c


fig.d


fig.e


fig.f


fig.g


fig.h

fig.a ordering 8 , 6m PVC pipes

fig b marking and cutting

fig c assembeling the small modules

fig d assembeling the bigger mdules

fig e and f lifting the structure

fig g filling with earth

fig h comleting the pavilion

Conclusion and Outlook

The Earth Shell was constructed with the help of 4 people during three days of cutting and drilling, and 4 hours of assembling on site. also 3 hours with two people of dissassembling

The final event took place in killesberg park with transsolar comunity.

Special thanks to:

Christian Frenzel
Christian Degenheart
kay
Moni Lauster
and all Transsolar Community