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Thermophysics Simulation in Manama, Bahrain

Energy Efficiency & Cost Computing Comparison Between Traditional Local Buildings in Concrete and Silicawood Panel Technology by BBuilding

illustrative report and energy need: anticipation survey with previsional calculations

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1.0	07/05/2012	1st Edition: preliminary data & calculations
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Document Versions

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Object of Study

This document has the purpose of explaining and motivating, basing the statements on scientifical data and thermophysical calculations, the methodology of computing applied to analyze and determine the energetical performances of the Silicawood panels and it's application in the field of house building.

There's also a comparison (in terms of energy performance and economical savings) between the BBuilding Eco Housing Sustainable Method and traditional constructions (mostly built with concrete blocks), in order to realize/build up luxury and residential buildings/houses in the mid-western territories, located in the areas of Kingdom of Bahrain.

All the obtained data and final results are going to be displayed and illustrated in a double approach: energetical and financial, in order to evaluate the all round advantages of this innovative building method and material.

Methodology Applied

As in the Midwestern areas and particularly in the Kingdom of Bahrain at the moment there is not any thermophysical law/regulation/rule/normative/prescription, in order to give a reliable and univocal rating for building performance; the proposed calculations and computational method used to compare traditional buildings with innovative BBuilding Silicawood panels is based on the actual technical rules and normative used in the European Community and in Italy too.

Particularly, all the applied methods are based on:

LIST OF NORMATIVES UNI EN ISO
(UNI: ITALIAN NATIONAL STANDARDS / EN: EUROPEAN STANDARD / ISO: INTERNATIONAL ORGANIZATION FOR STANDARIZATION)
UNI EN ISO 6946:2008 *Components and elements in building and construction field – Thermal resistance and transmittance - Method of Calculations*
UNI EN ISO 7345:1999 *Thermal insulation – physics, terms and definitions*
UNI EN ISO 13789:2008 *Energy Performance of Buildings – Coefficients of heat transfer under transmission and ventilation - Method of Calculations*
UNI EN ISO 13790:2008 *Energy Performance of Buildings – Computing of the energy need for heating and cooling purpose*
UNI EN ISO 14683:2008 *Thermal Spots – Coefficient of thermal transmission – Simplified method and reference values.*

LIST OF NORMATIVES UNI
(UNI: ITALIAN NATIONAL STANDARDS)
UNI 10351:1994 *Construction Materials. Thermal conductivity and vapor/steam permeability.*
UNI 10355:1994 *Walls and floors. Values of thermal resistance and calculation method.*

ELENCO NORME UNI/TS
UNI/TS 11300-1:2008 *Energy Performance of Buildings – Part 1: Determining the primary energy demand of thermal energy for building climatization in winter and summer.*
UNI/TS 11300-2:2008 *Energy Performance of Buildings – Part 2: Determining the primary energy demand of thermal energy for building climatization and performances for winter climatization and hot water production for home usage (drinkable).*
UNI/TS 11300-2:2008 *Energy Performance of Buildings – Part 3: Determining the primary energy demand of thermal energy for building climatization and performances for summer climatization.*

Procedures of Predictive Calculations and Proposal of Analytic Method

This analysis is intended in order to evaluate the energetic advantages granted by **1 square meter** of vertical or horizontal area (just the opaque/matt surface as walls, ceilings and roof) realized with the innovative building method proposed by BBuilding, thanks to the Silicawood panels; the same wall/floor area will be directly compared with traditional materials and constructive method. The referring building analyzed are imaginary located in the capital city of the Reign of Bahrain, Manama.

The fundamental hypothesis of this simulation, is that the compared buildings are identical to each other, with the only difference considered during the comparison consisting in the materials used in the building process to build up walls, roof and ceilings; this means that the comparison is made just on the opaque/matt closings.

The Silicawood panel performance has been evaluated in summer behavior (the most severe conditions of high temperature) and the confrontation/comparison has been made to the performance granted by walls realized with traditional standard materials currently used in existing buildings (mostly concrete and concrete blocks).
In order to obtain this comparison, has been applied the same equation of thermal exchange (thermal transmission) through an opaque/matt wall, supposing as a temperature difference the heat flow exchange from the internal home environment (considered approximatively around 26°C, also considered as a “comfortable” temperature in the tech norm UNI EN ISO 7730 in summer cooling environment) and the external “sun & air” temperature calculated from medium monthly values (considering the medium sun radiation plus the medium external air temperature).

In this way the comparison between Silicawood panels and traditional concrete walls/roofs/structures is strictly made basing the results on the endogenous solar contribution of a single square meter of area, no matter where it will be put and oriented. It has been also considered, obviously, the same coefficient of absorption, this means that the finishing of the external surfaces will be identical in both structures: Silicawood and traditional (concrete blocks).

Then, starting from all the previously obtained data, applying the thermal exchange equations in stable regimen (without considering any dynamic phenomenons, this hypothesis is precautionary considering the very high sun irradiance), it has been analyzed the thermal load of project cooling and the net energy demand for cooling for different kind of buildings, all characterized by different "form factor" indexes S/V (S is the external dispersive surface / V is the air conditioned volume) variable (from 0,2 to 0,9 units 1/m).
Thanks to this method we are able to make a comparison of all kinds of houses and buildings with different forms, shapes and house plans.
All this buildings are considered as residential, and are assumed as single or maybe double family home villas (1-2 levels; each level with an area of approx 70-110 m^2) and we can also include small flats for apartments (3-4 floors; gross area for each level of approx 160-200 m^2).

Hypothesizing then a plausible cooling implant supply for the Silicawood houses (fan coil units and electrical heat pump in reverse cycle: cooling), it can be determined the specific saving of primary energy and electricity a single unit of area cooled.
Then assuming the medium cost of electricity in Bahrain as 0,04 BD = 0,025 €/kWh, it can also be evaluated the specific amount of money saved each year, thanks to the usage of the Silicawood panels compared to concrete blocks.

Input of climatic data

				IRRADIATION		IRRADIANCE	
	Tmin [°C]	Tmax [°C]	Hirr [-]	Hh [Wh/ m²/day]	H(90) [Wh/ m²/day]	Ih [W/ m²/day]	I(90) [W/ m²/day]
January	14	20	7	3700	4440	528,57	634,29
February	15	21	8	4530	4270	647,14	610,00
March	18	25	8	5160	3370	737,14	481,43
April	22	29	8,5	5940	2470	848,57	352,86
May	26	34	10	7060	1770	1008,57	252,86
June	29	36	11	7620	1420	1088,57	202,86
July	30	38	10,5	7480	1580	1068,57	225,71
Augost	30	38	10,5	7120	2330	1017,14	332,86
September	28	37	10	6560	3610	937,14	515,71
October	26	33	10	5690	4800	812,86	685,71
November	22	28	9	4350	4970	621,43	710,00
Dicember	16	23	7	3550	4620	507,14	660,00
Year	23	30	9	5730	3300	3300	3300

Chart 1 - Bahrain climate data values

In Chart 1 the values shown are:

- Tmin minimum medium monthly temperature
- Tmax maximum medium monthly temperature
- Hirr medium number of hours of irradiation for each day
- Hh medium monthly irradiation on horizontal surfaces (from PVGIS: http://re.jrc.ec.europa.eu/pvgis/)
- H(90) medium monthly irradiation on vertical surfaces – south oriented (from PVGIS)
- Ih medium monthly irradiance on horizontal surfaces (from PVGIS)
- I(90) medium monthly irradiance on vertical surfaces – south oriented (from PVGIS)

NOTE:
Wheather & climate informations taken from the "World Meteorological Organization" official website: http://worldweather.wmo.int/wmo.htm

Input of thermophysical data

All the layers of the traditional concrete structures (walls, floors, ceilings, roofs) and the proper technical data and physics values are taken from the tech norm UNI 10355 referring to the traditional building method; on the other hand, all the Silicawood technical data and physics values are given directly from BBuilding S.r.l. official website, provided with downloadable tech papers and data.

VERTICAL SHELL COMPARISON (WALLS)

Traditional method (concrete blocks)

Plaster		
thickness [m]	l [W/mK]	R [W/m^2K]
0,02	0,9	0,02
Concrete blocks		
thickness [m]	l [W/mK]	R [W/m^2K]
0,2	-	0,27
Plaster		
thickness [m]	l [W/mK]	R [W/m^2K]
0,02	0,9	0,022

U_1 [W/m^2K] 2,06

Silicawood panels

Plaster		
thickness [m]	l [W/mK]	R [W/m_2K]
0,02	0,9	0,02
Silicawood panels		
thickness [m]	l [W/mK]	R [W/m^2K]
0,33	0,119	2,77
Plaster		
thickness [m]	l [W/mK]	R [W/m^2K]
0,02	0,9	0,022

U_2 [W/m_2K] 0,33

U = thermal transmittance: the lower, the better. $U_1 > U_2$ = U_2 has a 7x better performance!

HORIZONTAL SHELL COMPARISON (CEILINGS / ROOFS)

Traditional method (concrete + bricks)

Plaster		
thickness [m]	l [W/mK]	R [W/m^2K]
0,02	0,9	0,02
Concrete floor with bricks		
thickness [m]	l [W/mK]	R [W/m^2K]
0,24	-	0,3

U_1 [W/m^2K] 2,16

Silicawood panels

Plaster		
thickness [m]	l [W/mK]	R [W/m^2K]
0,02	0,9	0,02
Silicawood panels		
thickness [m]	l [W/mK]	R [W/m^2K]
0,4	0,119	3,36

U_2 [W/m^2K] 0,28

U = thermal transmittance: the lower, the better. $U_1 > U_2$ = U_2 has a 7x better performance!

It has also been supposed a coefficient of absorption of 0,3 (corresponding to white or cream surface colored buildings), and the following values for the air heat transfer coefficient, respectively internal, external and internal+horizontal.

To better comprehend/understand some terms used in this paper, it is strongly recommended to visit these sites above:

PRIMARY ENERGY DEFINITION:
http://en.wikipedia.org/wiki/Primary_energy

THERMAL RESISTANCE:
http://en.wikipedia.org/wiki/Thermal_resistance

TRANSMITTANCE:
http://en.wikipedia.org/wiki/Transmittance

ENERGY CONSUMPTION VS ENERGY DEMAND:
http://www.stonybrook.edu/sustainability/energy/facts/demand.shtml

Calculation Of Sun & Air Temperature min/max

Here's the calculation of the “sun + air” minimum and maximum temperatures on horizontal and vertical surfaces.
The “sun + air” temperature is the fictitious hypothetical temperature of the external environment climate that would bring on the external surface the same thermal flow that we have in real conditions on the walls/roofs thanks to the solar irradiation plus abduction with outside's air.
This value (T_{sa}) is fundamental in Midwestern hot climates for computing the highest peak of thermal load when we are cooling a room.

Here it is:

$$T_{sa} = T_e + \frac{aI}{h_e}$$

where the terms of the equation are:

- T_e is the external temperature in °C degrees
- a is the absorbing factor of the wall [-]
- I is the irradiance value [W/m^{2}K]
- h_e is the thermal external abduction (inductance) [W/m^{2}K]

Starting from the twofold data of maximum (T_{sa}max) and minimum (T_{sa}min) external temperatures, we can finally reach a determined range of values for that temperatures, referring to both horizontal and vertical surfaces.
Here are the calculations and the obtained temperatures data.

	HORIZONTAL		VERTICAL	
Month	T_{sa}min [°C]	T_{sa}max [°C]	T_{sa}min [°C]	T_{sa}max [°C]
January	20,34	26,34	21,61	27,61
February	21,80	27,80	21,41	27,41
March	25,74	32,74	23,06	30,06
April	30,39	37,39	25,49	32,49
May	34,47	42,47	28,12	36,12
June	37,31	44,31	30,55	37,55
July	38,55	46,55	31,81	39,81
August	38,14	46,14	32,66	40,66
September	35,87	44,87	32,33	41,33
October	32,83	39,83	31,76	38,76
November	27,80	33,80	28,63	34,63
December	22,09	29,09	23,92	30,92
Year	**30**	**38**	**28**	**35**

Chart 2 - Temperature “sun+air” on horizontal and vertical area surfaces.

Energy Output Data

Computing the reduction of the endogenous thermal contribution coming from the sun

Starting from the "sun+air" temperatures and also from all the proper previously computed informations regarding the thermal transmittances of the two construction methods (traditional concrete blocks Vs Silicawood panels), now we're going to determine the thermal peak reduction for a single unit of opaque/matt capturing surface/area (we can also call it "receiving surface"), then we're going to compare it to the performance of another identical building realized in the standard, traditional concrete blocks method.
All the values above are expressed in W/m^2, and are divided in each single month of the year.

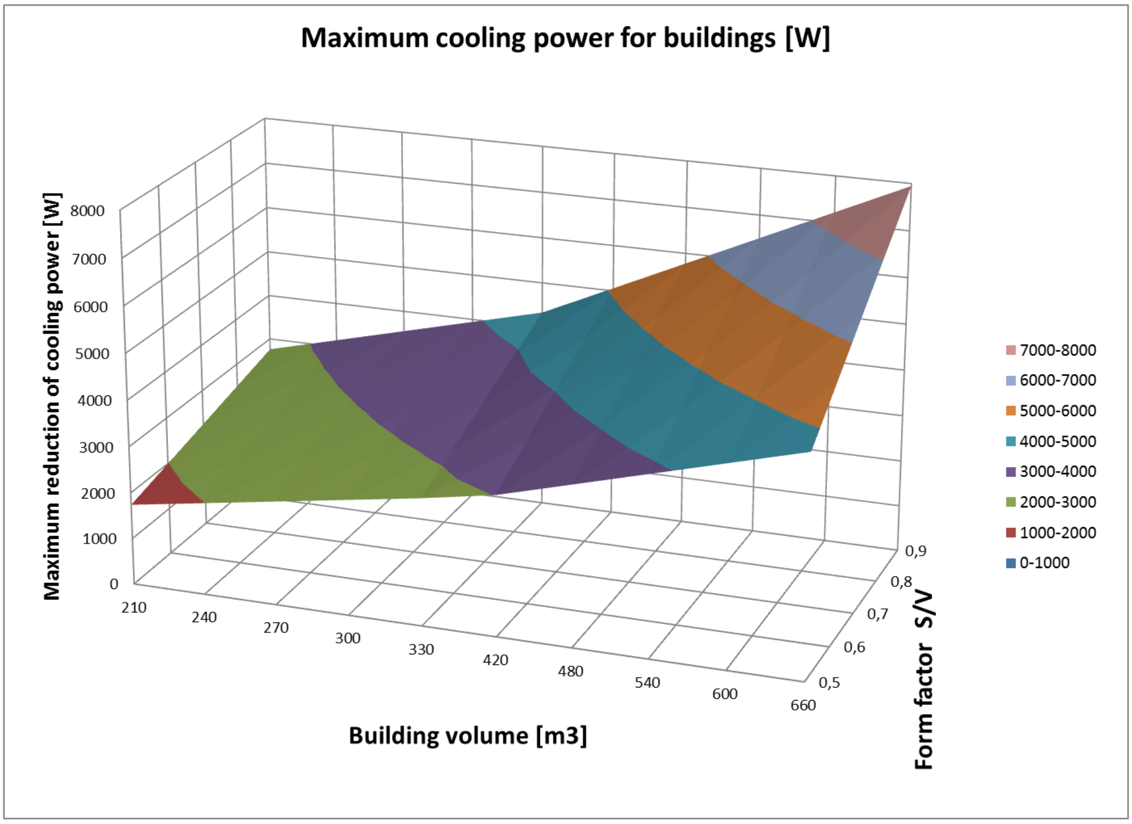
	Reduction of the thermal flow referring to a single unit of dispersive surface			
	Roof/Horizontal Structures		Walls/Vertical Structures	
Month	**$F_{op,min}$ [W]**	**$F_{op,max}$ [W]**	**$F_{op,min}$ [W]**	**$F_{op,max}$ [W]**
January	-9,79	0,59	-7,59	2,79
February	-7,27	3,11	-7,95	2,43
March	-0,45	11,66	-5,09	7,02
April	7,59	19,70	-0,89	11,22
May	14,66	28,50	3,67	17,51
June	19,57	31,68	7,87	19,98
July	21,71	35,55	10,04	23,88
August	21,00	34,84	11,53	25,37
September	17,08	32,65	10,95	26,52
October	11,81	23,92	9,97	22,08
November	3,11	13,49	4,54	14,92
December	-6,77	5,34	-3,60	8,51
Year	**7,69**	**20,09**	**2,79**	**15,19**

Chart 3 - Reduction of the endogenous thermal contribution in comparison with a traditional concrete blocks building

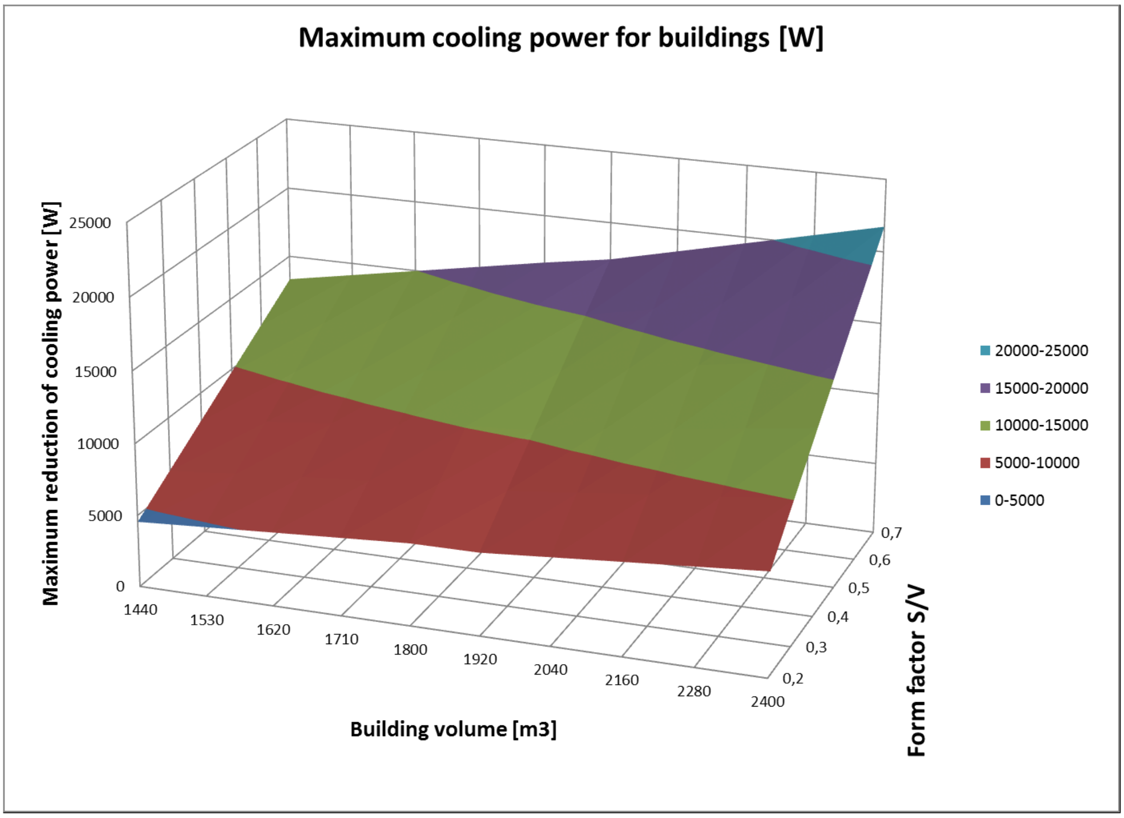
NOTE: the negative values are indicating that in the considered month there is no theorical need of cooling home environment. But obviously as there are more unpredictable variables (number of people at home, number of household appliances and we cannot also predict the activities done inside the buildings) in a cautionary way, in the next coming evaluations we're going to consider a constant cooling need along all year, in order to be sure to maintain a correct thermal comfort and humidity rate.

Reduction of the Thermal Load of Project and Energy Demand for Cooling

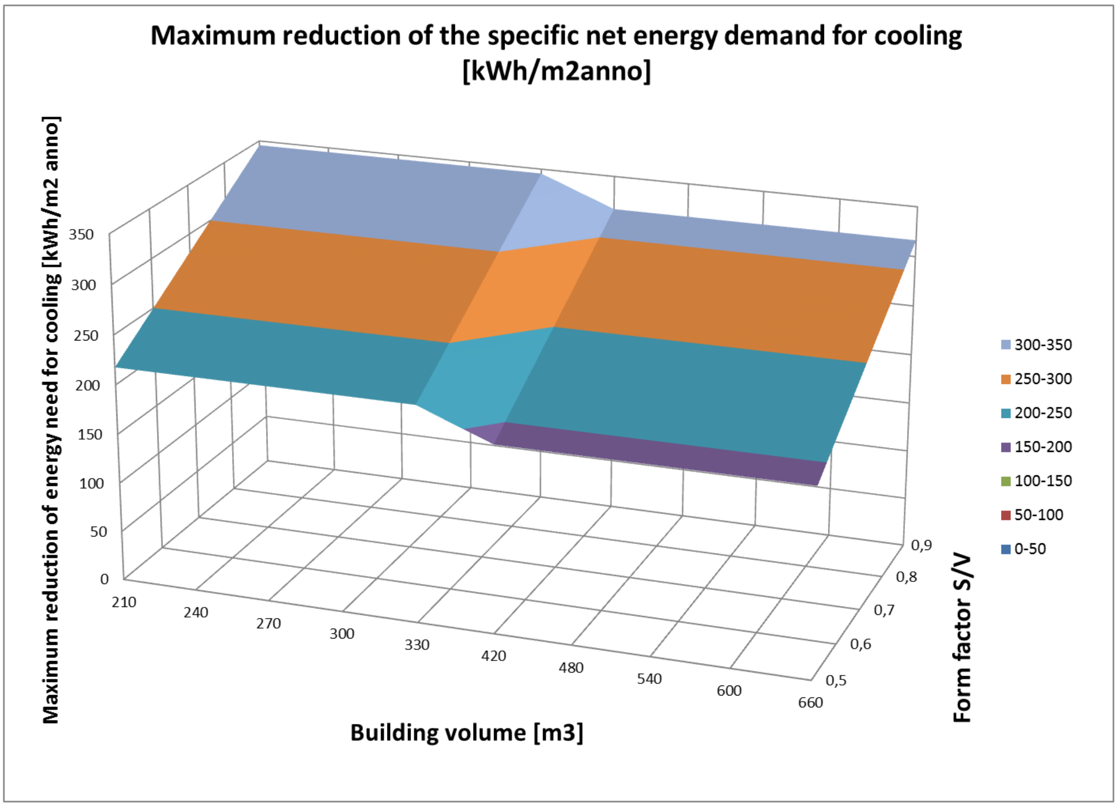
Then we determined the total reduction value of the thermal load of project for cooling purpose (remember that the evaluation is made in stationary regime and refers on each unit of area : 1 m^2 of opaque/mat surface exposed). This value of reduction of the net energy demand for cooling is just referred on a single part of the thermal balance equation (opaque/matt surfaces exposed) so it's not linear the relation between total energy saving and the reduction of thermal load on the exposed facades+roof.
The consequential money saving per each m^2 achieved can be seen on the following graphics (the hypotized cooling equipment is imagined with fan coils and electrical heat pump working in reverse cycle with EER: Energy Efficiency Ratio = 2).



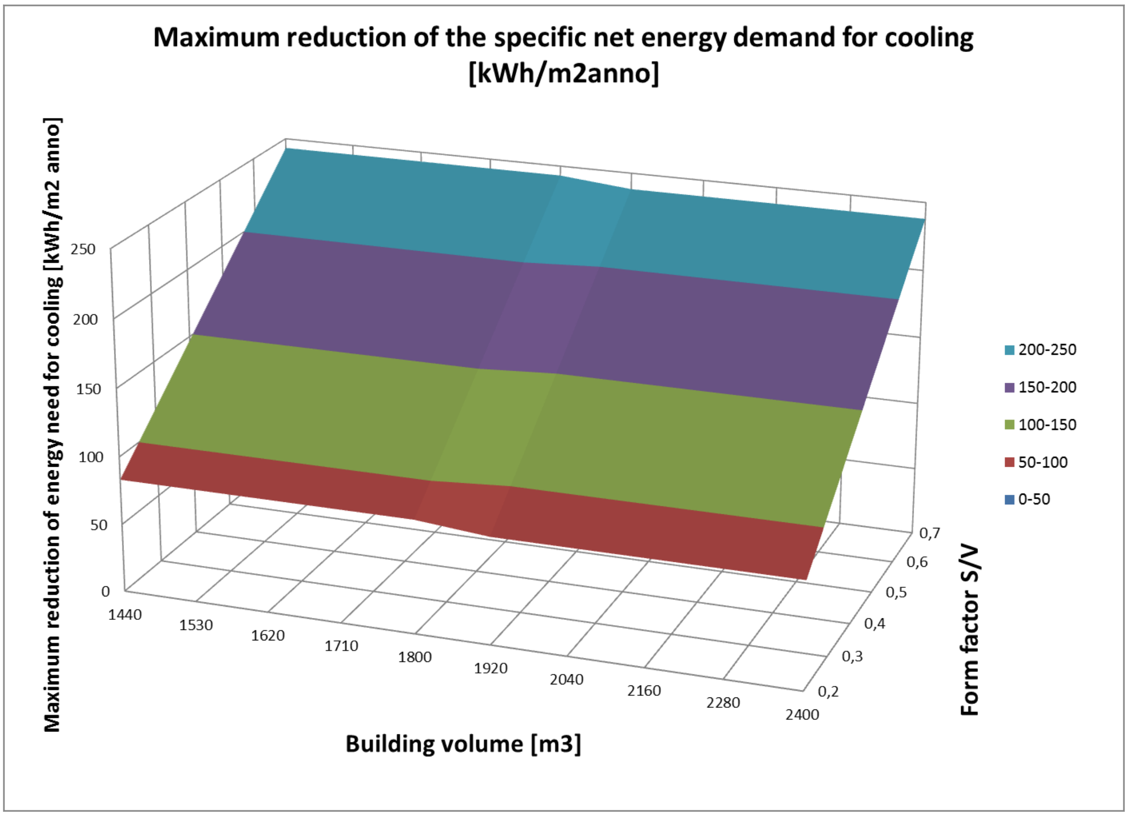
Graphic 1 - Reduction of the thermal load for single/double family buildings/houses
(comparison based on a single area of exposed surface: 1 m²)



Graphic 2 - Reduction of the thermal load for dwellings
(comparison based on a single area of exposed surface: 1 m²)



Graphic 3 - Reduction of the net energy demand for cooling single/double family buildings/houses expressed in [kWh/m²year] (comparison based on a single area of exposed surface: 1 m²)



Graphic 4 - Reduction of the net energy demand for dwellings expressed in [kWh/m²year] (comparison based on a single area of exposed surface: 1 m²)

Output Data and Economical Analysis

Assuming the medium cost for electricity around 0,011 BD = 0,025 €/kWh, it can be easily evaluated a considerable energy conservation that leads to a substantial medium saving per year for each unit of internal cooled area (each single squared meter = 1 m^2) thanks to the innovative Silicawood material and the BBuilding Eco-Housing revolutionary method.

The recapitulation of all the data, can be seen in the above prospect charts where the buildings are divided depending on the building type (single/double family villa or flats) and also on the "form factor" indexes S/V (S is the external dispersive surface / V is the air conditioned volume).

In order to obtain an even more easier and understandable rating value we can use the Riffa Views villa comparing it's total primary energy need in case it is built in traditional way with concrete blocks and with the innovative BBuilding Silicawood panels. This leads clearly to an outstanding performance of the Silicawood among the concrete blocks!

Always keep in mind that all these comparison are made between **1 m^2** of surface (exposed area) built with traditional method against the innovative Silicawood panels: **this means that the comparison allows not to give an absolute value!**

MAXIMUM ANNUAL saving for cooling [€/m^{2}year]											
Building Type	N. of levels [floors]	Plain Area [m^2]	Gross Volume Cooled [m^3]	S/V [1/m]							
				0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9
Single/double family buildings (villas)	1	70	210				3,14	3,60	4,07	4,53	4,99
	1	80	240				3,14	3,60	4,07	4,53	4,99
	1	90	270				3,14	3,60	4,07	4,53	4,99
	1	100	300				3,14	3,60	4,07	4,53	4,99
	1	110	330				3,14	3,60	4,07	4,53	4,99
	2	70	420				2,72	3,19	3,65	4,11	4,57
	2	80	480				2,72	3,19	3,65	4,11	4,57
	2	90	540				2,72	3,19	3,65	4,11	4,57
	2	100	600				2,72	3,19	3,65	4,11	4,57
	2	110	660				2,72	3,19	3,65	4,11	4,57
Flats & Apartments	3	160	1440	1,20	1,66	2,12	2,58	3,05	3,51		
	3	170	1530	1,20	1,66	2,12	2,58	3,05	3,51		
	3	180	1620	1,20	1,66	2,12	2,58	3,05	3,51		
	3	190	1710	1,20	1,66	2,12	2,58	3,05	3,51		
	3	200	1800	1,20	1,66	2,12	2,58	3,05	3,51		
	4	160	1920	1,13	1,59	2,05	2,51	2,98	3,44		
	4	170	2040	1,13	1,59	2,05	2,51	2,98	3,44		
	4	180	2160	1,13	1,59	2,05	2,51	2,98	3,44		
	4	190	2280	1,13	1,59	2,05	2,51	2,98	3,44		
	4	200	2400	1,13	1,59	2,05	2,51	2,98	3,44		

(**note:** in red & yellow the data referring to villas/mansions similar to Riffa Views building type)

MAXIMUM ANNUAL saving for cooling compared to traditional concrete houses/buildings (%)											
Building Type	N. of levels [floors]	Area plan [m²]	Gross Volume Cooled [m³]	S/V [1/m]							
				0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9
Single/double family buildings (villas)	1	70	210				86%	86%	86%	86%	85%
	1	80	240				86%	86%	86%	86%	85%
	1	90	270				86%	86%	86%	86%	85%
	1	100	300				86%	86%	86%	86%	85%
	1	110	330				86%	86%	86%	86%	85%
	2	70	420				85%	85%	85%	85%	85%
	2	80	480				85%	85%	85%	85%	85%
	2	90	540				85%	85%	85%	85%	85%
	2	100	600				85%	85%	85%	85%	85%
	2	110	660				85%	85%	85%	85%	85%
Flats & Apartments	3	160	1440	86%	85%	85%	85%	85%	85%		
	3	170	1530	86%	85%	85%	85%	85%	85%		
	3	180	1620	86%	85%	85%	85%	85%	85%		
	3	190	1710	86%	85%	85%	85%	85%	85%		
	3	200	1800	86%	85%	85%	85%	85%	85%		
	4	160	1920	86%	85%	85%	85%	84%	84%		
	4	170	2040	86%	85%	85%	85%	84%	84%		
	4	180	2160	86%	85%	85%	85%	84%	84%		
	4	190	2280	86%	85%	85%	85%	84%	84%		
	4	200	2400	86%	85%	85%	85%	84%	84%		

(**note:** in red & yellow the data referring to villas/mansions similar to Riffa Views building type)

Final Considerations

Thanks to this simulation, it clearly appears that the Silicawood panels and the BBuilding method shows an incredible and outstanding energy performance particularly suitable for Midwestern hot and sunny climates. **Efficiency** of the house "shields" (external structures: walls, ceilings, roof) compared with traditional buildings made of concrete blocks appears unequaled and incomparable as it saves around 85% energy (and money too!) for each unit of surface exposed (1 m^2 of opaque/matt area); this means that if the Kingdom of Bahrain is going to use for example a power plant oil generator with a peak power of **600 MW** of electricity, assuming a medium grid efficiency of **0,36** (this data refers to a typical Italian power plant oil generator) it can fulfills the energy demands of approximatively **7660** houses like the Riffa Views villas (V = 660 m^3, S/V = 0,6; Coefficient of comparison between Transparent surface area and Opaque/Matt surface area: S_{transp}/S_{op} = 0,2).
Just for comparison: traditional concrete villas to fulfill this production are a lot less: **6660**.
Particularly relevant are the advantages for each square meter of pavement surface (cooled area), in small and medium buildings with compact S/V values, thanks to significantly reduced volumes to be cooled.
Finally it can be estimated a **medium annual reduction consisting in -15% of energy needed** for cooling the buildings and keeping a higher level of thermal & humidity comfort conditions inside the houses.

Proposals and Development of Ideas and Projects

As the simulation has been made under stationary regime with a wide range of "S/V" factors considered (different housekinds) and hypothesizing the comparison basing our calculations on a single area of exposed surface (1 m^2; with fixed unique thickness of walls considered), the values of savings can be just considered just as a general result for each m^2 and certainly not an absolute value, suitable for each house.
We can surely put forward a more focused simulation, done with variable regime climate data (but, of course we need much more input elements and approximatively 60 days of work and calculations), studying and suggesting the perfect thickness of Silicawood panels suitable to the Midwestern climate in order to provide a **global net energy reduction of approx -30% or even also -40%**; this calculations can be made only if we focus and tailor the thermophysical simulation and if we optimize the architectural project too, basing the study **on each single type of building**: this means no more generic "S/V" form factors and no more general results.
The global reduction of energy can be achieved only through studying each single housetype, considering it as an unique environment were to apply the equation of thermal balance.
In addition, we can also arrange (working in team with Bahrain University Professors and specialists) a national technical rule for housebuilding in the Kingdom of Bahrain, in order to optimize the energy consumption, reducing all the total energy amount needed for cooling the buildings.
The more energy saved means more energy available to be sold in outer markets and more incomes!
This proposed plan will lead to a significant national fuel saving and reduction of pollution, thanks to the introduction of smart grid too (for electrical supply) plus the enforcement of a tailored building law based on specific climate data of Bahrain.
We have specific background experience and worked for the regional energy plan of Piedmont, Italy; so we can be (if needed) a reliable technical consultant partner for developing this project of optimization.
Our C.V. in English (PDF format) are attached to this simulation with the EXCEL (XLS format) data sheet containing the formulas & input data used for this preliminary study.