Re- Thinking Courtyard Housing:

Development of Traditional Islamic Courthouses into Zero-Energy Buildings

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1. INTRODUCTION

Energy is one of the most important factors of development and production in most countries. The growing trend in building energy consumption will continue during the coming years due to the expansion of built area and associated energy needs, as long as resource and environmental exhaustion or economic recession allows it. Private initiative together with government intervention through the promotion of energy efficiency, new technologies for energy production, limiting energy consumption and raising social awareness on the rational use of energy will be essential to make possible a sustainable energy future as Lombart et al indicated. In simple terms, a Net energy building is a very low energy building that balances its low annual energy consumption by the use of renewable energy on site.

- To reach the Net-zero energy-building goal, we decided to conduct two important strategies at the design stage:

i) To reduce demand using passive solutions and energy efficient systems.

ii)To generate sufficient electricity by renewable energy systems to achieve the desired energy balance.

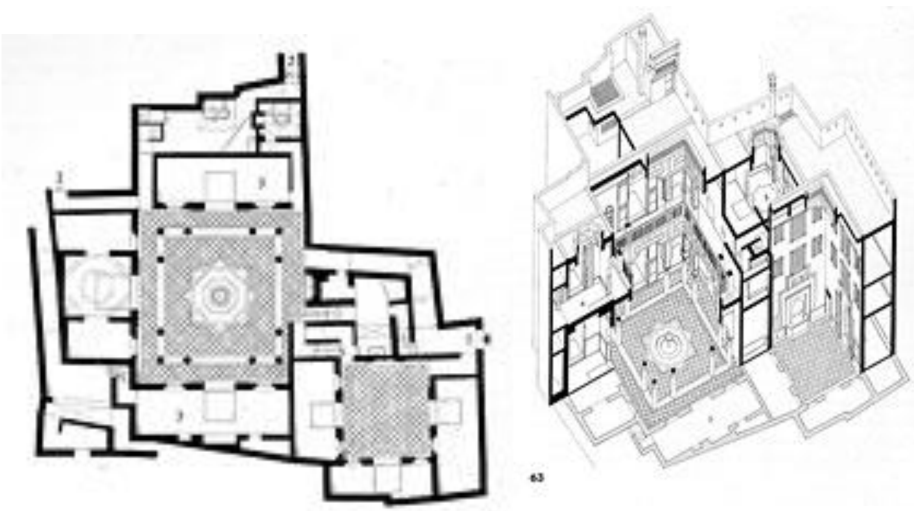
- In 2005/2006, the Net zero buildings concept was still generic and in 2006 there was no harmonized understanding about what was really a Net Zero Energy Building. This was one of the principal motivations for an international collaborative research project that started in 2008 within the framework of the International Energy Agency “Towards Net Zero Solar Energy Buildings”. The objective of the current study is to suggest a sustainable, zero energy consumption, contemporary courtyard house design in Alexandria city in Egypt as a development of the passive architectural vocabulary of the traditional Islamic courtyard houses and with the aid of recent computer Environmental analysis to act as a first prototype in such building.

- The traditional ZEB definitions can be also divided according to the building type. In the prevailing literature there is almost no specific difference between the ZEB definition for neither a commercial building nor a residential building. Commonly in the publications three phrases are used: “zero energy building”, “zero energy house” and “zero energy home”. As the first term is the most comprehensive and includes both residential and commercial building, the two others typically are used for the residences.

- Based on the climatic data of Alexandria downloaded from US department of Energy deduced from ZEH, 2016 and the features of traditional Islamic courtyard house the design has been established and then calculations were performed to compare the energy consumption in the traditional design and the new suggested design.

- The courtyard as a volume inside the traditional Islamic courtyard house was re-defined and reshaped using previous environmental analysis to a new proposal to integrate the shade design with the cross ventilation design to eliminate the need of HVAC by achieving the thermal comfort inside the house.

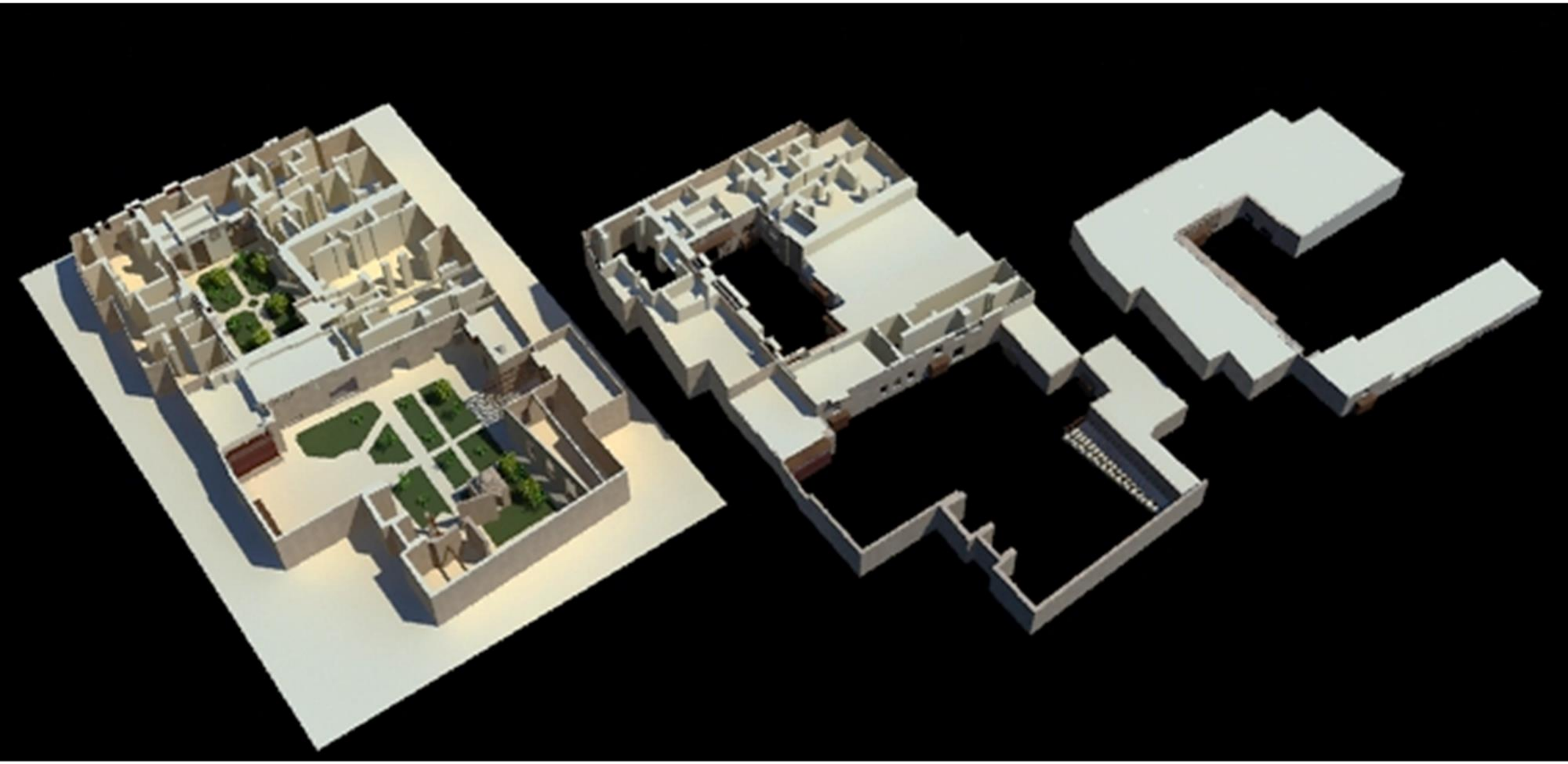
- Passive approaches play a crucial role in the design of Net ZEBs (Net Zero Energy Buildings) as they directly affect the heating, cooling, ventilation and lighting loads put on the building's mechanical and electrical systems, and indirectly reduce the sizing of the renewable energy systems that balance the consumption.



63 Axonometric section, ground floor and first floor plans of a double courtyard house in Fez, serving a large family and embracing several semi-independent sub-units. The house is located in a privileged position between three residential clusters, allowing the owners to accede from different deadend alleys.
1 Main entry
2 Side entries from other lanes
3 Typical living unit (bait)
4 First floor apartment composed of two small baits and its own central light shaft
5 Separate upper-floor apartment (masriya)

ORIGINAL BAYET AL SUHAIMY

ORIGINAL BAYET AL SUHAIMY



2.Potentials of Court Houses vocabulary formulating the contemporary design

2.1.Relation between Zero Energy Approach and Courtyard:

- Many studies were conducted on courthouses due to its high climatic potentials either in cold whether or hot arid areas. Edwards et al studied their climatic impact in his book. Courtyard housing is one of the oldest forms of domestic development spanning from at least 5,000 years and occurring in distinctive form in many regions of the world. Traditionally associated with the Middle East where climate and culture have given shape to a particular type of courtyard housing; other examples exist in Latin America, China and in Europe where the model has been reinterpreted.

- Besides having double facades, by courts, one inner and the other outer so increasing the perimeter of the exposed walls to daylight, the Inner facades are under shade most of the day, so providing indirect lighting and good thermal environment. Also, Leslie Martin and Lionel March carried out an extensive study of the environmental performance of courtyards at Cambridge University in the late 1960s. In a number of influential papers they addressed the question: 'What building forms make the best use of land?' The question of course implies a definition of 'best use'. Martin and March bound themselves to quantifiable parameters, such as 'built potential (the ratio of the floor area of the built form to the site area) and 'daylight availability'.

- They analyzed different archetypal built forms, such as pavilions, streets and courtyards. Their findings, based on mathematical analysis, showed that the courtyard was eventually the best performing urban type in terms of efficiency in site coverage: the court form is seen to place the same amount of floor space on the same site area with the same condition of building depth and in approximately one-third the height required by the pavilion form.
- The ingenious solution of the courtyard house type in hot-arid climates, such as in Egypt, is the use of high thermal mass to store heat through the expansive external surface area during the day in order to benefit from it during the cooler nights.

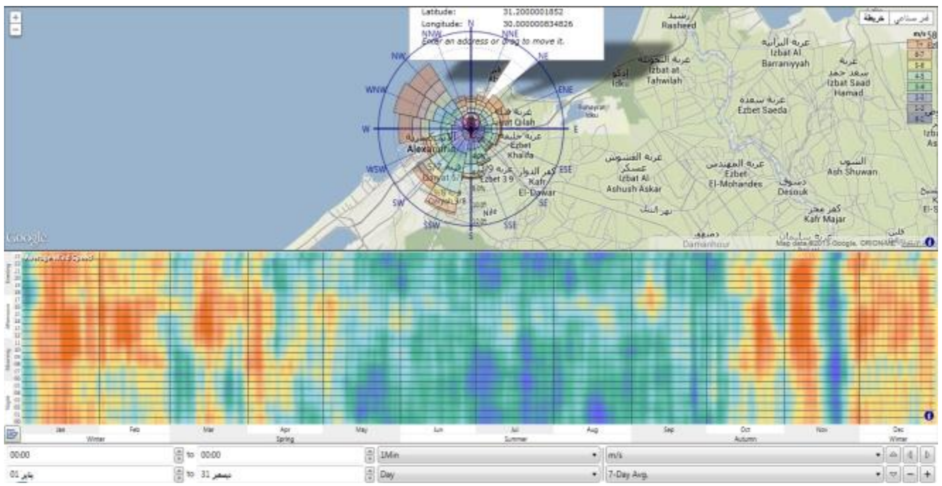


Figure. 1: Wind Rose of Alexandria [8]

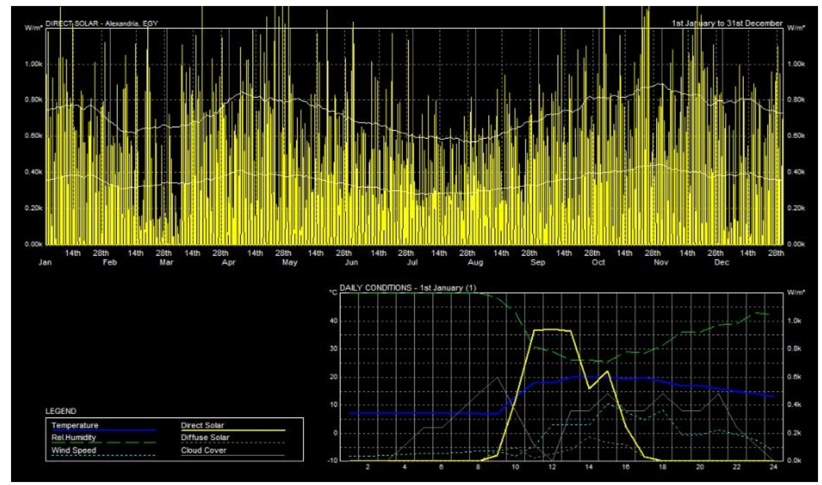


Figure. 2: Alexandria average solar radiation [8]

- The proposed design, in the current study, addresses the following criteria in designing the new court:
  - Increasing the surface to volume ratio to increase the perimeter of the inner façade, which results in a more indirect illumination of natural light.
  - Increasing the shadow density based on the average data solar radiation to create a thermal hot areas versus cold areas to help in breeze immigration from positive to negative pressure areas.
  - Breaking down the one volume of the traditional court into multi-volumes to create cross ventilation from dominant wind patterns.
  - Increasing sky view factor (SVF) to decrease the solar exposition to the open court aluminum shading louvers were introduced to the design. The function of these aluminum louvers is to reflect the indirect sun light into the court and derive the direct wind breeze into the court as well and to replace the traditional ancient Mashrabia in old courtyard Islamic houses.
  - The new court design has changed the introversion volume approach into broken down multi volumes mass to allow cross ventilation and was tested by Computational fluid dynamics (CFD) virtual wind tunnel simulation after processing the local digital file obtained from the US department of energy using the wind-Rose. The other parameter, LUX levels of natural light measurement, is based on detecting day lighting on the ground at hourly intervals on a piece of Alexandria city for a given day of the year (Figure 2). Then the average number of hours of shadows is calculated at each point. Steemers and Ratti (Steemers K. et al. 1999) used this parameter as an environmental indicator to inform bioclimatic urban design.

3. Results and Discussion

- In our proposed new design of the court, it was divided into multi small courts allowing the sun to enter simultaneously during the day hours. In addition to the design, other measures were taken to reduce the house energy consumption and achieve the target of ZEB: a) the substitution of traditional bulb lamps with LED lighting. b) The use of energy star appliances. c) The use of solar panels to provide required electricity.

- Energy consumption analysis of buildings is a difficult task because it requires considering detailed interactions among the building, HVAC system, and surroundings (weather) as well as obtaining mathematical/physical models that are effective in characterizing each of those items.

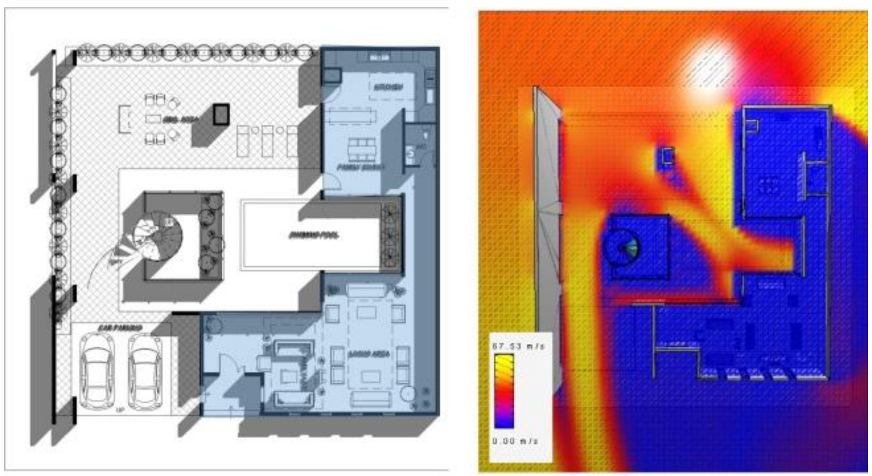


Figure. 3a, Plan of the first floor of the suggested design and its CFD

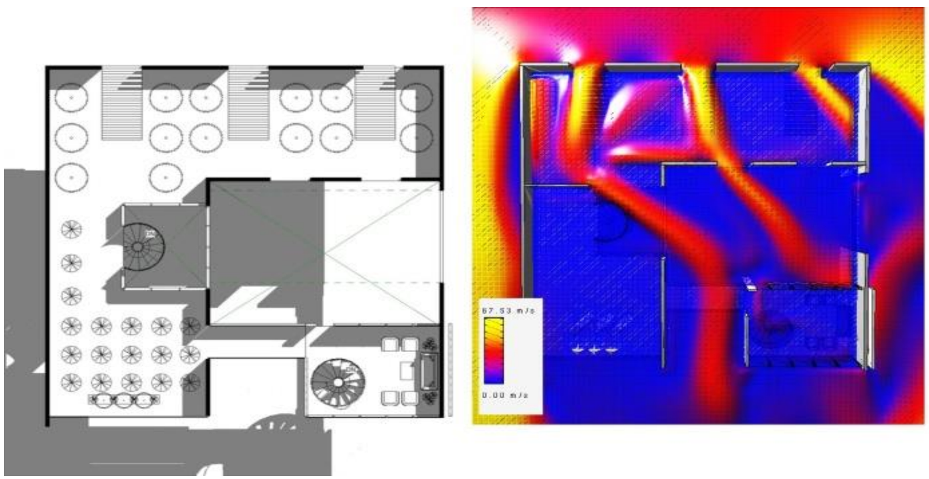


Figure. 3b, Plan of the second floor of the suggested design and its CFD

- Although this difficulty we substituted the physical model using virtual simulations by Autodesk CFD simulation as a virtual wind tunnel simulation and Autodesk Ecotect 2011in electrical consumption calculations and Lux levels of daylight using DIAlux 4.

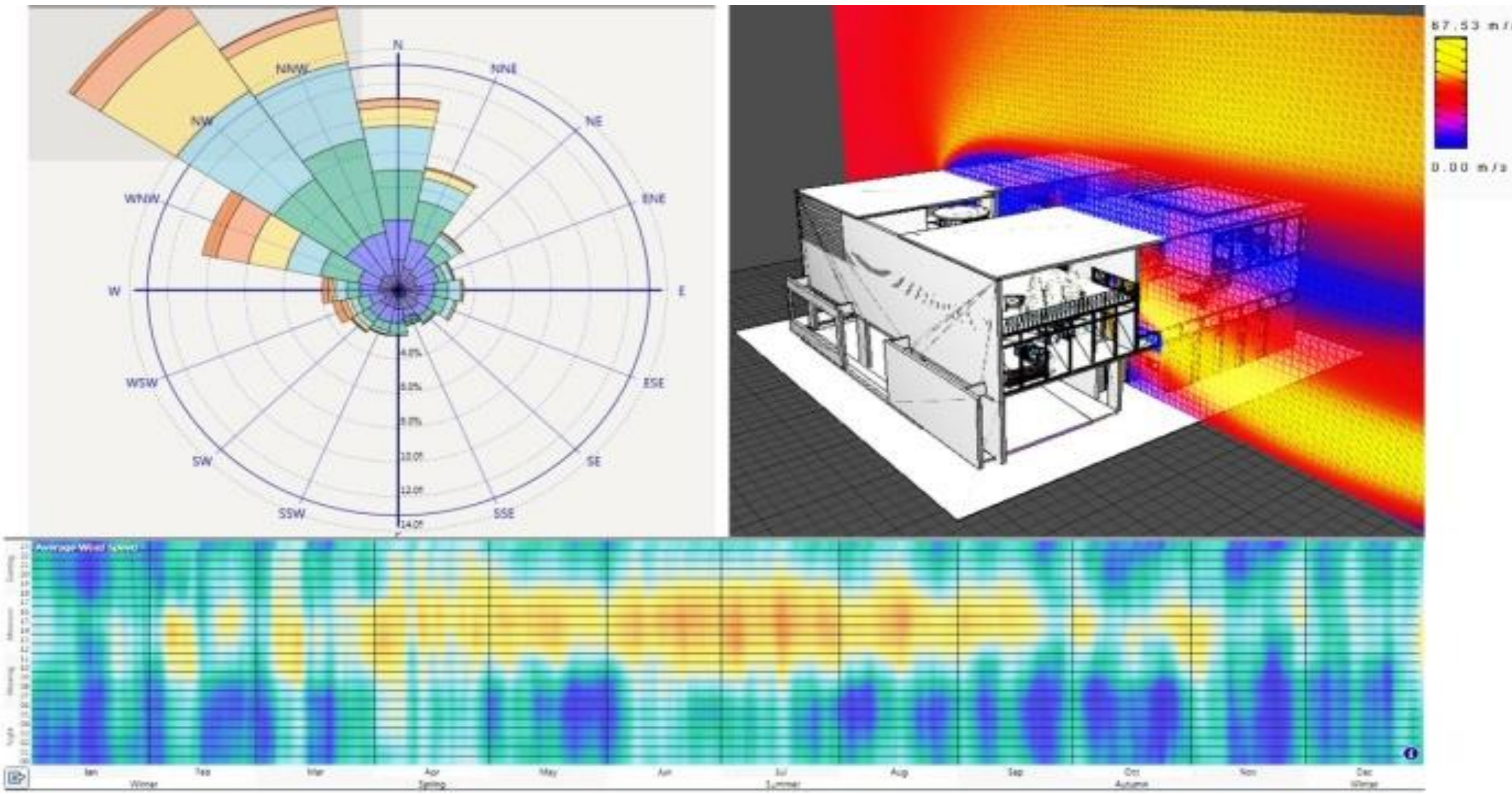
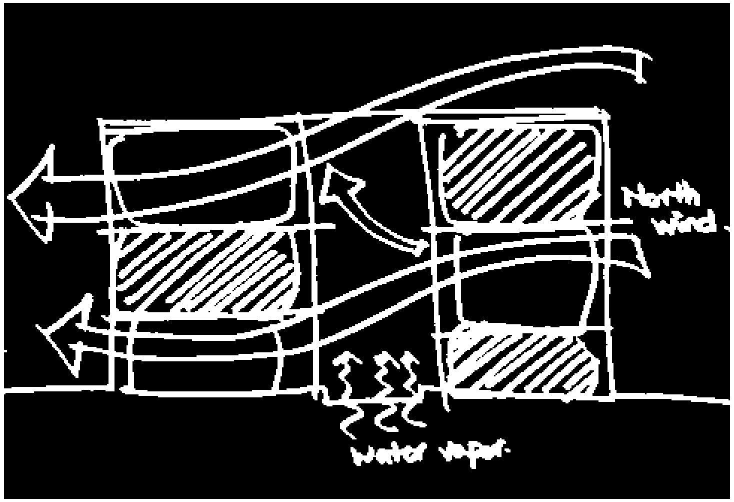
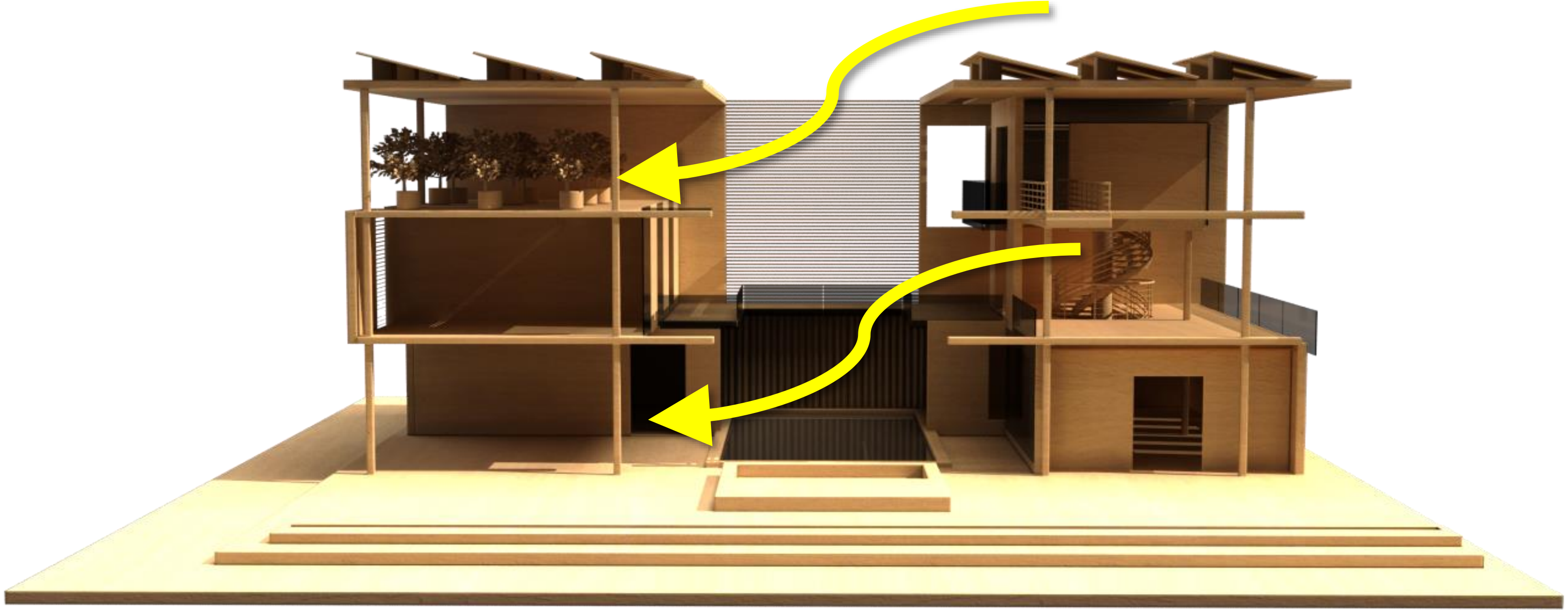


Figure. 3c, CFD of the designed house

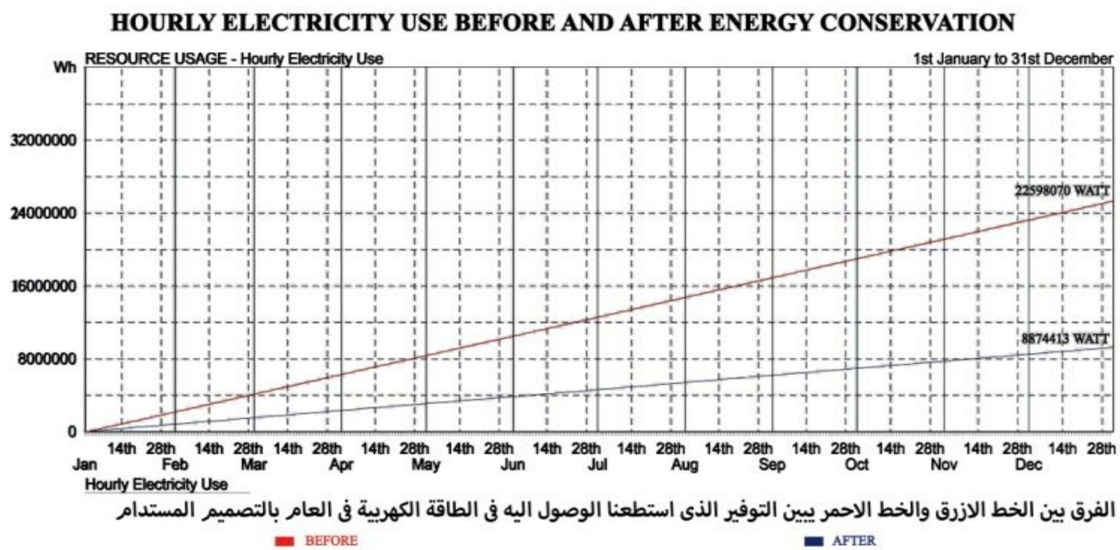
Dispersed masses to Allow air to pass through





3.1. Hourly electricity use and energy consumption :

- By comparing the hourly electricity use before and after the energy conservation measures, it was found that an energy saving of about 60% was achieved as shown in (Figures 4 and 5). This can be attributed to the elimination of air conditioners need due to normal ventilation and the replacement of conventional appliances by energy efficient ones in addition to the increase in daylight factor .



BEFORE

MONTH	ELECTRICITY (Wh)	SCHEDULED (ج م)	FLAT-RATE (ج م)
Jan	1924114	127.52	969.28
Feb	1747082	116.10	879.80
Mar	1917222	131.36	961.52
Apr	1841196	133.81	915.72
May	1883224	142.55	930.93
Jun	1836066	135.69	910.93
Jul	1951034	124.14	988.02
Aug	1941016	123.92	982.52
Sep	1858090	130.20	928.97
Oct	1913690	135.26	955.60
Nov	1870078	124.49	941.51
Dec	1915261	137.29	954.46
TOTAL	22598070	1562.34	11319.25

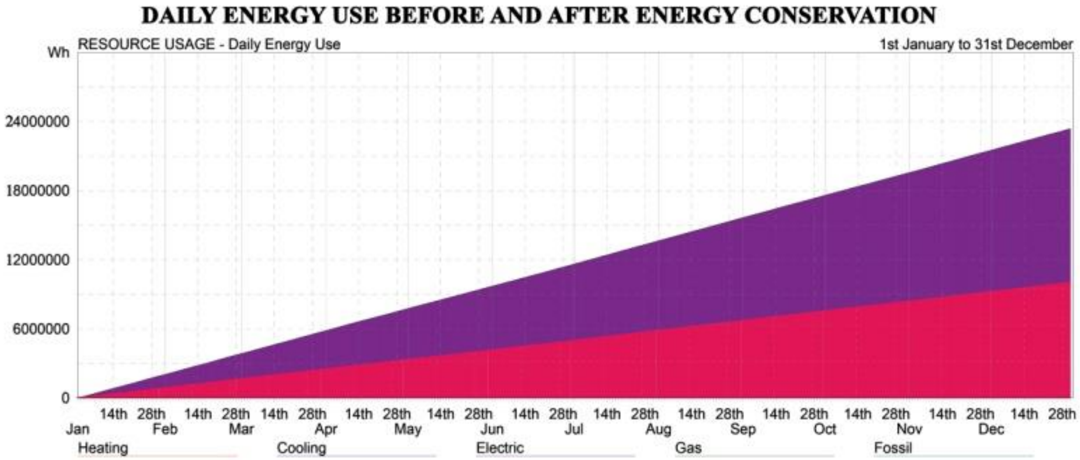
AFTER

MONTH	ELECTRICITY (Wh)	SCHEDULED (ج م)	FLAT-RATE (ج م)
Jan	758907	18.74	436.64
Feb	687270	16.90	395.50
Mar	754162	19.37	433.17
Apr	720960	19.88	412.74
May	736521	21.43	420.52
Jun	718150	20.21	410.72
Jul	768758	17.84	443.46
Aug	766207	17.98	441.79
Sep	728254	19.11	417.88
Oct	750264	19.95	430.25
Nov	735796	18.15	423.37
Dec	749165	20.20	429.35
TOTAL	8874413	229.77	5095.40

Figure.4, Hourly electricity use before and after conservation.

3.2. Light measurement:

- The interplay between the divided volume of the courtyard surrounding the mass resulted in significance decrease in the need of artificial light as mentioned earlier. (Figure6) shows the light measurement in Lux determining the sky view factor.



BEFORE

MONTH	HEATING (Wh)	COOLING (Wh)	ELECTRIC (Wh)	GAS (Wh)	FOSSIL FUEL (Wh)
Jan	0	0	1997025	0	0
Feb	0	0	3810572	0	0
Mar	0	0	5801209	0	0
Apr	0	0	7712330	0	0
May	0	0	9665002	0	0
Jun	0	0	11567872	0	0
Jul	0	0	13590791	0	0
Aug	0	0	15603918	0	0
Sep	0	0	17528842	0	0
Oct	0	0	19510070	0	0
Nov	0	0	21446430	0	0
Dec	0	0	23428522	0	0
TOTAL	**0**	**0**	**23428522**	**0**	**0**

AFTER

MONTH	HEATING (Wh)	COOLING (Wh)	ELECTRIC (Wh)	GAS (Wh)	FOSSIL FUEL (Wh)
Jan	0	0	819379	0	0
Feb	0	0	1561194	0	0
Mar	0	0	2375650	0	0
Apr	0	0	3154492	0	0
May	0	0	3950090	0	0
Jun	0	0	4726955	0	0
Jul	0	0	5559378	0	0
Aug	0	0	6389114	0	0
Sep	0	0	7177450	0	0
Oct	0	0	7989626	0	0
Nov	0	0	8784039	0	0
Dec	0	0	9590393	0	0
TOTAL	**0**	**0**	**9590393**	**0**	**0**

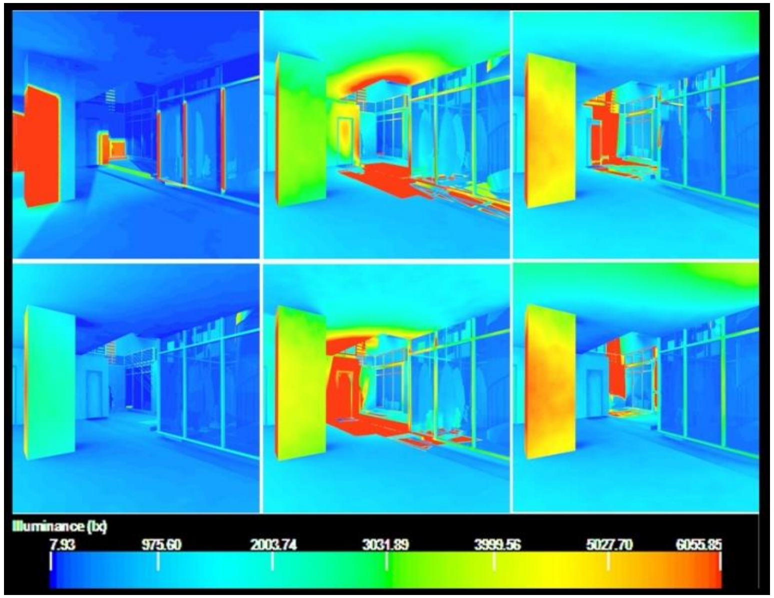


Figure. 5, The daily energy use before and after enrgy conservation

Figure. 6, Light measurement in Lux

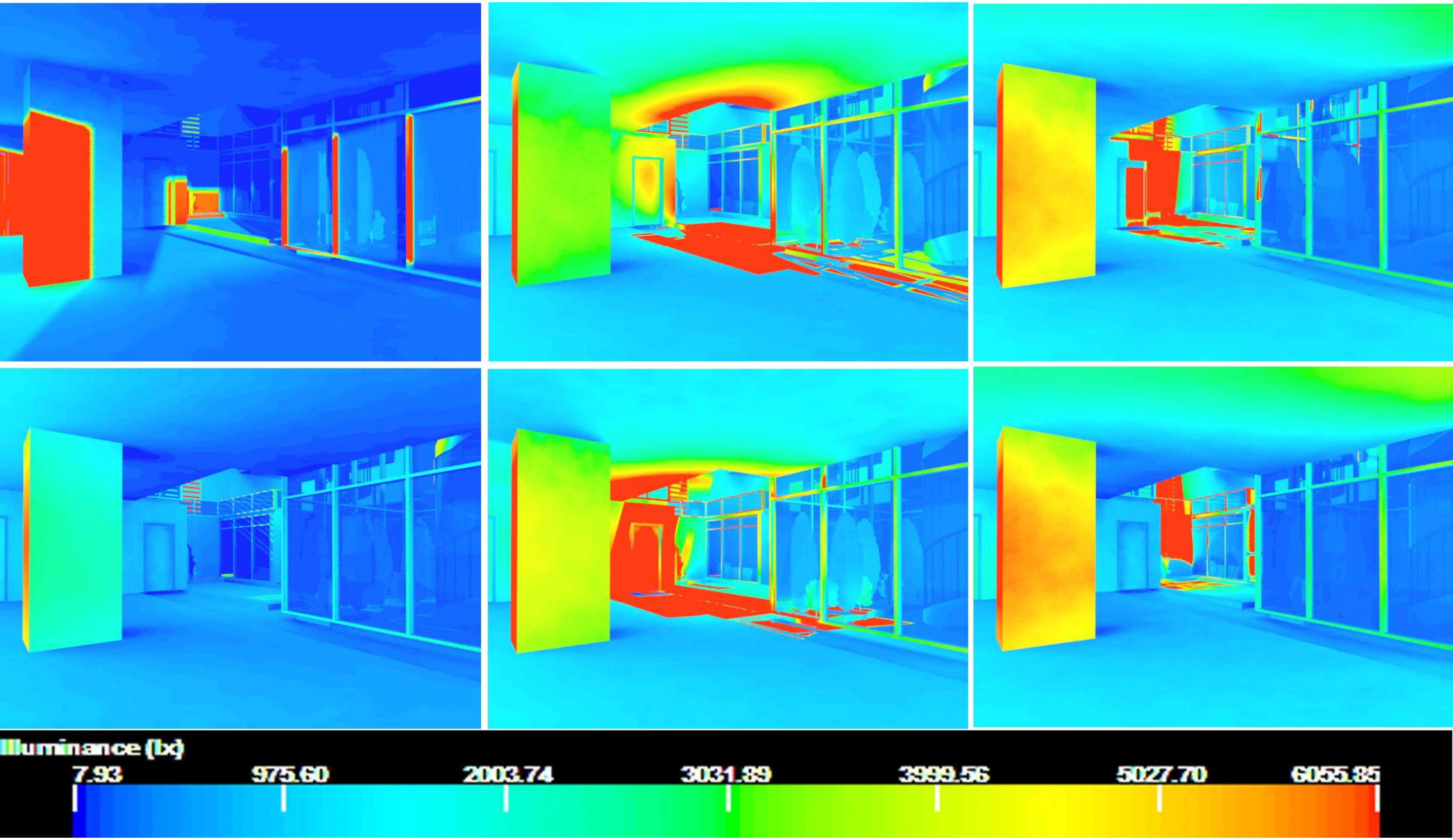


Figure. 6, Light measurement in Lux

4. Conclusions:

- The overview and simulation of the blending of redefined courtyard and Net ZEBs carried out in the framework of this research has led to the identification of new ways of design for this type of ZEB courtyard house. The courtyard volume should be broken to multi-small courts scattered in the house mass in order to improve cross natural ventilation and daylighting. Its envelope should be multi-functional element to filter the outside environment to a set of free sources of energy such as wind, sun.

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BAYET AL SUHAIMY 2011
Contemporary Egyptian Model for a Self Sufficient House
SAMER EL SAYARY ARCHITECTS

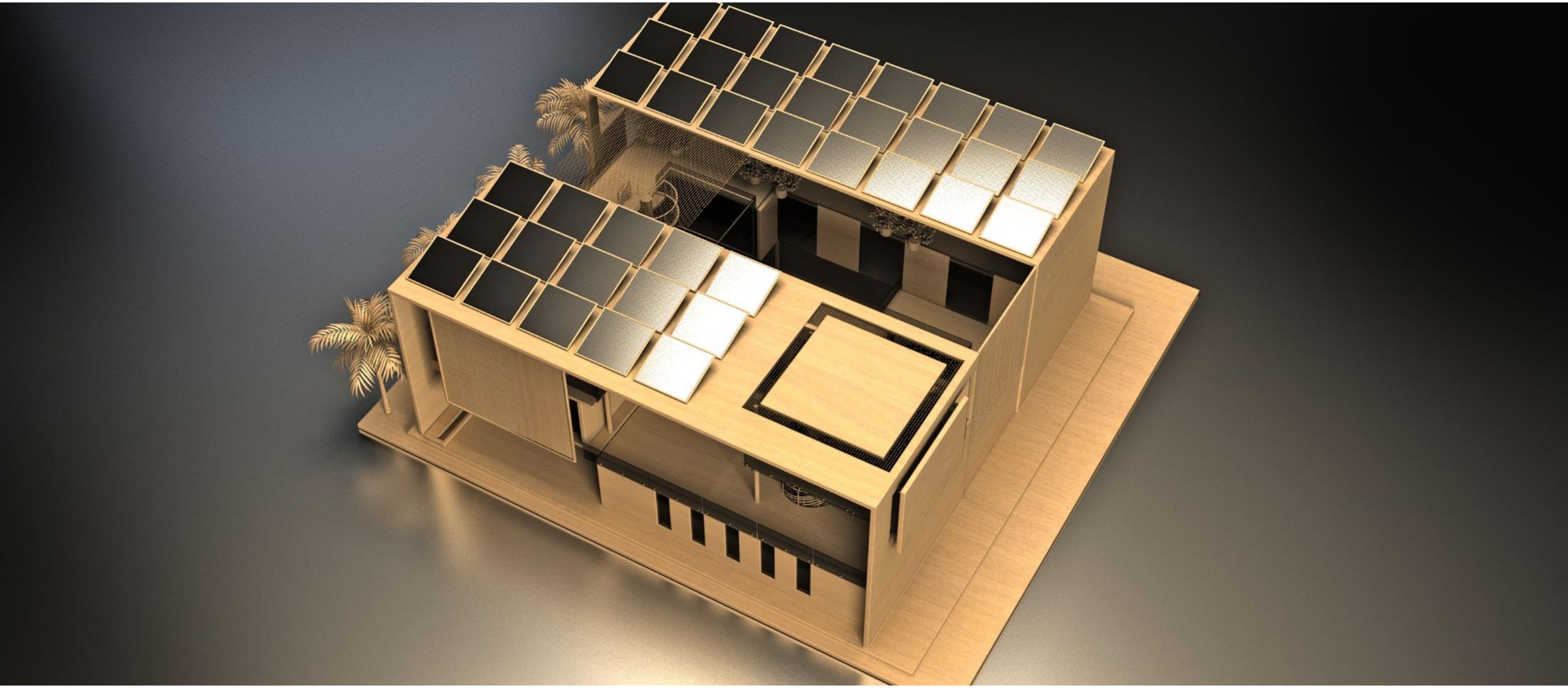

A-A
B-B
C-C
SAMER EL SAYARY ARCHITECTS

From *passive cooling* to zero carbon,
Net energy, self sufficiency ,waste management…….

BAYET AL SUHAIMY 2011

Contemporary Egyptian Model for a Self Sufficient House

From *privacy* to enhancing social interaction, creating social spaces,introversial design...



39 PV generating 7 to 8 watt for consumption of 5 family members

Thank you