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Computational Approach to Optimize Refugee Shelters, Al-Baqa'a Palestinian Refugee Camp in Jordan

Material-Based Design

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Abstract

This paper is part of an ongoing study for generating a sustainable module using computational approach for shelter design, it aims to introduce a material-based design toward obtaining thermal comfort through shelter optimization process, and it targets the slums in one of the oldest Palestinian refugee camps in Jordan. The optimization was generated from an ecological platform, according to Jordan's natural substances and climatic conditions. It is formulating the role of design contribution in improving Al-Baqaa's refugee camp, and transform it from "Temporary shelters into permanent affordable housing" as it has been established for 70 years, which renders it a permanent shelter rather than a temporary or emergency one. The paper followed a combined research methodology by discussing the formulated issue and presenting an empirical computer-aided material optimization process, using "design builder software", with the plugin "energy plus", where the performance of the selected materials was tested according to the achieved internal thermal comfort, energy consumption, and conductivity of each material, in the most hot summer day and most cold winter days of the year, followed by testing the ability of using a solar system as a source for energy in the camp. Moreover, as part of a larger study that seeks to generate a sustainable model, the paper also includes a brief cost comparison that was generated using archival data and online interviews with contractors in Jordan. It clarifies the actual role of computational thinking and early use of CAD tools in design processes as an enhancer to achieve more efficient results, better living conditions for similar cases, and decrease the multi-layered load on countries that host many refugee camps similar to Jordan.

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Keywords— Shelter, Computational approach, energy consumption, Material-based design, Thermal comfort

Introduction

Referring to the political condition between Jordan and Palestine, culture, and the geological location –sharing borders all along the west- Jordan was one of the countries that hosted the highest number of Palestinian refugees who were expelled from their land in the Arab-Israel wars,(1948-1967). Until 2009 45% of the refugees were registered in jordan (Ababsa 2013), and depending on the UNURWA's official recordings, Jordan has 13 camps in variant cities, three of these camps is not officially under the responsibility of the UNRWA and not listed in their archive files, which the Jordanian government is taking care of, and providing shelters. The first Palestinian refugee's camp in Jordan was created 70 years ago in 1950, in Al- Zarqa'a city, but was not the biggest since it had only 20,000 refugees out of 2.1 million refugees officially recorded in the relief committees archives in Jordan. The biggest camp back then was Al-Baqa'a camp which consisted of 7000 dwelling unit and hosted around 119,000 refugees. By the UN credence, 65% of the Palestinian refugees were settled in the official 10 camps, Table (1), (Alnsour & Meaton 2014).

Table 1:
the recorded camps by UNRWA:

Name of the refugee camp	**Location**	**Area m2**	**Establishment**	**%**
Wehdat	Amman	477000	1955	15.37
El-Hussien	Amman	338000	1952	8.95
Al-	Amman	1307000	1968	27.66

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Baqa'a				
Talbieh	Amman	133000	1968	1.90
Souf	Jerash	596000	1967	5.93
Husun	Irbid	754000	1968	6.55
Gaza	Jerash	507000	1968	7.05
Irbid	Irbid	219000	1950	7.55
Heteen	Zarqa'a	894000	1968	13.47
Zarqa'a	Zarqa'a	189000	1949	5.57

The Palestinian refugee's critical political situation regarding the "Return Rights" affected the camps situation in a noteworthy way for so long, which caused a very slow development through all these years, and caused the issue of the low quality living conditions until today, For such reasons the dwelling units of those slums in the camp are still listed under the term "emergency shelter" which is meant to refer to a temporary accommodation, but what does not make sense in this issue, that 70 years of life can't be considered as a temporary situation.

In 2014, UNCHR have stated that the world recorded 20 million refugee, 38% million of them were internally displaced, all suffering low quality living conditions and food insecurity. (UNHCR 2017), associated with other multi-layered issues, such as health, economic, social, and of course as a spontaneous result caused environmental issues.

According to the conducted studies around the world in the field of refugee's shelters through the past few years. Researchers, designers, experts and engineers developed refugee's shelter design, and living environment from various platforms and preferences "ecological performance, aesthetical platform, social impact, political situation, psychological impact, urban clusters and shelters layout, and the ability of growth and communication" these preferences and many others were discussed and developed from several particulars.

Based on that, In the method of this paper computational approach was assumed to be a proper approach toward simplifying similar multi-layer issues, it focused in specific on the energy optimization though material-based-design; enable to reach energy security, what led to food security, water security, heating and cooling as basic needs toward a good quality living. (Aste , et al. 2017).

Computational thinking (CT) is a relatively new terminology deliberated since the early 90's, but originally mentioned for the first time by Seymour Papert in 1980 in his book "Mind storms" for describing the development of the mental skills of a children caused by practicing programming, and conceptualized later by (wing 2006). Through expanding on Papert idea: "apply novel approaches efficiently to problem solving in 1996". Wing said that computational thinking is "a fundamental skill for everyone, not just for computer scientist" and stated that CT is not about transforming human brain into a computer machines but how human solve a problem by drawing on the concepts of computer science fundamentals, and emphasized on that by a computer science education research in 2009, by making an example of a DNA clarifying the way of applying computer science techniques on other disciplines using a code sequence. (A. Weinberg 2013).

Despite all the conducted researches in the field of computational thinking in the last decade by diverse disciplines, it is still cannot be stated in one single clear definition, but a common theme can be imprinted or rationalized by looking into those definitions formulated by researchers from variant disciplines. Starting back in the

1930's, when CT was simply stated as an evaluation of a recursive function by (Sieg 2006)**,** and described as an abstraction for a sequence of states evaluated through built-in algorithms in (Turing 1936), when in 1960's, the computer was considered as a thinking aid that force human brain to think in problems differently and accelerate the rate of human brain developing himself as a spontaneous result for just having computer machines in the surrounding (Caspersen and Nowack 2013).Computational approach according to (Penrose 1990), is understanding and rationalizing the problem itself enable to assume effective solutions, it is breaking the problems into a chain of small, recognizable patterns, where important details can be justified, abstracted and represented in a designed algorithm with more stronger systemized bonds toward actual solutions.

Case Study: Al-Baqa'a Refugee's camp in Jordan:

Al-Baqa'a camp is located 20 km north Amman city, and present the most sufficient environment for developing the module of this research as it went under several transferring and upgrading processes by UNRWA and Jordanian government, (tawil 2009) the camp was established 1948 in Jericho inside the borders on Palestine before being transferred inside Jordan's borders in the 70's, in the first stage the shelters was only was created using fabric and plastic tents, Figure (1) , few years later, upgraded to prefabricated caravans with zinc roofs after the first relocation , Figure (2) (Meaton 2014),in the late 90's the second relocation process occurred a noteworthy change, the UNRWA gave 50-100 sqm for each shelter "unit" in Al-Baqa'a and up graded the construction material to be brick walls and cement plaster, but the critical issue that shelters has no glazing material (replaced with plastic sheets) and the roofs are still made of zinc, Also on the urban scale the shelter clusters layout evaluated very poorly. Figure (3) (4) (Ababsa, ATLAS OF JORDAN 2014)

Figure 1: Al-Baqa'a camp in Jericho 1948 – first stage.
Source: UNRWA Archives

Which later caused an actual urban growth issue, random clusters and individual efforts to expand based on that the responsible authorities had to take a serious action in the past few year and started partial re-upgrading process, which transformed more that 50% of the camp into regular neighborhoods. (Rueff and Viaro 2009).

Figure 2: Al-Baqa'a camp on Jordan's borders- second stage.

Source: UCL-Samar Maquasi

Figure 3: Al-Baqa'a camp in Amman city- third stage.

Source: UNRWA Archives

Figure 4: Al-Baqa'a camp in Amman city- third stage site plan.

Source: Google maps

Methodology

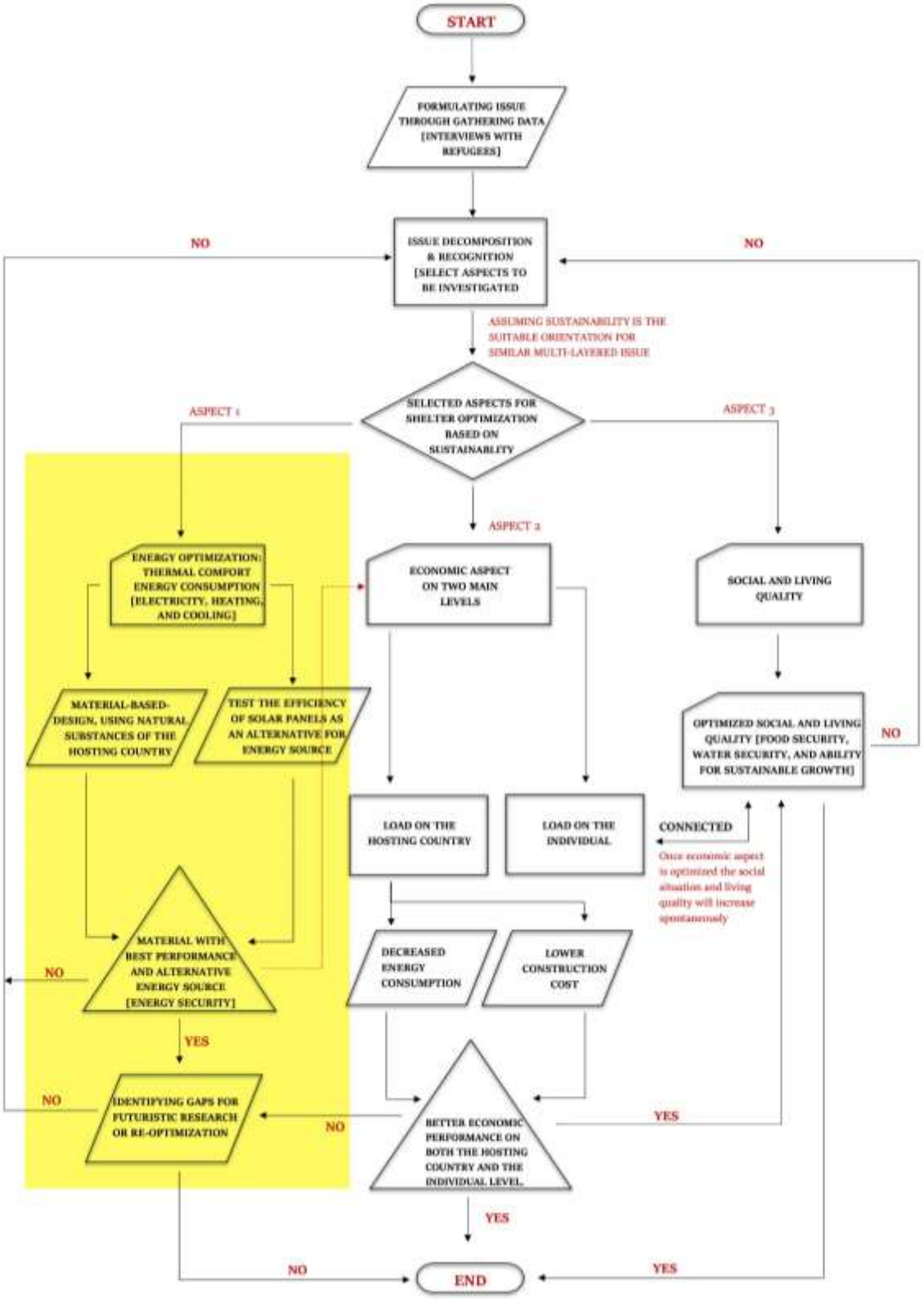

Figure 5: Research Algorithm

Through a brief literature review, followed with combined empirical and qualitative research methodologies, as the primary data was gathered previously through interviews with the refugees on camp (sample of 65 people-selected randomly-all above 18 years old) and was limited to one open question "if you have the chance to ask for the missing in your shelter/camp to feel like home, what would It be?", and the aspects were selected according to the highest record, supported with the literature review and as per (Aste , et al. 2017), energy security guarantee food security, water security, and naturally solve all related issues. Figure (5).

The optimization process for this paper was limited to achieving thermal comfort, through material-based-design, and testing the solar panels efficiency as an alternative energy source, using CAD tools "energy plus plugin- design builder software". The optimization used the natural substance of the hosting country to avoid additional construction cost.

The geological and natural substances in Jordan:

Jordan's climate is characterized of hot, dry, long summers, and a short, cold winters, it has the Arabian Desert's aridity with the humidity of the Mediterranean Sea according to the geological location (Freiwana and Kadioˇglu 2007). Through research developments on most prevalent materials in Jordan, three materials were identified for the optimization process conferring to Jordan's architectural history and material properties fitting into construction requirements:

Cement blocks: which is the current used material for shelters "the default status in the optimization process, with an average conductivity of 0.99 W/mK. (W/mK: Watts per meter-Kelvin). (Saini, Gangwar and Mishra 2019) (Zhang, et al. 2017).

Stone blocks: as Jordan has variant stone types "AL-Ghasheem" stone recorded the most sufficient hardness property that might be proper for construction demands, with an average conductivity of 1.3 W/mK. (Tarrad, Al-Omari and AL-Rawashdeh 2012).

Earthen blocks "clay & Straw": material of mud and fibers "fibers of the palm tree leave and straw", with an average conductivity of 0.3 W/mK. (Saini, Gangwar and Mishra 2019) (Atiyat 2017).

Material-based-design

Thermal simulation engines are now used commonly by all professions related to built-up environment. Enable to get accurate, integrative, and effective results. Similar simulations usually have to be accomplished in cooperation with all design team members, where all necessary professions are engaged to provide the inputs/particulars. (Bahar, et al. 2013).

Whereas, for this research it was very simplified based on the very basic data only to evaluate the role of the carefully systemized steps through solving similar cases "computational thinking", and to assets the role of the CAD tools in the early stage of design process .

A long-term Shelter design proposal:

Referring to the granted area for each shelter by the UNRWA and Jordanian government (50-100) sqm, a basic-regular architectural proposal was generated for the purpose of the optimization process of this research. Figure (6).

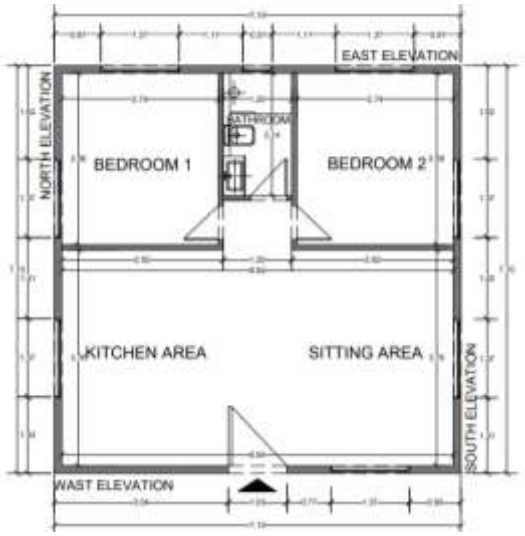

Figure 6: The architectural plan of proposed shelter –Half unit 50 m2.

External walls 30cm thickness, one layer, and 10 cm for the internal divisions and partitions. Double glazed windows of 6mm glass thickness and wooden doors. This experiment is demonstrating the association between material performance, thermal comfort, and required energy for heating, and cooling, though simulating a virtual space assumed according to the agreed unit total area by the UNRWA, (half unit 50 sqm).Figure (6).

Followed with testing the solar system as Al Baqa'a Is one of the relatively hot places in Amman, Jordan, to evaluate the efficiency of the system as an alternative energy source. Based on (oxman 2007) (McCarter 2005)the architect Louis Khan described the buildings differently as an inert arrangement of elements, but "Living organic entities", where the term brick/block, is replaced with the term material, and task/function is replaced with "performance".

Given context and Results Discussion:

The model input, was basic simplified and tested for the half unit with a total occupied area of 54.6m2 as per proposed plan, and 191 m3 total volume. Figure (7).

Floor Areas and Volumes	
Building rotation (°)	0.0
Occupied floor area (m2)	54.6
Occupied volume (m3)	191.0
Unoccupied floor area (m2)	3.3
Unoccupied volume (m3)	11.4

Figure 7: Occupied area.

Building thermal simulation engines predict the thermal performance of the space according to the given context related to the climatic condition of the geological location, occupant activities, HVAC system, building geometry, time assumed for simulation, furniture and partitions configuration, room's layout, and not to forget the building orientation, and the construction elements, such as windows, and doors.

For the purpose of this simulation, which is comparing the material performance "heat gain and loose through walls" the proposed plan was simulated empty "without furniture and no occupants" then re-simulated with default activity of 5 people; to compare the impact of the internal activities on the overall performance of the walls material. The environment control was limited between 12-22C^{o} for the heating and 24-28 C^{o} for the cooling. With an electrical based System instead of fuel; enable to check the required electricity and evaluate the efficiency of PV coverage for similar case accordingly. Figure (6), Figure (6).

Figure 6

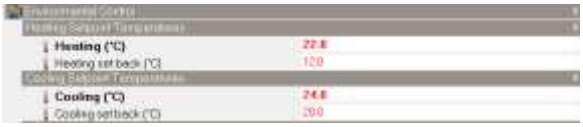

Figure 6

For the first material "**cement blocks**" while building is empty, the highest heat gain through walls was recorded in August with a value of "824 k/wh", while heat loss in January "-1340", February "-1173", December "-1179". Whereas, while building is occupied recorded heat gain of "658 k/wh" in July, - "686 k/wh" in August. And heat loss of "-1093 k/wh" in January, "-965 k/wh" in February.

Table 2: Figure 8:

	While occupied	While Empty	
Month	**Heat transfer through walls k/wh**	**Heat transfer through walls k/wh**	**Variation**
January	-1093	-1340	-247
February	-965	-1173	-208
March	-517	-670	-153
April	-182	-279	-97
May	326	411	85
June	504	611	107
July	658	797	139
August	686	824	138

September	499	617	118
October	54	43	11
November	-553	-713	-160
December	-931	-1179	-266

Table (2): Table (4): heat transfer through walls – cement block –simulation results

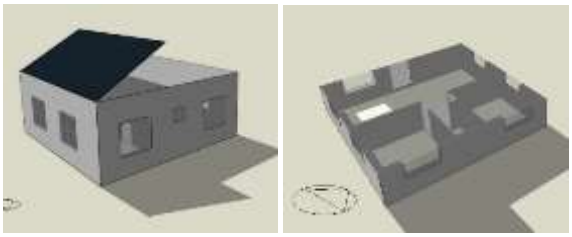

Figure 8

For the "**clay blocks**" material performance, while building is empty, recorded heat loss through December and January with an average of "538 k/wh" and heat gain of "360 k/wh" during July and August,Whereas, while occupied, it recorded heat loss during January, February, and December with an average of "-453 k/wh" and heat gain during July and August with an average of "302 k/wh".

Table 3: Figure 9:

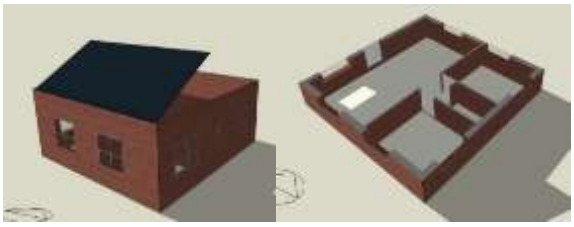

Figure 9: Clay block model

	While occupied	While Empty	
Month	**Heat transfer through walls k/wh**	**Heat transfer through walls k/wh**	**Variation**
January	-495	-569	-74
February	-428	-488	-60
March	-254	-294	-40
April	-98	-118	-20
May	131	156	25
June	211	248	37
July	298	339	101
August	305	348	43
September	216	256	40
October	32	31	1
November	-262	-304	-42
December	-437	-507	-70

Table (3).heat transfer through walls – clay block –simulation results

Stone material have recorded the highest values for both heat gain and loss comparing to the cement and clay blocks, as the loss values for the empty building during January, February, and December was an average of "1144 k/wh", and gain values during July and August of "940 k/wh". The variation between the occupied and empty building for the stone was relatively low. Table (4), Figure (10).

	While occupied	While Empty	
Month	**Heat transfer through walls k/wh**	**Heat transfer through walls k/wh**	**Variation**
January	-1557	-1256	-74
February	-1376	-1117	-60
March	-782	-588	-40
April	-333	-205	-20
May	490	385	25
June	717	585	37
July	924	754	101
August	956	787	43
September	725	579	40
October	38	54	1
November	-836	-635	-42
December	-1368	-1059	-70

Table 4: heat transfer through walls – stone block –simulation results

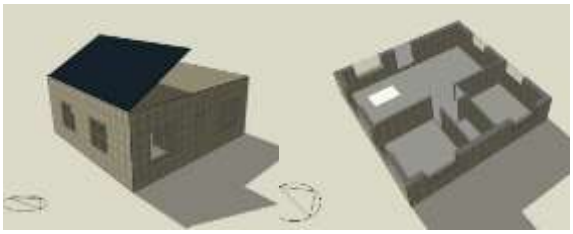

Figure 10: Stone block model

Based on the simulation results for the three materials in both cases, empty and occupied, clay blocks recorded the best performance, it has 18% less cooling system energy, 18.8% less heating system energy and 18.4% less total energy, and the heat of the surfaces didn't exceed 24 C^{o} , and that was for the south elevation only and 25% of the roof area. Figure (11), Figure (12).

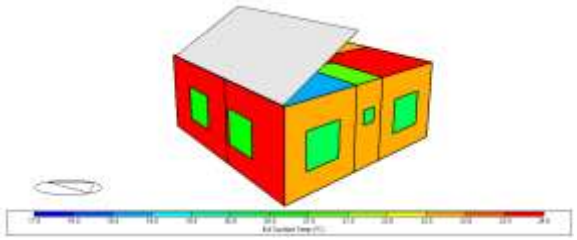

Figure 11: Annual average of surface temperature -south

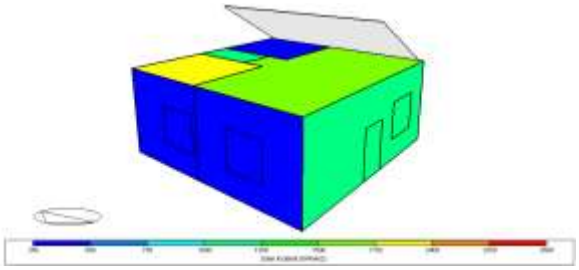

Figure 12: Annual average of surface temperature -north

For the Photovoltaic panel inputs: coverage for 32 m^2 was assumed- panel efficiency is %18.7 – 25 panel's photovoltaic, and Power plant capacity was 5 kW. Table (5),

Model					
Solar cell (125*125mm)	Mono	Mono	Mono	Mono	Mono
Maximum power (Wp)	180Wp	185Wp	190Wp	195Wp	200Wp
Maximum power voltage (V)	36.36	36.48	36.62	37.4	36.1
Maximum power current (A)	4.95	5.08	5.22	5.22	5.26
Open circuit voltage (V)	45.04	45.06	43.90	44.80	45.30
Short circuit current (A)	5.45	5.47	5.49	5.75	5.79
Cell Efficiency (%)	16.75%	17.38%	17.90%	18.23%	18.7%
Module Efficiency (%)	14.10%	14.58%	14.90%	15.3%	15.7%
Number of cells (PV's)	72(6*12)				
Size of module (mm)	1500×680×15mm				
Maximum system voltage (V)	1000V				
Temperature coefficient of Isc (%)	+0.1 °C				
Temperature coefficient of Voc (%)	-0.38 °C				
Temperature coefficient of Pm (%)	-0.47 °C				
Temperature coefficient of Im (%)	+0.1 °C				
Temperature coefficient of Vm (%)	-0.38 °C				
Temperature Range	-40°C ~~~ +85°C				
Surface Maximum Load Capacity	150m/s(540kg/m²)				
Allowable Hail Load	clear ice ball fall down from 1m height				
Weight per piece (kg)	15				
Junction Box Type	PV-RH3004 TUV				
Connectors and Cables Type	With TUV certificate				
Length of Cables (mm)	900mm				

Table 5: Photovoltaic panel inputs

According to the results of the annual required energy if the construction material was clay blocks is [5343 KWh], then the annually generated electricity by the PV system, which is 11860 kWh, can easily cover the unit need electrical need. Table (6), Figure (13).

Model	Heating	Cooling	Total
	kWh	kWh	kWh
Cement Blocks	5613	4336	9948
Clay Block	2873	2470	5343
Stone Blocks	6428	4871	11300

Table 6:

Heating, cooling yearly required energy

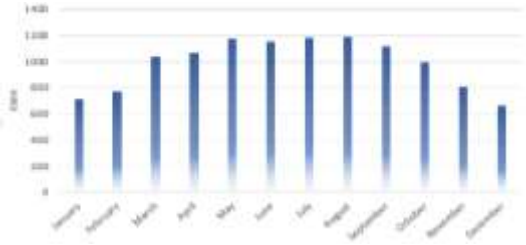

Figure 13: Annual PV system Production.

Brief Cost comparison

Enable to check the efficiency and reliability of the solar system, assuming the construction material as the material with the best performance "clay", an online interview with 2 Jordanian contractors was conducted; to question the cost of construing similar unit using clay comparing to the current situation with is cement blocks.

The contractor have stated that clay blocks for similar unit would cost an average of 127-141USD per m2 which means a grand total of "6,350 USD for the half unit and 12,700 USD, for the full unit", excluding the interior finishing's such as tiling, paint…etc., whereas, cement block is around 212 USD per m2. Which means "10,600 USD for the half unit and 21,200 USD, for the full unit".

The estimations were based on the early stage records mentioned in (Alnsour & Meaton 2014). Where 7000 dwelling unit was officially recorded by the UNRWA, and lived there around 119,000 refugees. Accordingly, the construction cost would be decreased around 60% which is an average of [88,830,000 USD] of the overall amount if it was constructed using the clay blocks instead of cement one.

Furthermore, the cost of the solar system to cover the required energy for 119.000 refugee is about [100,674,000 USD], in this case the amount saved from the construction would cover around 89% of the required for the PV system.

Conclusions

The results of the simulation recorded the best performance for the clay material regarding the thermal comfort what as a spontaneous result decreased the energy consumption for heating and cooling, clay block materials recorded 18% less consumption while the building is occupied for, and 18.8% was recorded for empty space simulation, which means around 18.4% less consumption for the average of the annual overall energy consumption.

Having a fully understanding for an issue means being able to achieve an efficient performance for long term not only in instantaneous, and reducing error probability. When steps are systemized, and planned according to a set of instructions designed carefully to respond and perform a required task, it seems as easy as multiplying two numbers, while in fact it is performing multi-task in parallel coherently, as the early decomposition and recognition of the issue make it easier to recompose it is away that respond and give a result as a puzzle operation.

The hereinabove mentioned result relatively proof that the adoption of computational approach would be highly effective for similar cases "refugee camps", specially the long term shelters as same as Al Baqaa camp, which went through more than one relocation process, and if we think about the manufacturing of the previously used tents and metal/aluminium caravans, or even the current situation "cement block", we can easily find the clay unit's has less pollution in the construction and the demolition comparing to the other materials, what "again" support more than one aspects of what we need to be taken into consideration during similar optimization processes.

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