ISBN 978-93-84422-62-2
Proceedings of 2016 2nd International Conference on Architecture, Structure and Civil Engineering (ICASCE'16)
London (UK), March 26-27, 2016

Towards Energy Autonomous House in Beirut

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***Abstract*:** *Energy autonomous house EAH does exist. Many of these energy sufficient buildings are found in Europe and monitoring them showed that they are almost energy autarky under normal conditions. Beirut, the capital of Lebanon, is a dense city in the Middle East that suffers from the lack of infrastructure and electricity in first place. The question the paper rise is; does Beirut need an EAH and could its environment help in achieving energy sufficiency? A description of the current situation will be presented and analyzed to form the base of a methodological framework that aims to investigate the technical, practical and financial feasibility of energy autonomy for a hypothetical house in Beirut. Furthermore, two case studies for different EAH in the UK and Germany will be examined and demonstrated to state the importance of reducing energy demand by using passive design and energy efficient appliances. Finally, this paper may reach to appropriate solutions for providing renewable energy resources that can be applied on Beirut's existing residential buildings roofs and facades in addition to a set of design guidelines applying new constraints on the new developments.*

Keywords: *architecture, energy autonomous house, renewable resources, financing*

1. Introduction

An "autonomous house" is defined as a house that can function independently of support and services from public facilities [1]. However, the energy autonomous house does not require users to lead solitary, penny-pinching lives. The aim of EAH is creating a sustainable, high-quality and comfortable living environment using renewable energy technologies to reduce environmental load. Energy Autonomous Houses are built with significant energy saving features. The heating and cooling loads are lowered by using high efficiency equipment, added insulation, high efficiency windows, natural ventilation, and other techniques. Its main aim is to reduce carbon emissions and limiting the dependence on fossil fuels. Globally there is a long tradition in energy autonomous housing. The purpose is to broadly assess the available renewable energy technologies in terms of their likely cost and physical requirements in order to determine whether energy-autonomy is feasible and worthwhile. By 2021, in the European Union the nearly zero-energy building-standard will be obligatory for all new buildings [2]. Electric energy is a need in our lives. Imagine a life without television, radio, internet, smartphones or any other electrical appliances. However, this energy is mainly produced on fossil fuel resources.

Cities are growing bigger constantly, nowadays more than half of the world's population accommodates in the cities and by 2030 nearly this number will swell to 5 billion [3].

In Lebanon, the cost of electric power is expensive, though there is not 24 hours coverage even in the capital. Lebanese citizens are paying yearly near $600M as electricity bills to EDL and almost $1.2B for private diesel generators' owners. In summer, the demand is at its peak due to the hot weather and the increase of accommodation percentages due to tourism. In this period of the year, the seashore areas in addition to the areas located below 1000 m altitudes use huge amount of energy on cooling the inner space in which it leads to lowering the period of EDL coverage of electricity. And here comes the role of the private diesel generators' suppliers to compensate the demand and yet increasing the bill value on the citizens.

Lebanese government intends to meet 12 percent of its total energy needs from renewable energy sources by 2020. However, less than 1% will be from Geothermal Energy [4]. Hence, the need of an EAH is increasing day by day however this approach will have its determinants. Achieving an EAH in Beirut needs sufficient roof and south oriented façade areas to install solar panels. Moreover, financing this plan is still hard to achieve since a supported sustainable energy plan loan for buildings is still not feasible to attract the buildings' owners. The initial cost will increase thus there are no comprehensive guaranties that the renewable energy costs may not lessen in the future and then leading to a major loss. Also, there is still a lack of expert designers and builders who have the necessary skills or experience in order to held the construction of the Energy Autonomous House. However, this approach will have more benefits on the inhabitants and the buildings' owners respectively. They will be isolated from the expected future increase in energy prices, they will reduce the requirements for energy austerity, and they will get a higher retail value, as potential owners demand more EAH than available supply.

In this paper, Lebanon's energy is analyzed in terms of numbers and data. Then, a number of renewable energy solutions will be stated and discussed. Finally, two case studies will be discussed and compared to come up with design criteria for achieving the energy autonomous house in Beirut.

2. Lebanon's Energy and Energy Efficiency Market

The electrification rate in Lebanon is almost complete thanks to the private diesel generators owners who close the gap between the demand and supply in the market. In 2012, the electricity consumption was around 15 TWH however 95% of this energy was produced on fossil fuels [5]. Only 5% of the energy production was on renewable resources and mainly on hydroelectricity.

2.1. Primary Energy Supply

The Lebanese primary energy supply is mainly depending on oil products as shown in (Figure 01). However, Lebanon imports most of its petroleum products since the country does not produce oil or coal and most of its energy needs are imported until this period of time. Unfortunately, the petroleum prices are continuously on a rise and the electricity sector's debt is getting larger and larger.

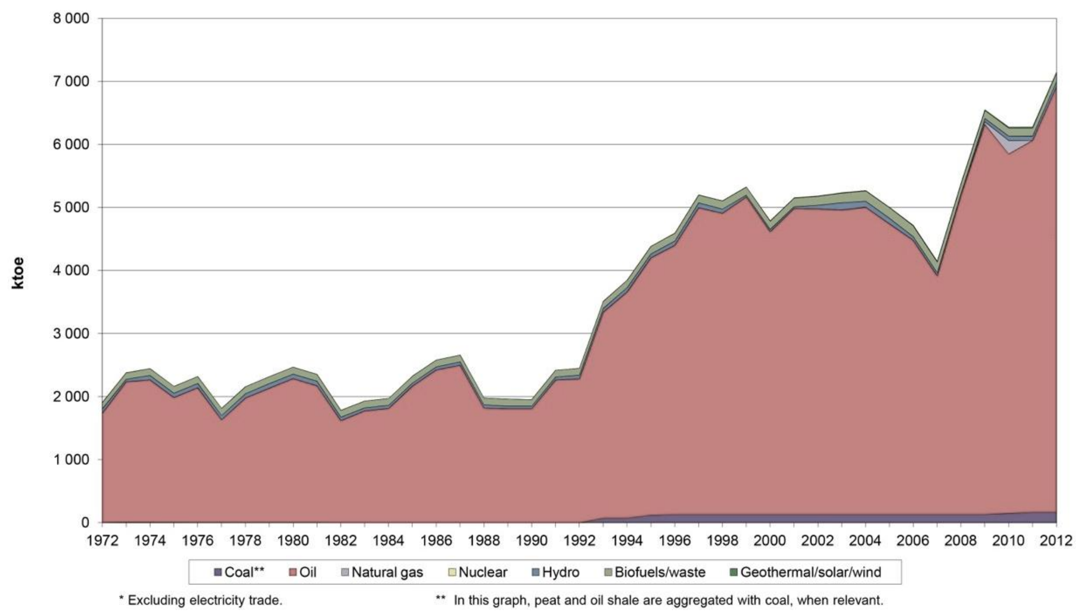

Fig. 1: Total primary energy supply, Lebanon [6].

2.2. Electrical Consumption per Sector

According to the International Energy Agency IEA, Lebanon's electricity consumption in the residential sector represents 38% of the country's total electrical energy consumption.

TABLE I: Electrical Consumption per Sector (2012)

Sector	Residential	Industrial	Commercial	Others
Consumption %	38%	26%	17%	19%

2.3. Residential Energy Consumption in Beirut

Residential energy consumption is mainly divided into six end-use groups:

Space cooling; between May and September.
Space heating; between December and March.
Lighting
Electrical appliances
Water heating
Cooking

3. Renewable Energy Technologies

3.1. Theoretical Framework

Energy autonomous house binds the three areas of architectural design, sustainable environment and energy application. Zooming in into the considerations, architectural design and sustainable environment include passive design principles and active equipment. Regarding the architectural design and energy applications, items combine compatibility between inputs and outputs and feasibility assessment. Sustainable environment and energy application cover solar and wind green energy (Figure 02).

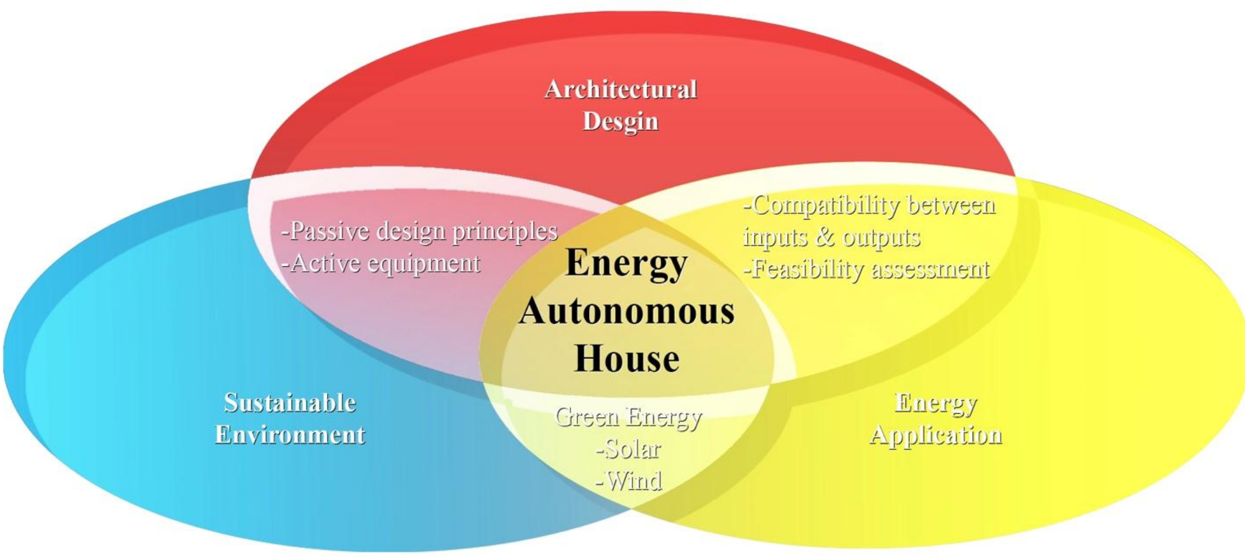

Fig. 2: Energy autonomous house theoretical framework.

3.2. Passive Design

Energy autonomous house and passive design strategies are strongly connected. These strategies include window size and position, glazing type, shading, thermal insulation and thermal mass [7] in addition to natural ventilation (Figure 03).

Insulating the inner space from the external atmosphere
Solar gain in winter, shading in summer
Air tightening the building prom heat loss
Natural lighting during the day
Natural ventilation to prevent inner space air pollution

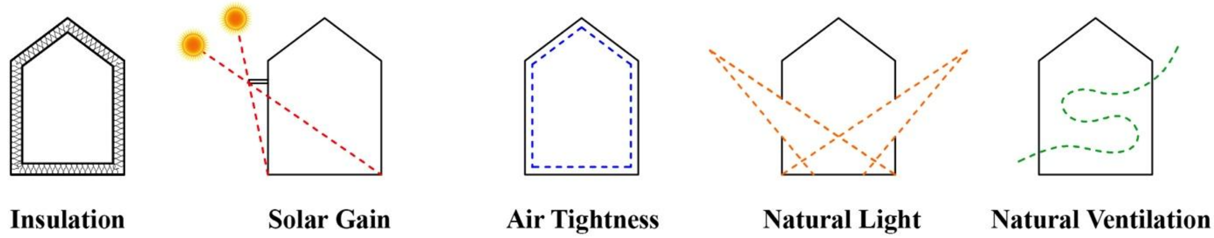

Fig. 3: Passive design strategies.

3.3. Renewable Energy Resources

Renewable energy resources are generally defined as energy that come from which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat [8]. Talking about the sun and wind as renewable energy resources, the energy generated would be stored in batteries and either converted to the house or to the grid connection (Figure 04).

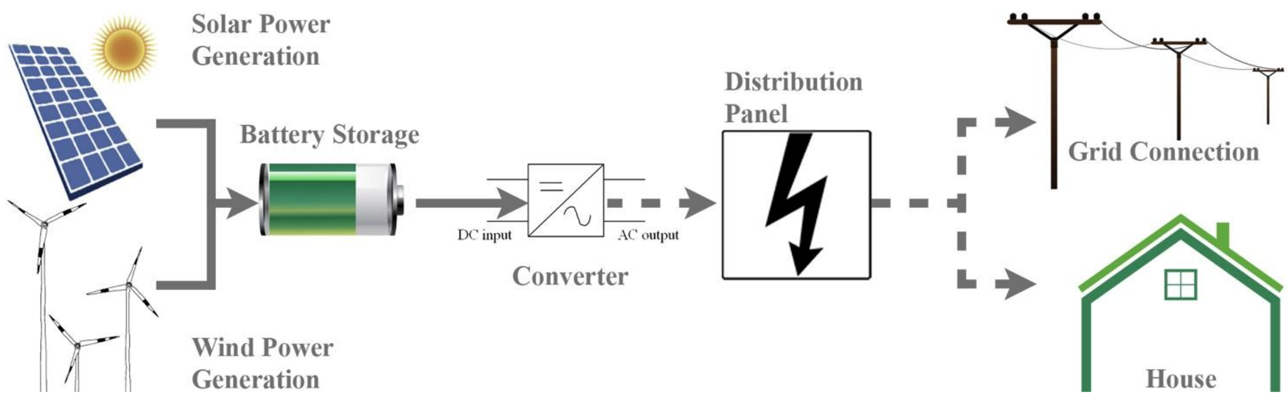

Fig. 4: Renewable energy sources.

3.4. Storage Models

There are several storage techniques available, the main types are either electrical (SMES, capacitors etc.), electrochemical (batteries) or mechanical (flywheel, pumped hydro etc.) [9]. In this case, only battery storage models will be applied.

4. Financing and Feasibility

The solar power is expanding into new sectors in Lebanon thanks to several financing sources. The National Energy Efficiency and Renewable Energy Action (NEEREA) grants 14-year loans to the private sector with new zero interest. Moreover, the Central Bank recently announced a $200 million to support the NEEREA mechanism [10].

5. Design Criteria

TABLE II: Design Criteria

Solar Gain	Glazing double/triple	Building Orientation	Solar Panels	Batteries	Wind Mills	High Levels of Insulation

6. Case Studies

Two case studies will be analysed and compared. The first case is The Cropthorne autonomous house in Worcestershire, England and the second one will be from Germany “The Energy Autonomous House in Kumhausen”.

6.1. The Cropthorne Autonomous House, United Kingdom

This house whose area is 150 sqm, which is located in Middle Lane, Cropthorne Pershore, Worcestershire, England, makes more money than it spends! High thermal mass construction, super-insulation and meticulous airtightness detailing remove the need for an installed heating system. Hot water is heated entirely by solar panels. Rainwater harvesting & dry composting toilet results in no mains water or drainage connection: PVs supply electricity; low-energy lighting and pumps are used throughout [11] (Figure 05).

Measures of success:

- Intelligent use of renewable energy makes the house carbon negative.
- Obtains its servicing almost entirely from the land on which it stands, giving it a tiny environmental footprint.
- Although different to a conventionally serviced house, life in it is designed to be every bit as good.

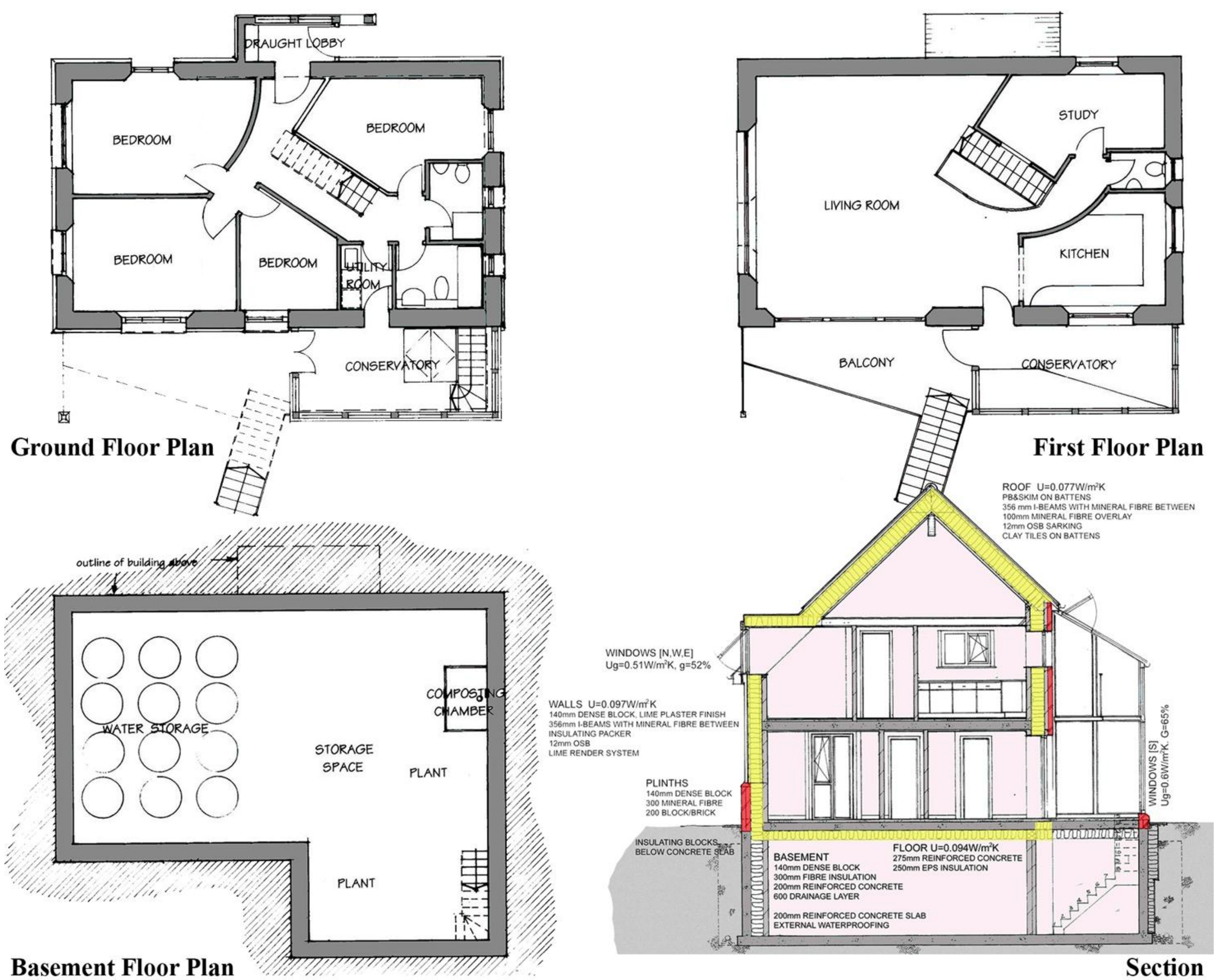

Fig. 5: The Cropthorne autonomous house plans and section.

6.2. Energy Autonomous House, Kumhausen, Germany

This energy autonomous house is located in the northern hemisphere in Germany. Its area is 170 sqm and it is a three-bedroom house (Figure 06).

- Standard heat demand: 6 Kw
- Year heating energy requirements: 8,350 kWh
- Collector area: 68 m²
- Combined water tank 11 m³
- Solar coverage : 77 %

Fig. 6: Kumhaussen energy autonomous house plans.

7. Comparing Case Studies

TABLE III: Case studies comparison

	The Cropthorne Autonomous House,	Kumhausen EAH
Solar Gain	Available	Available
Glazing	Available	Available
Building Orientation	South Oriented	South Oriented
Solar Panels	Available	Available
Batteries	Available	Available
Wind Mills	n/a	n/a
High Levels of Insulation	Available	Available

8. Conclusions and Recommendations

Energy autonomous house is possible and encouraging in Beirut. Environmentally speaking there is an average 8 hours of sun per day yearly. Moreover, the banks are financing solar project with almost zero interest.

Obtaining a Fully autonomous house could be a great future challenge, the building would generate its needed energy and recycle its wastes and sewage and retransform them to energy too.

9. References

[1] Vale, B.; Vale, R. *The Autonomous House: "Design and planning for self-sufficiency"*; Thames and Hudson: London, UK, 1975; p.7.

[2] Directive 2010/31/EU of the European Parliament and of the Council of 19. May 2010 on, "*The energy performance of buildings"*: OJ L153 of 18.6.2010. English, in: Official Journal of the European Union, Article 9.

[3] www.unfpa.org/urbanization. Access: (25/10/2015).

[4] Lebanese Energy and Water Minister Arthur Nazarian attends a ceremony in Baabda. A version of this article appeared in the print edition of The Daily Star on March 25, 2014, on page 5.

[5] http://www.localiban.org. Access: (25/10/2015).

[6] http://www.iea.org. Access: (25/10/2015).

[7] Norton, Brian (2014). Harnessing Solar Heat. Springer. ISBN 978-94-007-7275-5.

http://dx.doi.org/10.1007/978-94-007-7275-5

[8] Omar Ellabban, Haitham Abu-Rub, Frede Blaabjerg, Renewable energy resources: Current status, future prospects and their enabling technology. Renewable and Sustainable Energy Reviews 39, (2014), 748–764, p 749, doi:10.1016/j.rser.2014.07.113

http://dx.doi.org/10.1016/j.rser.2014.07.113

[9] A. Price and B. Davidson, "Recent developments in the design and applications of utility-scale energy storage plant", in CIRED, (Amesterdam, Netherlands), p.4.22, 2001.

http://dx.doi.org/10.1049/cp:20010848

[10] Y.Alieh. (October 2015). Sun Power, the solar power market is expanding into new sectors. *Lebanon Opportunities*. ssue 220. Pp. 45-49.

[11] http://www.cropthornehouse.co.uk Access: (15/10/2015).