Atomic Spectroscopy

Article

Design and Analysis of a Net Zero Electrical Energy Building in Beirut - Lebanon

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ABSTRACT: Lebanon is facing a severe economic crisis, which has resulted in a catastrophic decline of its currency, making it impossible for the government to procure fuel imports. This has led to a nationwide shortage of diesel and fuel, causing widespread power outages and plunging critical services, such as hospitals and residential buildings, into crisis. To address this energy crisis, this paper proposes an innovative solution: designing a hybrid power generation system in a building in Beirut composed of 20 typical apartments, which utilizes alternative energy sources like solar panels and wind turbines. The system will be connected to the grid, allowing excess energy generated on-site to be fed back into the utility grid, effectively offsetting periods of high demand. This approach aims to achieve zero net energy consumption and provide a sustainable solution to the country's energy woes

Keywords: Zero Net Energy Building ZNEB, Solar PV, Hybrid Energy, Wind Turbine.

INTRODUCTION

INTRODUCTION TO ZERO NET ELECTRICAL ENERGY BUILDING ZNEEB

The notion of a zero-energy building (ZEB) in a modern sense has been discussed since the 1970s, prompted by the petroleum shocks of the decade and subsequent concerns about the consequences of fossil fuels dependency1. After the significant increase in carbon emissions that our planet is experiencing, "zero-energy building" was mentioned again, because buildings are responsible for producing pollutions both directly and indirectly as shown in Figure-1, where buildings has the highest pollution percentage among sectors, generating nearly 50% of annual global CO2 emissions and direct building emissions accounting for 27% of yearly emissions 2 were Net-zero buildings benefit their owners and the environment equally. For example, these buildings contribute to the future of sustainability by lowering our carbon footprint by reducing harmful emissions, energy consumption, and unnecessary waste and also to improve the power quality issues [11].

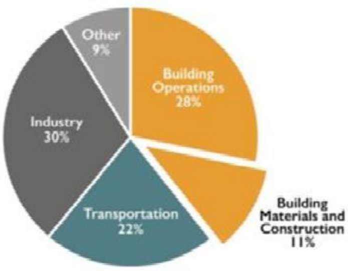


Figure-1: Global Co2 Emissions by Sector

Zero energy buildings combine energy efficiency [9] and renewable energy generation to consume only the amount of energy that can be produced on-site using renewable resources provided by a hybrid system or microgrid [10]. These buildings are generally connected to the grid and have the ability to sell excess power as well as purchase additional power during times of high energy demand. This building, on the other hand, will be net zero over the duration of a year because it effectively produces as much energy as it consumes [3]. A variety of micro generation technologies are used to supply heat and electricity to the building, including the use of the following: Renewable energy sources would include sun, wind [14], biomass, hydropower, and even combining the need for electricity with natural gas heat generation [13]. In addition, the equipment used in buildings are being more efficient where buildings energy consumption is decreasing with time as shown in Figure-2, such as LED lighting, digital inverter-equipped refrigerators and air conditioners, windows that heat homes in the winter, and even the use of new technologies such as solar-absorbing curtains or windows, which will help to produce more electricity [4]. All outdated technologies that consume a lot of electricity must be replaced. This will save a significant amount of energy and money (up to 19%).

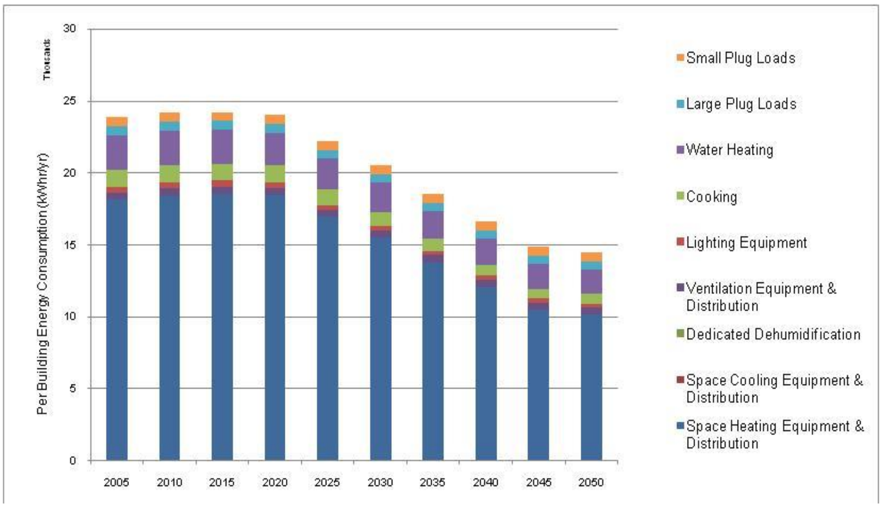


Figure-2: Energy Consumption per Building since 2005 and as projected until 2050

The focus of this paper will be on the issues that the city of Beirut is facing as a result of power outages and the majority of inhabitants' inability to pay the expense of running private generators [6]. Additional problems that power transmission network suffers also from overload [7,12]. All of these difficulties will be addressed by developing a NZEEB and stressing the usage of renewable technology, as well as altering people's attitudes around power. Because of its northern hemisphere position, Lebanon is one of the sunny nations that may use solar energy all year, with energy collected directly through photovoltaic cells per square meter per day ranging from 14 to 30 mega-joules. As a result, Lebanon is an ideal site for generating power and even heating water using solar energy.

There are parallels and distinctions between zero energy buildings ZEB and green buildings GB. "Green" structures frequently emphasize operating energy while ignoring the embodied carbon footprint of construction. 8 According to the IPCC, between 2024 and 2050, embodied carbon will account for half of all carbon emissions. Green Buildings aim to use resources more effectively and reduce a structure's negative environmental impact. Zero energy buildings meet one crucial goal: they export as much renewable energy as they use in a year, lowering greenhouse gas emissions. ZEB objectives must be specified and established since they are crucial to the design process. Zero energy buildings may or may not be deemed "green" in all categories, such as waste reduction, reuse of construction materials, and so on. However, zero energy, or net-zero buildings have a far smaller environmental effect throughout the life of the structure than other "green" buildings that require imported energy and/or fossil fuel to be livable and fulfill occupant needs.

As a similar case study, the main head quarter of Apple company is already powered entirely by renewable energy on a worldwide scale. As part of its commitment to combating climate change and creating a healthy environment, the firm announced today that its global facilities are powered entirely by sustainable energy. This milestone comprises retail outlets, offices, data centers, and co-located facilities in 43 nations, including the US, the UK, China, and India 4. Figure-3, depicts Apple Park, the company's new 175-acre ring-shaped net zero energy headquarters structure in Cupertino, California, is now the biggest LEED Platinum-certified office building in North America. The 2.8 million-square-foot main building is the world's largest naturally ventilated building, with no heating or air conditioning required for nine months of the year. It also houses a 17 MW rooftop solar array that will power 75 percent of the building during peak daytime hours, making it the largest solar on-site producer, with the remaining 25 percent coming from other renewable-energy sources such as Bloom Energy fuel cells, which have a capacity of 4 MW. It also returns renewable energy to the public grid during periods of low occupancy.5

Figure-3: Apple's Net-Zero Energy Headquarters Megaproject.

TYPES AND REASONS OF WASTING OF ENERGY IN BUILDINGS IN LEBANON

Buildings must be energy self-sufficient because they consume more energy than they produce. Furthermore, this business requires a considerable amount of grid electricity, which is often provided by polluting and unsustainable central fossilfueled power plants. Buildings receive less media attention than other energy-intensive activities like transportation. Consider the various advertisements that show this. People barely hear about construction in the media since a carpenter who builds houses is unlikely to have Tesla's marketing budget. In contrast, the home page of consumers' internet browsers always displays information about Tesla electric automobiles, acknowledging that a single medium-sized medical facility consumes more energy per year than 1,000 automobiles, and a residential building consumes more energy than all other modes of transportation combined as shown in Figure-3.

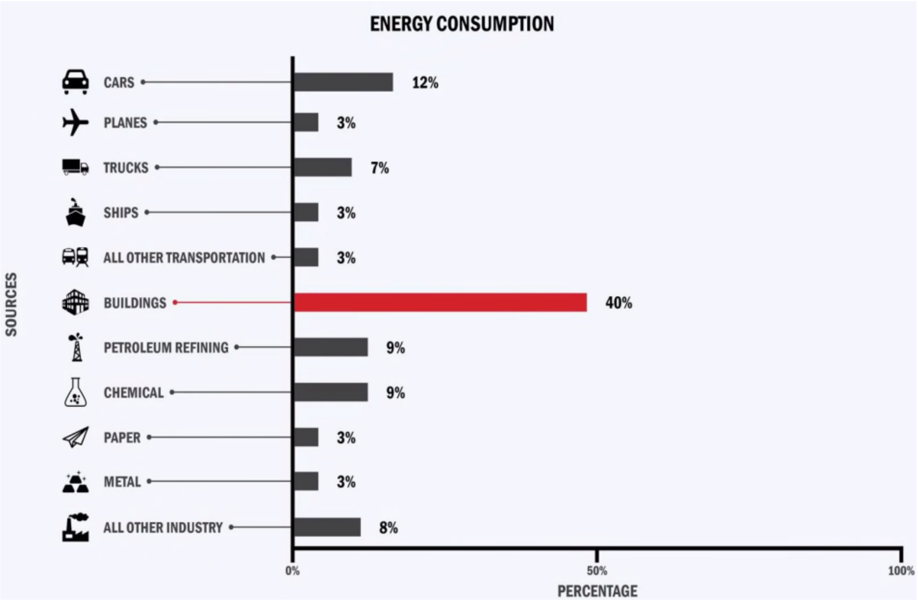


Figure-4: Buildings Energy Consumption Percentage versus Other Sources

Knowing that buildings are the greatest energy guzzler, it is estimated that around 35% of the energy supplied to the households is wasted. The typical sources for wastage include:

- Inadequate insulation for heating and cooling
- Faulty gadgets or appliances
- not using energy efficient models of appliances like refrigerators, AC
- Vampire appliances or electronics (consume power even when switched off or in standby mode)
- Use of incandescent or spot lights

While many households might not even be aware of this wastage, but at the global level, this wastage adds up to a significant percentage of the energy generated. The objective of this paper is to improve the economic, climate change, and environmental situations by bringing attention to how people's attitudes toward energy production and usage should change by designing a residential building in Beirut, Lebanon, with net zero energy consumption, which means that the total energy used by the building on an annual basis is equal to the amount of renewable energy generated on the site using renewable technologies like wind turbines and solar panels this will emit more than 80% less C02 ,will liberate people from expensive energy prices and if the government plans to implement more of these projects by 2030, Lebanon would generate more than 30% of its electricity from renewable sources. Within the context of climate change, Lebanon has specified its global contribution to limiting climate change by switching 30 percent of its energy production to renewable energy by 2030. This was released a few months ago as Lebanon's Nationally Determined Contribution (NDC), and thus Lebanon has committed to reaching 30 percent renewable energy by 2030; we are currently at around 7 percent only. Furthermore, the number of premature fatalities in MENA nations is predicted to reach 65,000 as a result of air pollution caused by fossil fuels. In 2018, the projected average number of premature deaths in Lebanon as a result of air pollution caused by fossil fuels was 2,700, resulting in a rate of 4 fatalities per 10,000 people, one of the highest rates in the area, along with Egypt's. “These frightening numbers reveal a hidden and unknown health crisis and sound the alarm about the high levels of air pollution in Lebanon, which put the health and life of every Lebanese citizen at risk,” Greenpeace MENA Program Manager Julian Jreissati said.3 Whereas the blackouts that used to last three to six hours and can now leave large areas with little more than one hour of state power per day, as well as the removal of fuel import subsidies and the increase in energy costs as a result of Lebanon's economic crisis

Design Steps For Transferring To ZNEEB Of Buildings In Lebanon

The block diagram of the scenario to transfer to ZNEEB is shown in Figure-5, where it depicts the data, inputs, and difficulties that the building was experiencing prior to installing the system, as well as the recommendations for achieving a net-zero energy building, with the majority of the energy produced on site coming from alternative sources.

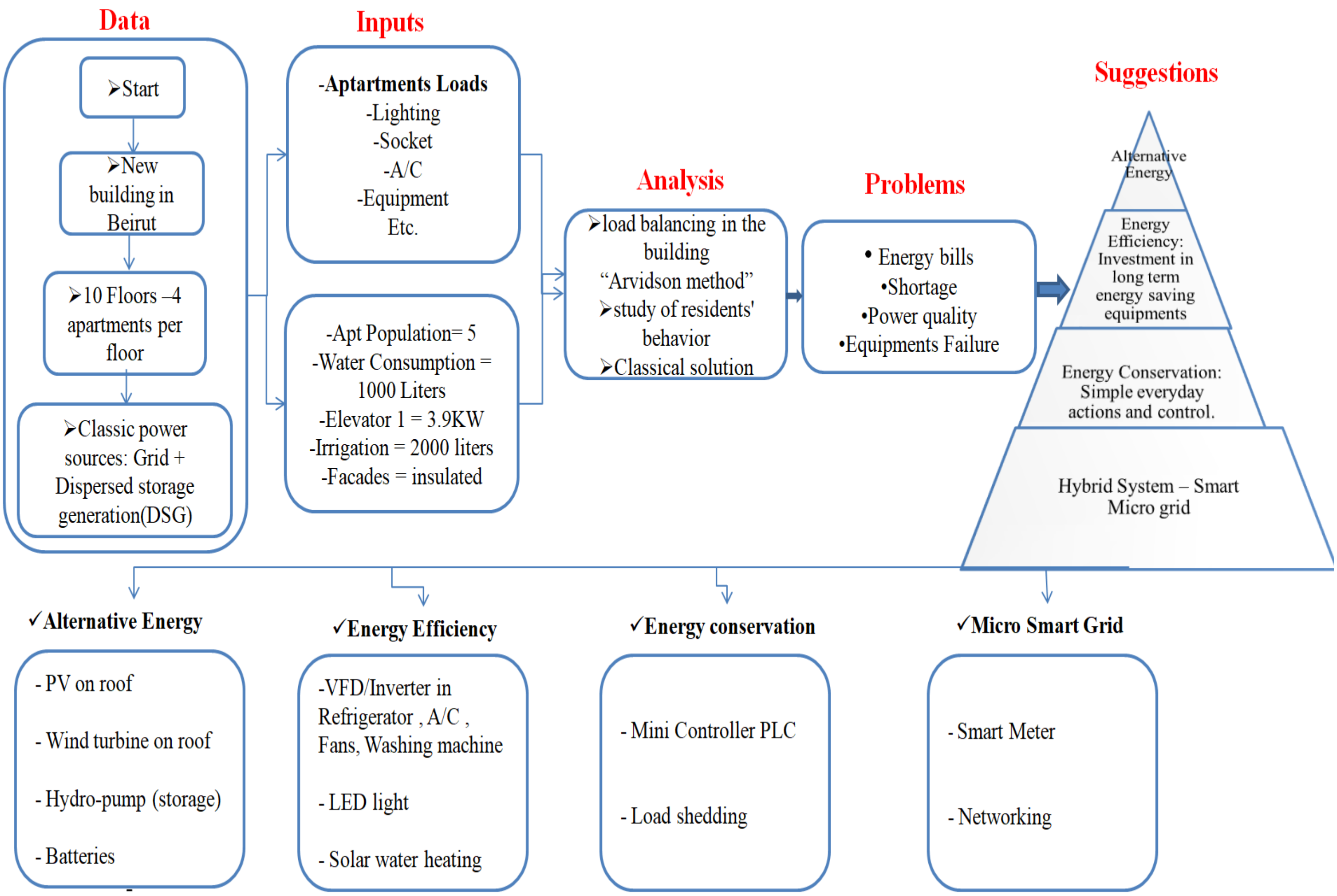


Figure-5: Block Diagram of Transferring to ZNEEB

To begin with, a smart micro grid it should be ready to distribute and import energy from the grid. Then, energy conversion is a vital aspect of the building, where automated energy management is crucial in a building with energy-efficient equipment. Finally, alternative sources should be installed.

Case Study: The system will be erected in a Five-story building in Beirut, with four units on each floor and two basements. Each apartment will be 185 square meters in size, with a 750 square meter roof space for solar panels. The whole load of the building, which will be calculated using "Arvidson Method" [15], will be used to calculate the system diversified demand load. The results will allow the system's connections and the amount of needed equipment to be determined. Moreover, an electrical design will be modeled using AutoCAD, and the system will be presented to show how it may be utilized in real-world circumstances. As behavior is crucial in system design and affects the entire system, the focus will be on how individuals must use power properly in order to meet demand. A simplified single-line diagram and a detailed description of the system's functionality will be included. Also, the renewable systems (mainly photovoltaic and wind turbine) will be used to compensate a partial demand and around 40 to 50%. Figure-6, presents the flow chart of the design steps of the hybrid solar and wind turbine system.

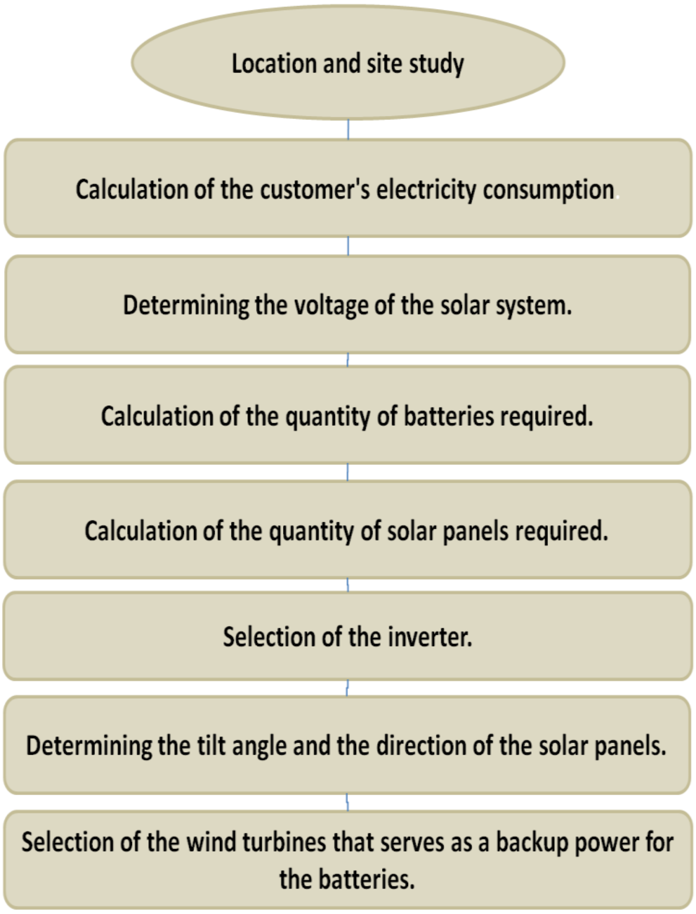


Figure-6: Flow Chart of Solar-Wind Hybrid System

Main Components Of ZNEEB System

The main components of the hybrid system are shown in the single line diagram of the Figure-7

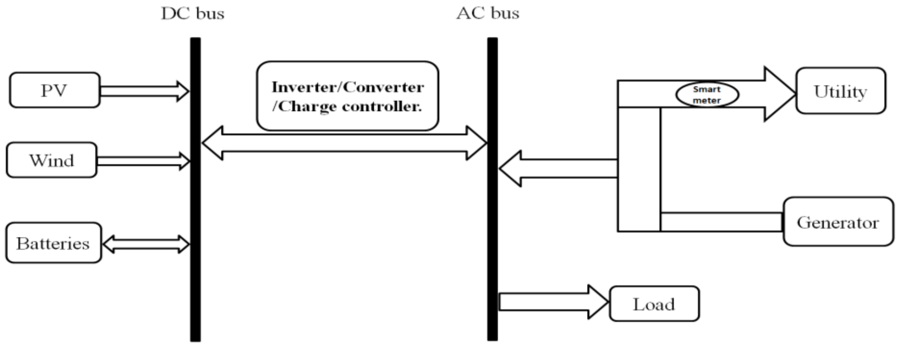


Figure-7: Single Line Diagram of Hybrid System

Photovoltaic Solar Panels Hiku7 Half cut Mono PERC Canadian Solar; these mono-crystalline panels as shown in figure-8 are commonly utilized in commercial and residential rooftop projects as they offer a high efficiency of up to 21.2 percent and a long lifespan. At standard test conditions (STC), the module power is up to 665 W, the optimal operating voltage (Vmp) and current (Imp) are 38.5V and 17.28 A, respectively, and the open circuit voltage is 45.6 and the short circuit current is 18.51 A. There are also three bypass diodes, and the maximum system voltage is 1500 V (IEC) or 1000 V (IEC).

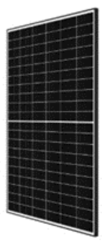


Figure-8: Canadian Solar Module

Wind Turbines As shown in figure-9 below, Tumurly's new Turbo5000 wind turbine with a charge controller and a dump load is a high-quality, incredibly durable, highly efficient and high-performance wind turbine. It has specifically built wings that generate nearly little noise with a maximum noise level of 30 dB, a rated power of 5000 Watt (at 12 m/s), a blade diameter of 2.813 m, a swept area of 6.15m2, a beginning wind speed of 3 m/s, and a charging wind speed of 4 m/s.

Figure-9: Tumuli Wind Turbine

Inverter Deye Hybrid Multi-Mode Inverter in Figure-10 below with Battery Backup. These inverters can power the apartments, charge batteries, and transfer excess electricity back onto the grid. In the event of a power outage, the machine will switch to battery power and function independently of the grid. A hybrid inverter with a rated AC output power of 16kw and a battery voltage range of 48V, 3 MPPT trackers and 2 strings per MPPT, an MPPT range of 150-425, a maximum number of parallel (PCS) of 16, and a particular strategy for lithium-ion batteries with self-adoption to BMS is available.

Figure-10: Deye 16 KW Hybrid Inverter

Batteries The 48V 300ah device in Figure-11 has 45x 3.2 V and 100 AH lithium iron phosphate LiFePo4 CMX48100S battery cells. The device includes a built-in battery management system for managing the 45 cells while also acting as a master to control additional parallel units. Units with several safety and communication features that ensure the high efficiency of the battery pack in parallel systems.

Figure-11: CoreMax Battery Unit

Net Meter: ABB 3 phase Net-metering will allow electricity to flow in both directions, from the grid to the building and from the building to the grid. The net result is the difference between the energy spent and the energy created. The device as shown in Figure-12 measures the amount of energy delivered to the grid and imported from it in kilowatt hours.

Figure-12: ABB Net Meter

Grid of Lebanon: The country's peak power consumption is roughly 3,500 MW [12], while total output does not surpass 700 MW, resulting in barely 5 hours of electricity each day. Domestic power is supplied at 220 volts and 50 hertz. A typical type of the power transmission lines is shown in Figure-13.

Figure-13: Grid of Lebanon

Generator: As shown in Figure-14, a 500 KVA Cummins is a six-cylinder diesel turbo generator. Fully enclosed sets with a very compact design [14], water cooled, so they can operate in hot weather—Super Quiet—fully enclosed sound proof canopy, remote start, and an automated transfer switch plug. This 550 KVA generator also offers full three phase output and can power a wide range of three phase appliances. Where single phase and three phase appliances may be connected to the same generator- ideal for both 240V and 415V appliances
• Stand By kVA: 500 • Prime kVA: 455 • Cylinders and build: 6 - INLINE
• Engine speed: 1500 RPM • Fuel Consumption at 74.2 L/H • 1200L Fuel Tank
• Noise Level: 72 dB (A) @ 7M • Oil Recommendation: 15W40
• Size 450cm x 165cm x 250cm • Weight 6750 kg 14.

Figure-14: Cummins 500 kVA Generator

Energy-Saving Appliances in the Residences: All selected appliances are having high efficiency and characteristics of latest generation of energy saving category as shown in Figure-15, the type and power consumption of appliances are as follows:

Refrigerator: LG GNB-500w which is an inverter refrigerator can be used with a capacity of 427L and dimensions of 700 (width) x 1680 (height) x 700 (depth). Its main features are multi-airflow and a frost-free cooling system. The important feature of this machine is its low energy consumption. This type of machine works by controlling the frequency of the input current. It will let the compressor operate at a variable speed, which means consuming a small amount of energy.

***Air Conditioner**:* The air conditioner it will be used to cool the rooms. There are two types of A/C: the regular A/C and the inverter A/C. The A/C inverter starts running at a low speed, which will consume less energy before increasing to its maximum energy. In this type, the compressor has many speeds to run on, since the regular type has only one speed. Figure-15 shows the Gree GWH09AGA is an inverter A/C with a capacity of 9000btu rated power 1000W. His cooling area will cover up to 25 m "square" and in the heating system it will cover an area up to 50 m "square".

Lightning: A LED lamp is one of the lighting types. It has more features than other types (with energy saving more than 30%). It is more efficient than incandescent and fluorescent types. It has a longer life than others and its cost is better and have efficacity 100lumen/1watt.

Television: Selecting LED TV-43" that requires small power around 100W instead of 400W for plasma type.

Washing machine: With a new inverter that enables it to be both powerful and efficient at the same time, figure-15 shows the Samsung WA70N4261SS Top Loading with Digital Inverter Motor 7.0Kg is a 5-star washing machine that is perfect for a family of five and uses up to 40% less energy. It requires 2000watt and 300W without heating.

Iron: With a100% efficiency, figure-15 shows the Rowenta Autosteam steam iron is the perfect blend of flawless ironing results and energy savings it requires 2000W as maximum power but using steam it make energy saving of around 25%.

Electric Water Heater 150 Liters: it requires 1500W for resistance element instead 2000W.

Figure-15: Energy Efficient Home Appliances

Load And Energy Calculation Based On Classical Applinaces

The total diversified demand is calculated through the following tables where Table-1, shows the connected load per appliance in a typical residential house named H or an apartment of 185 sqm. Arvidson derived a method of assessing loads in residential areas in which maximum diversified demand (MDD) decreases as the number of consumers increases. And by employing the varied demand strategy, which takes into account the variety of identical loads as well as the non-coincidence of the peaks of different types of loads. Hence, according to Arvidson method for residential buildings, the average maximum diversified demand is given by,

$$\boldsymbol{MDD}\ (average, maximum) = \boldsymbol{\Sigma MDDi} * \boldsymbol{m} * \boldsymbol{Si} * \boldsymbol{fi}(\boldsymbol{t}) \qquad (1)$$

MDD (average, maximum): is the maximum average diversified demand for all appliances for all consumers.
MDDi: is the maximum diversified demand per customer of that type.
m: refers to the total number of apartments under consideration. In this case *m* = 20
Si: refers to the Appliance saturation rate.
fi (t): is the hourly variation factor of appliance. This factor equal to one for the average maximum demand.

Table-1: The Connected Loads of Appliances in the House Type H

Type of loads of House H	Classical Appliances
1- 3xAir-condition – 3x9000BTU	3000W
2- Lighting and sockets	1500W
3- Electric water heater	1500W
4- Washing machine	2000W
5- Refrigerator	500 W
6- TV-43" LED	400W
7- Iron	2000W

And Table-2, and 3 are showing the maximum average diversified demand according to the number of customers for both classical and energy saver appliances.

Table-2: Maximum Average Diversified Demand According to the Number of Customer Using Classical Appliances

Loads	1xH	5xH	10xH	20xH	40xH	80xH	120xH	200xH	300xH
A/C	3	2.25	1.69	1.27	0.95	0.71	0.53	0.40	0.30
LT+SK	1.5	1.13	0.84	0.63	0.47	0.36	0.27	0.20	0.15

EWH	1.5	1.13	0.84	0.63	0.47	0.36	0.27	0.20	0.15
WM	2	1.50	1.13	0.84	0.63	0.47	0.36	0.27	0.20
REF	0.5	0.38	0.28	0.21	0.16	0.12	0.09	0.07	0.05
TV	0.4	0.30	0.23	0.17	0.13	0.09	0.07	0.05	0.04
IRON	2	1.50	1.13	0.84	0.63	0.47	0.36	0.27	0.20

Table-3, is showing the saturation rate of appliances according to some statistical studies in Beirut area.

Table-3: Percentage of Saturation Rate of Appliances According to the Number of Customer

Loads	1xH	5xH	10xH	20xH	40xH	80xH	120xH	200xH	300xH
A/C	100%	90%	90%	85%	80%	70%	70%	60%	50%
LT+SK	100%	100%	100%	100%	100%	100%	100%	100%	100%
EWH	100%	100%	100%	100%	98%	97%	95%	92%	90%
WM	100%	100%	100%	95%	92%	90%	88%	85%	80%
REF	100%	100%	100%	98%	96%	94%	92%	90%	88%
TV	100%	100%	100%	100%	100%	98%	96%	94%	92%
IRON	100%	100%	99%	98%	96%	94%	92%	91%	90%

Table-4, is concerned with the Hourly variation factor Fi(t) that corresponds to the coincidence and non-coincidence of different appliance in a given time of the day. Also, this table gives the calculation of the hourly consumed energy hence the daily energy.

Table-4: Hourly Variation Factors fi(t) of the Appliances with the Calculation of the Hourly consumed Energy

Loads	12am-3am	3am-6am	6am-9am	9am-12pm	12pm-3pm	3pm-6pm	6pm-9pm	9pm-12am
A/C	0.4	0.6	0.8	1	0.9	1	0.7	0.6
LT + SK	0.3	0.3	0.2	0.1	0.4	0.6	1	0.5
EWH	0.2	0.8	0.6	0.4	0.2	0.2	0.4	0.5
WM	0.1	0.7	0.6	0.6	0.4	0.3	0.2	0.2
REF	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
TV	0.3	0.3	0.3	0.3	0.6	0.8	0.8	0.4
IRON	0.1	0.6	0.4	0.4	0.4	0.2	0.4	0.2

Hence, the Table-5, is giving the energy for each period then the total daily energy.

Table-5: Daily Energy after Applying the Hourly Variation Factor for Classical Appliances

Time / **Loads**	**12am-3am**	**3am-6am**	**6am-9am**	**9am-12pm**	**12pm-3pm**	**3pm-6pm**	**6pm-9pm**	**9pm-12am**
A/C	0.304	0.588	0.784	0.98	0.882	0.98	0.686	0.588
LT + SK	0.141	0.183	0.122	0.061	0.244	0.366	0.61	0.305
EWH	0.094	0.48	0.36	0.24	0.12	0.12	0.24	0.3
WM	0.058	0.525	0.45	0.45	0.3	0.225	0.15	0.15
REF	0.135	0.18	0.18	0.18	0.18	0.18	0.18	0.18
TV	0.039	0.048	0.048	0.048	0.096	0.128	0.128	0.064
IRON	0.061	0.474	0.316	0.316	0.316	0.158	0.316	0.158
Total kw	**0.832**	**2.478**	**2.26**	**2.275**	**2.138**	**2.157**	**2.31**	**1.745**
Period 3h	3	3	3	3	3	3	3	3

Energy KWh	2.496	7.434	6.78	6.825	6.414	6.471	6.93	5.235
Daily Energy/Ap	49							

Based on tables 3 and 4, and for Fi(t) = 1

The MDD for one apartment using classical appliances is found = 3.2KW
The MDD for 20 apartments = 64KW
The Maximum daily energy of classical appliances of 20 apartments = 64x24=1536KWh

LOAD AND ENERGY CALCULATION BASED ON ENERGY SAVING APPLIANCES

Table-1, shows the connected load per appliance based on the energy saving appliances compared to classical appliances

Table-6: The Connected Loads of Appliances in the House Type H

Type of loads of House H	Classical Appliances	Energy Saving Appliances
1- 3xAir-condition – 3x9000BTU	3000W	2100W
2- Lighting and sockets	1500W	1000W
3- Electric water heater	1500W	1000W
4- Washing machine	2000W	1500W
5- Refrigerator	500 W	200 W
6- TV-43" LED	400W	100W
7- Iron	2000W	1600W

And Table-2, and 3 are showing the maximum average diversified demand according to the number of customers for both classical and energy saver appliances.

Table-7: Maximum Average Diversified Demand According to the Number of Customer Using Energy Saver Appliances

Loads	1xH	5xH	10xH	20xH	40xH	80xH	120xH	200xH	300xH
A/C	2.1	1.988	1.911	1.834	1.715	1.526	1.337	1.148	0.952
LT+SK	1	0.966	0.931	0.875	0.84	0.791	0.756	0.735	0.7
EWH	1	1.022	0.959	0.854	0.763	0.721	0.672	0.63	0.588
WM	1.5	1.35	1.29	1.14	1.05	0.96	0.87	0.78	0.75
REF	0.2	0.2	0.2	0.2	0.2	0.172	0.16	0.16	0.16
TV	0.1	0.1	0.075	0.05	0.025	0.025	0.025	0.025	0.025
IRON	1.6	1.44	1.376	1.216	1.12	1.024	0.928	0.832	0.8

Based on tables 2 to 5, the daily consumed energy between classical and energy saver appliances is calculated as follows:

- The MDD for one apartment using energy saving appliances = 2.2KW
- The MDD for 20 apartments = 2.2 x 20 = 44KW
- The Maximum daily energy of saver appliances of 20 apartments = 44x24=1056KWh

Comparing with classical appliances, an energy saving of 5**00**KWh (or around 35%) due the use of modern appliances instead of the classical ones.

Table-8: Daily Energy after Applying the Hourly Variation Factor for Energy Saving Appliances

Time / Loads	12am-3am	3am-6am	6am-9am	9am-12pm	12pm-3pm	3pm-6pm	6pm-9pm	9pm-12am
A/C	0.212	0.318	0.424	0.53	0.477	0.53	0.371	0.318
LT + SK	0.096	0.096	0.064	0.032	0.128	0.192	0.32	0.16
EWH	0.062	0.248	0.186	0.124	0.062	0.062	0.124	0.155
WM	0.044	0.308	0.264	0.264	0.176	0.132	0.088	0.088
REF	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054
TV	0.009	0.009	0.009	0.009	0.018	0.024	0.024	0.012
IRON	0.049	0.294	0.196	0.196	0.196	0.098	0.196	0.098
Total kw	**0.526**	**1.327**	**1.197**	**1.209**	**1.111**	**1.092**	**1.177**	**0.885**

Period 3h	3	3	3	3	3	3	3	3
Energy KWh	**1.578**	**3.981**	**3.591**	**3.627**	**3.333**	**3.276**	**3.531**	**2.655**
Daily Energy/Ap	**25.572**							

ENERGY SAVING BASED ON ENERGY CONSERVATION

The energy conservation is based on the management and load shedding by using a PLC to control the loads according to certain priorities and according to a timing schedule. Let's assume that the Air-Condition load has the lowest priority and that it can be disconnected through PLC to make load peak shaving. The energy conservation may requires to use double glazing windows, double walls with insulation to save the thermal cooling or heating inside the house or apartment. The energy conservation may lead to a reduction of 15 to 20% from 2400KWh. The net consumed energy after conservation is around 2000Kwh.

SIZING OF PV SYSTEM

The sizing of PV system is based on the global irradiation on Beirut (Zone of Tallet Khayat) that gives around 5.9Kwh/m2/day as per Figure-16 and Table-9

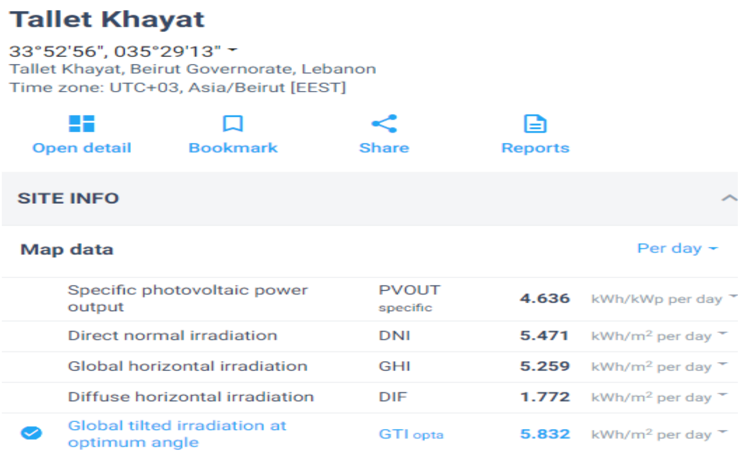


Figure-16: The Average Solar Irradiation per Day via Global Solar Atlas

Table-9: The Average Monthly Solar Irradiation in Beirut

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Solar Irradiation KWh/m2/day	3.44	3.5	4.75	6.5	7.41	8.03	8.5	7.5	6.33	5.6	4.8	3.3

The roof area 750sqm can accommodate 154 PV-665Wp each panel 3.1sqm and that gives 600KWh for average irradiation 5.832KWh/m2/day at Beirut area **(2)**

$$PV\ modules\ KWp = \frac{Total\ daily\ watt\ hour}{average\ sun\ peak\ hours} = \frac{600KWh}{5.832h} = 100kw$$

$$Number\ of\ PV = \frac{100kw}{665w} = 154\ modules \quad (3)$$

Batteries Sizing: To size the capacity of batteries, it is assumed that batteries will feed the load when grid or generators are disconnected or off. The total demand from 6:00pm till 6:00am is calculated from Table…and equals to 1100KWh. The batteries to be used at night equals to the total demand at night from 6:pm till 6:00pm and to feed only the demand of (Lighting + Sockets + Refrigerator + TV) where the daily energy consumption of these loads is 268KWh. Adding to this capacity, 200KWh as provisional capacity for additional storage to be used at day when there is shortage in PV, or Grid or Genset.

$$Ah/day = \frac{Total\ consumption(kwh)"}{Battery\ Bank\ voltage} = \frac{462 * 1000}{48} = 9{,}625Ah/day \quad (4)$$

$$Number\ of\ parallel\ batttery = \frac{Amp - hour\ adjusted}{Current\ of\ the\ battery} = \frac{9{,}625}{300} = 32 \quad 05)$$

$$Number\ of\ series\ battery = \frac{battery\ bank\ voltage(inverter)}{voltage\ of\ the\ battery} = \frac{48}{48} = 1 \quad \textbf{(6)}$$

The battery can be charged through PV, grid or generator or wind according to the availability of sources and according to a programmed time schedule.

Inverter Selection

As the assigned demand is around 100KW, then the best selection is 6* 16KW inverters those will be connected in parallel.

Table-10: The Specifications of the Selected Inverters

Type	Hybrid
Power Rating	96 kW- 6x16KW per inverter
System voltage	48 V- 48 V per inverter “parallel”
Charging Current	1740 A – 290 A per inverter
Surge power	125kW- 25KW per inverter
Frequency	50HZ
Maximum DC input Voltage	500 VDC
Number of MPPT Trackers	3 / 2 strings per MPPT
MPPT Range (V)	150-425

Parallel connections (Figure-17) between inverters are also used to offer system redundancy and high dependability.

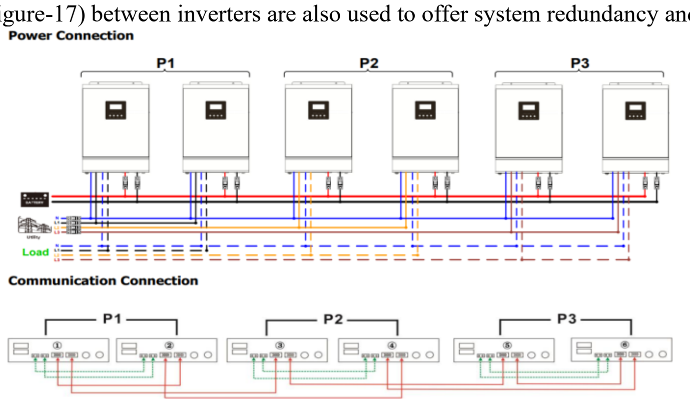


Figure-17: Parallel Inverters Power Connection

SIZING OF THE WIND TURBINE

The windiest season of the year, which lasts for 3.8 months from December 11 to April 6, is when solar panels lose some of their effectiveness, the average daily wind speed in December to February has been around 11 km/h, that’s the equivalent to about 7 mph, or 6 knots. (Figure-18)

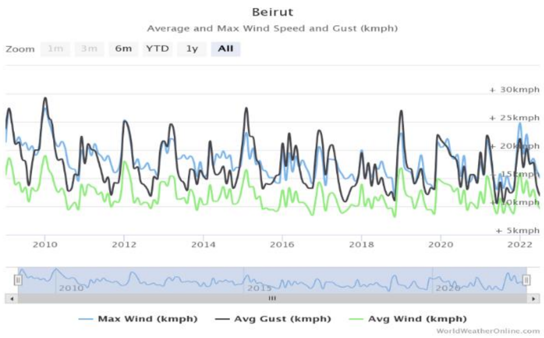


Figure-18: Average and Maximum Wind Speeds and Gusts over the Years

In recent years the maximum sustained wind speed has reached 74 km/h, that’s the equivalent of around 46 mph, or 40 knots while in March and April the average daily wind speed increase to 12Km/h.**Error! Reference source not found.** thus, 4x 5000 watt each wind turbines will be chosen as a backup for the solar panels and to charge the batteries.

The maximum rated power of the wind turbine is approximately 6000 watt (at 15 m/s) wind speed with a blade diameter 2.813 m as shown in Table-… turbine specification.

In the first four months of the year, the average daily wind speed is 7 meters per second, resulting in a total daily power output of approximately 107 kilowatt-hours from the four wind turbines. In contrast, during the remaining months, the average wind speed is slower, at 4 meters per second, and the turbines produce around 19 kilowatt-hours of electricity per day. So, the total daily average energy is around 50Kwh. This energy is directed to charge the batteries at night. (Table-11)

Table-11: Wind Turbine Performance Test Result

Turbine Specification			
Wind Turbine Model	Turbo5000 Prestige	Rated Power @12m/s	5000W
Serial Number	TW202204	Max. Power @15m/s	6005W
Type	Horizontal	Rotor Diameter	2813 mm
Generator Type	Permanent Magnet	Generator Output	3 phases
Test Statistics			
Execution Date	10.05.2022		
The Turbine Performance Parameters measured			

Wind Speed (m/s)	Rotor RPM	Power (W)
1	0	0
2	104	112-195
3	135	234-365
4	165	435-597
5	197	635-789
6	228	1145-1225
7	265	1579-1785
8	301	1811-1825
9	360	2224-2322
10	402	3377-3901
11	456	4370-4780
12	503	4950-5125

The power of the wind is given by the following equation:

Power =1/2*power coefficient*Air density*Area*(Wind Speed)^3 (7)

The Complete Design of The Hybrid System of the NZEEB

The design drawing (Figure-19) and the summary with criteria are as listed below:

Solar Panel System:

- 154 modules are installed on a 750-meter square roof, with an area of 3.1 meter square per module.
- The modules are arranged in 24 strings, with 8 modules per string.
- The modules are mounted to the south with a tilt angle of 30 degrees.
- The electrical system is depicted in Figure 4.6, which shows the inverter and DC-DC charge controller connections.

Inverter Configuration:

- The inverter MPPT (Maximum Power Point Tracking) range is 150-425 V.
- Each inverter is connected to 2 parallel strings, with 8 PV panels linked in series due to the open circuit voltage of the panel (43 V).
- Two MPPTs are used in each inverter, and six inverters are linked in parallel.
- Each pair of inverters is connected to a phase, allowing them to power three-phase components.

Wind Turbine Configuration:

- Four wind turbines are directly connected to a rack of 32 parallel units through a DC-DC charge controller.
- A dump load is attached to each controller to redirect any extra energy once the batteries are fully charged.

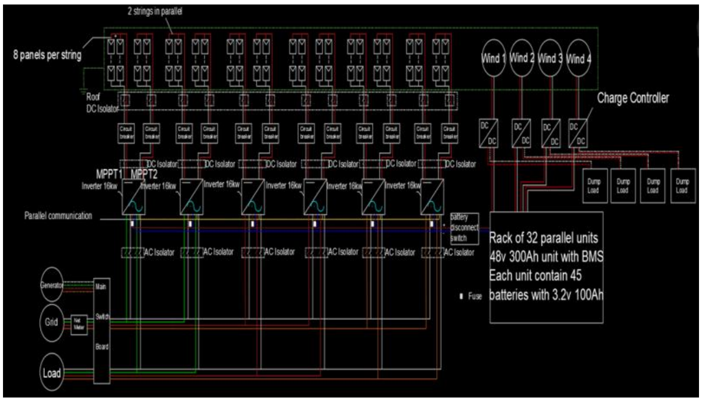


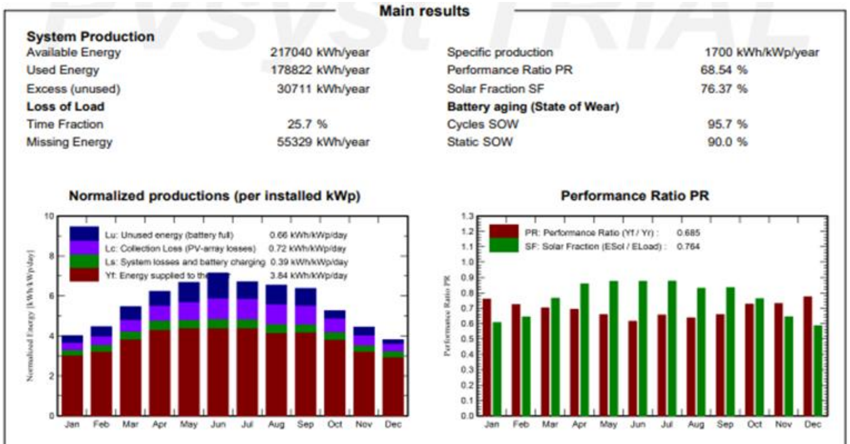
Figure-19: AutoCAD Electrical Drawing Design for the Hybrid System

RESULTS AND SIMULATION

The Table-12 shows the final results of the global produced energy by the renewable sources and the energy consumed by the load hence the balance between sources and load also Figure-20, gives the simulation of PV system in Beirut area.

Table-12: Global Energy of Sources and Loads

	Energy / Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sources	Solar Energy MWh	10.1	10.8	13.9	19.5	22.4	25.8	25.5	24.2	20.2	17.3	13.5	10.3
	efficiency	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
	Total Solar	8.585	9.18	11.815	16.575	19.04	21.93	21.675	20.57	17.17	14.705	11.475	8.755
	Wind Energy MWh	4.2	4.2	0.7	0.6	0.3	0.2	0.2	0.2	0.6	0.7	4.2	4.2
	efficiency	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
	Total Wind	3.57	3.57	0.595	0.51	0.255	0.17	0.17	0.17	0.51	0.595	3.57	3.57
Load	Load Energy MWh	12.96	12.96	13.68	15.84	18	18.72	21.6	22.32	18	15.84	15.12	13.68
Balance	Sources - Load	-0.81	-0.21	-1.27	1.25	1.30	3.38	0.25	-1.58	-0.32	-0.54	-0.07	-1.36
	Net Zero Energy	0.01											
Control	From Grid/To Grid	From	From	From	To	To	To	To	From	From	From	To	From



Balances and main results

	GlobHor kWh/m²	GlobEff kWh/m²	E_Avail kWh	EUnused kWh	E_Miss kWh	E_User kWh	E_Load kWh	SolFrac ratio
January	83.3	118.9	13725	1311	7814	12072	19887	0.607
February	94.0	119.3	13754	1676	6408	11554	17962	0.643
March	143.6	161.5	18420	2538	4678	15209	19887	0.765
April	176.4	177.6	20025	2663	2711	16534	19245	0.859
May	215.7	196.3	21904	3842	2485	17402	19887	0.875
June	235.3	203.0	22403	4805	2391	16855	19245	0.876
July	223.1	196.8	21477	3316	2459	17428	19887	0.876
August	200.1	192.5	20946	3712	3386	16501	19887	0.830
September	166.2	182.0	19931	3221	3185	16060	19245	0.834
October	127.1	155.4	17254	1441	4741	15146	19887	0.762
November	91.4	127.2	14303	1473	6848	12398	19245	0.644
December	77.3	112.8	12896	714	8223	11664	19887	0.587
Year	1833.6	1943.2	217040	30711	55329	178822	234151	0.764

Figure-20: Simulation of PVsys

System Output:

- The annual PV system production is estimated to be 181.45 MWh/year.
- The annual wind turbine production is estimated to be 17.25 MWh/year
- The total system production annually is 201.84 MWh/year.

Building Consumption:

- The annual building consumption from alternative sources is estimated to be 198.73MWh/year.
- The annual grid consumption is estimated to be 6.08 MWh/year.
- The extra energy available is 6.09 MWh/year, which can be used to send back to the grid.

Net Zero Energy:

- To achieve net zero energy, the system needs to send and consume equal amounts of energy to the grid.
- In this case, the net energy zero is achieved by sending back 6.08 MWh/year and consuming the same amount from the grid.

Software Results:

- PVSystem results show that the available energy from the system is 217 MWh, with unused energy of 30.7 MWh, missing energy of 55 MWh, energy supplied to the user of 178 MWh, and user's energy need of 23M KWh. (approximately same results on Table-12)

Analysis of Results:

- The hybrid energy system has the potential to achieve net zero energy by sending excess energy back to the grid.
- The system's output is sufficient to meet the building's energy needs, with a surplus of 6.09 MWh/year.
- The use of high-quality products and multiple energy sources makes the system sustainable and cost-effective.

Overall, this analysis demonstrates the feasibility of a hybrid energy system for a large building in Lebanon, with a potential to achieve net zero energy and reduce energy costs.

CONCLUSION

The study shows that achieving net zero energy systems is possible in any country, regardless of its level of development. Although Lebanon is currently experiencing power shortages, the findings in this paper can still be useful and relevant. In developed countries, however, the grid can be used continuously, allowing for maximum efficiency and reducing the need for expensive components like solar panels and batteries. These components are crucial in the production process, but their high cost can be mitigated by optimizing their use. The project's results address the challenges posed by fluctuations in demand and supply, ensuring a reliable output for users. While further research is needed to improve the system's performance, the study highlights the importance of resident behavior in energy consumption. Excessive energy usage can have a significant impact on the entire system and energy storage needs, emphasizing the need for sustainable practices.

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