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Energy Applications in Green Building to Fulfil the Goals of Sustainable Development: The Case of Jordan

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ABSTRACT

The aim of this study is to explore measures and options for utilizing the most abundant energy source in Jordan, which is solar energy. The study looks into the actions that Jordan can adopt that will give the stakeholders a higher return on investment. It emphasizes the importance of using such facilities in the applications of green building, which is growing in the country. The methodology is descriptive and analytical, using official data to support these options, such as the price of labor, land, oil, as well as equipment that is used in the building of energy infrastructure. The importance of the options stems from the fact that they minimize the energy gaps to form a thorough policy for any organization or ministry in the government. The study showed that the payback period for the installation of both solar water collectors and solar cell panels is approximately 2 and 2.5 years, respectively. This study has also arrived at several actions and recommendations to shrink the energy gap. The disparity between subsidies for low-energy users and high-energy users has slowed the development of alternative energies. Other kinds of renewable energy, such as hydroelectric and wind power, are underutilized in Jordan, although they can be utilized to reduce the volatility of oil and gas prices.

Keywords: Energy in Jordan, Green Building, Energy Policy, Sustainable Development
JEL Classifications: Q42; Q43; Q48; K32; L78; N75

1. INTRODUCTION

Energy demand in Jordan has been steadily rising in recent years; while this can be attributed to many reasons, the result has been an increase in public spending on energy production. This growth in public spending has placed an additional encumbrance on the economy in Jordan. Thus, we reached a level of unsustainable growth that intimidates the survivability of future generations that are living in Jordan. This means that the current gap in the energy being produced domestically and the total energy used disadvantages future generations. This disadvantage is in the form of depleted resources, debt, and future commitments that will have to be honored. The three spheres of sustainability: economic, social, and environmental, have come to form the interaction of human beings with their surrounding. In fact, humans have come to rely almost entirely on these three pillars to gauge how well human populations are reconciling the needs of all three with each other to guarantee a balanced system of growth and prosperity. The way any given society drives each component's interaction with the other two determines the characteristics of its growth in it. The most important pillar of sustainability is the environmental one. It is the most critical component, as it is the basis of the building of the other two pillars. Comparing the environmental component to the economic sphere will reveal that putting a value on economic capita and accurately exchanging it across borders in the form of currency, goods, and services; the same cannot be done with environmental capita. Valuing environmental capita would require creating a system with set exchange rates; this is very difficult because identical environmental resources have different values in different countries. Weak sustainability, however, remains a flawed concept and one that cannot provide a sound foundation for sustainable growth. To understand why this is so, it is necessary to consider how flawed the reasoning behind it is. Weak sustainability trades present-day natural resources at their current value without taking into account future values that might be calculated differently. This difference in calculated value is partially due to new uses and methods of extraction future advances in technology will come up. Furthermore, some natural capital may occupy such a unique niche in maintaining the equilibrium in an ecological system that they cannot be substituted or traded with any other capital (Ekins, 2011). The shortcomings of sustainability have led to the creation of strong sustainability.

Clearly, building a system of regulations to support sustainable growth must use strong sustainability as the foundation. In this sustainable system, it is necessary to define what capital will be recognized and exchanged. A typical power station using fossil fuels will generate electricity through electromagnetic induction. In essence, this is the conversion of mechanical power into electrical power via rotating turbines. A simplified version of the process is as follows: first, fuel is burned through combustion to heat water and turn it into steam. Next, steam is routed through pipes to turn turbine blades in a rotational motion that will cause the electromagnet in the core of the turbine to create a magnetic flux. This magnetic flux will induce a flow of electrons which in turn becomes current. The speed of the rotating turbines is positively proportional to the current; thus, the faster the turning turbines will produce more current. After that, the steam will flow to a cooling tower that will allow the steam to condense back into liquid form, after which it will either be discharged into a local body of water, such as a river or lake, or it can be recycled to be reheated and turned into steam to power the turbines for more cycles in more modern and efficient power systems. Fossil fuel is the most common mode of producing electricity in the forms of natural gas, coal, and oil. Take the U.S. as an example; the figure below details the interaction of energy consumption and sources by sector. Adding up the figures from the graph, it was found that coal made up 41% of electrical generation. Natural gas contributed 24%, and petroleum added 1%. In total, 66% of electricity generated in the U.S. in 2012 came from fossil fuels. If the study considers how efficiently these fossil fuels are used, it must look at the methods used to generate electrical power.

2. LITERATURE REVIEW

Several studies have been done on the renewable energy efficiency in green building and how it is used to gain the goal of sustainable development, which also include economic development and the effect of energy security on policymakers worldwide (Singhal, 2019; Sandri et al., 2020; Yu et al., 2011; Kumari and Paul 2013; Edge 2019; Erickson, 2020). The single largest consumer of electrical power in the Middle East, North America, and Europe is residential use, followed closely by the industrial sector. Though this is not always the case, a few years ago, the industrial sector had the lion's share of the annual energy bill. It would, therefore, make sense for an energy policy to tackle both sectors first, starting with the residential (Momani, 2013). To counter this increase, one must look to local and regional governments to place regulations and incentives for the adoption of cleaner production methods and environmentally aware consumer behavior, as shown in Figure 1. Heating, Ventilation, and Air Cooling (HVAC) is the major user in the residential sector. "The annual peak load in Jordan occurs in summer, particularly between July and September every year, which is due to the profuse use of air-conditioning and ventilation systems as a result of the dry climate and high temperatures" (Momani, 2013).

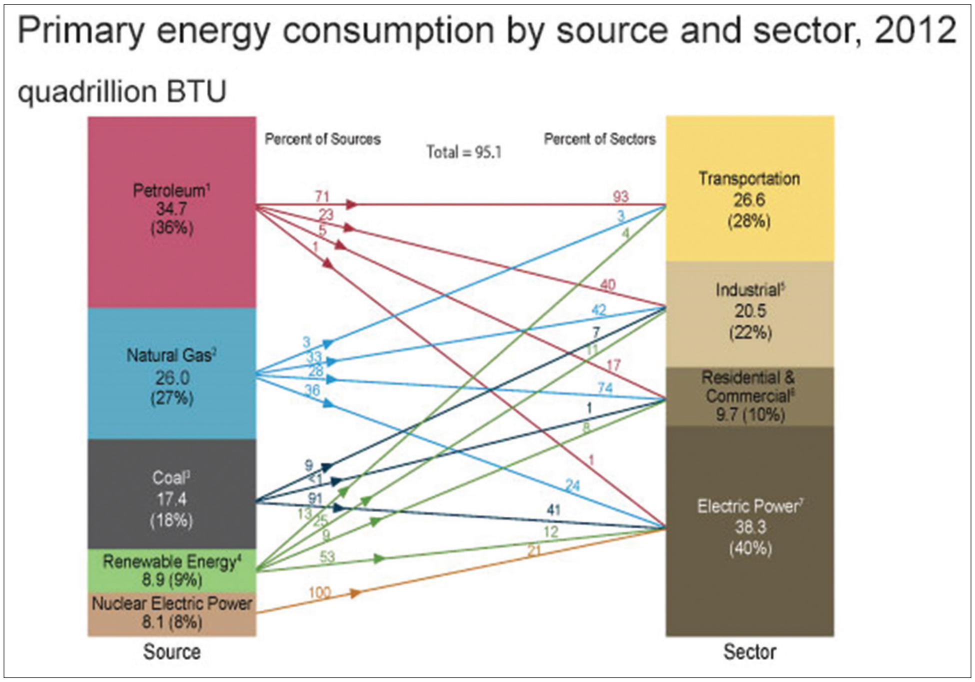
In this study, a much deeper look is taken at how to implement green building design initiatives. The importance of how much residential buildings contribute to energy consumption was discussed (Omer, 2009). In the study, the author suggested some measures to alleviate the pressure placed on the energy grid by residential buildings. With the end goal of having completely independent houses with a non-existent energy footprint, some scientists have been looking into the concept of zero- and low-energy housing. Further advances were made in the concept of sustainability (Ferrante, 2012). To unify this ideal standard, the study defines zero and least energy buildings as "A 'nearly zero energy building' is a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby" (Ferrante, 2012).

Another source of significant energy drain in residential buildings is the actual construction of the buildings prior to being occupied. Construction activities require lots of energy, as pointed out in the study of Minzhen (2012). Others have gone further in sustainable thought by emphasizing integrating a building with its surroundings and the mobility needs of its occupants, as proposed in "Integrating Building Energy Efficiency with Land Use and Transportation Planning in Jinan, China" (Shirgaokar et al., 2013). When integrating the different aspects of any construction project, there will always be competition between environmental, social, civil, and economic factors. How the competition plays out will always be dependent on the end user's priorities and local governmental input. The world of sustainable energy and development, however, is not uniform. There exists a massive gap between developed countries and developing countries. This gap was briefly explored in the study of Iwaro and Mwasha (2010). These findings prove that architectural innovation, in the case of compactness, can provide further advances in building efficiency that materials cannot.

When it comes to creating a positive environment for the application of energy-saving methods and pushing the sustainable energy agenda in industry, two methods come to mind, government regulations and incentives. With regulation, the stakeholders have no choice but to follow government guidelines or face penalties, the risk of losing work permits, and other punishments. With incentives, on the other hand, an atmosphere for innovation is created, where collaboration can take place between the industries, academia, business owners, and the end user. The incentives approach was supported in "Using Economic Incentives to Reduce Electricity Consumption: A Field Experiment in Matsuyama, Japan," which is presented by (Mizobuchi and Takeuchi, 2012).

The trouble with these systems is that they are all based on the needs and the conditions of their respective countries. Applying

Figure 1: Detailed interaction of energy consumption and sources for the US



them blindly to Jordan would not be correct or efficient. Thus the need arises for a unique system that applies to Jordan, which has been invented for the most part, by the Jordanian Green Building Council (JGBC). In developing their system, the JGBC first looked at the notion of green buildings in Jordan. This provides a look at what Jordan's topography is like. However, the study fails to list critically more important numbers. For example, the study lists the highest and lowest temperatures, but a much clearer picture of the temperature in an area would be mean summer and mean winter temperatures since they would give a better indication of the expected temperature. The study also left out any mention of sun days, considered when deciding the suitability of solar energy uses for heating and electrical power generation. In addition, no data is given for expected rainfall needed to justify the need for water conservation measures and ranking them or assigning points in relation to other green building-rated activities.

3. METHODOLOGY

The first measure addressed in this study is installing solar water heaters. These collectors are connected to a cold-water storage supply and, subsequently, to a highly insulated hot water storage tank. If the system is placed at a lower elevation than the residence, a pump will be needed to deliver the hot water and provide better water pressure. Finally, an optional copper heating element can be installed in the storage tank of hot water to boost the temperature on overcast days when there is not enough sunlight to reach the system.

These systems can be mounted on flat open roofs, the dominant form of roofing in Jordan, on pitched roofs, or in open areas adjacent, or buildings that provide enough sunlight to fall on the absorbers. Once a suitable area has been found and a system installed, other options can be added to maximize the efficiency of the solar collector system. Using thermal sensors linked to a home automation system, a homeowner can monitor the temperature of the water held in the storage tank and decide if it is suitable for use. If the temperature is too low, then a previously installed copper heating element would be turned on to provide an extra source of energy.

This study investigated the feasibility of these systems. The cost of a system relies on the number and type of collectors used, the storage tanks, and the optional addition of a copper heating element if a thermal sensor is used to monitor the temperature of water in the storage tank of hot water.

To simplify the feasibility analysis, the study will use the following perimeters:

1. 200 m^2 residential area
2. Location is Amman, Jordan
3. Six adult occupants
4. Rooftop installation with no structural shading from adjacent buildings
5. Only shower water will need to be heated by the solar collector
6. One shower per occupant per day
7. A standard shower being ten minutes, with water dispensed from a showerhead at the rate of 10 l/min
8. Negligible heat losses from tank and plumbing
9. Unheated water is stored at room temperature of 25°C
10. For the solar collector to fully replace an electrical geyser, it must produce water at a temperature of 60°C
11. Negligible heat and electrical losses from the electrical geyser
12. An electrical geyser will be used to compliment the solar collector if the water temperature falls below the required temperature (60°C)
13. No pump will be required to increase water pressure
14. Electricity is sold at a cost of 0.086 Jordanian Dinar (JD) per kilo Watt*hour.

PVSYST software is used to run all the study simulations, which is designed to be used by architects, engineers, and researchers. The study assumed a rooftop location; this is due to the limited space surrounding the residential property used in the study. Second, there is a limitation set by the local power transportation companies pertaining to the amount of power a household can set up. This power production limit roughly equals the quantity of energy consumed by the end user; it is meant to prevent the local population from installing large systems and then using the system as a competing revenue stream. Furthermore, the structure used should be designed to withstand local weather conditions, especially the additional force of compounded snow and high winds. The structure should be made of aluminum or galvanized steel to withstand corrosion better.

4. RESULTS AND DISCUSSION

4.1. Residential Solar Collectors

The dominant parameter here will be the amount of heating needed, which is driven by the number of occupants. The amount of water used in a standard shower can be estimated by using the time spent under the shower head multiplied by the amount of water a showerhead dispenses. Given the above parameters, 100 l/shower has been achieved. The study used the assumption of six adult occupants to arrive at a total storage tank capacity of 600 l/day of water. Inside the collector, the pipes are in series, and the internal flow uses the exchange of hot water and cold water by the effect of natural convection, which is caused by the temperature difference that leads to the density variation. The study recommends using two to eight solar panels to heat the needed amount of water (600 l/day). Four panels are recommended to allow for an increase in exposed water during the heat gain hours of sunlight. Finally, in the case of overcast days, a copper heating element to accommodate a sudden reduction in solar radiation or a temporary increase in the number of occupants is recommended.

The cost of a four-panel system will be more than JD1,500, depending on the country of origin. The justification for such a system comes from the cost of heating the same amount of water using an electrical geyser. There is an energy gain of 4,186 Joules per liter per degree Celsius, or 4.186-kilo Joules per liter per degree Celsius if water at room temperature of 25° Celsius is used and heated to a temperature of 60° Celsius. However, electrical power is measured in Watt*hour, so the study must convert the units to match the billing system used by all power providers.

Since one-kilo Joules equals 0.27778 Watt*hour, the research team can state that 1.163 Watt*hour is needed to raise the temperature of each liter of water by one degree Celsius. To raise the water temperature from 25°C to 60°C, there is a need to cover an energy gain of 35°. This would mean an energy input of 41 Watt*hour per liter of 60°C to produce ready-to-use shower water. The assumed household mentioned above needs 600 l of shower water a day. Multiplying 41 Watt*hour by 600 l gives 24600 Watt*hour per day of energy use. There is a daily cost of 2.1 JD for heating shower water, given that the residential cost of energy assumed above is JD0.086. In a 365-day year, JD767 will be spent on the heating shower water.

A similar system of European origin sold locally comes with a price tag of JD 2000-2500. The lower-end system would have a payback period rounded off to 2 years and 2 months, the more expensive system would need 3 years and 3 months to pay back the original investment, not accounting for the time value of money of inflation. The following is why this should be the first to be supported:

1. The poverty line in Jordan stands at JD323 a month. This would place even the lower-end system well out of the reach of most households
2. The system has a payback period is just under 2 years with a safety factor to account for off-year performances
3. The system is easily installed on existing structures; thus, it requires no infrastructure investment from the government.

4.2. Residential Electric Generation Assumptions and Parameters

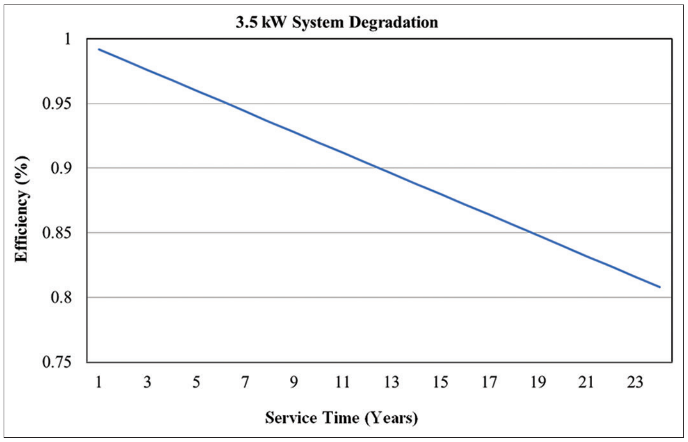
The first measure discussed above will help to minimize the electrical load on the national grid, as well as to lower the utility bill of the end user. In addition, there are other measures that can go a step further by supplementing the national production capability. Photovoltaic cells can produce electricity on a large scale and in the case of this study (residential scale).

The values estimated generated are for the 1st year only, as the values are foreseen to deteriorate by 0.8% every year, as shown in Figure 2 below.

4.3. Feasibility of Photovoltaic Residential Systems

To justify the installation of PV systems and gain the support of government and commercial entities, this study must provide evidence of potential financial gain. The study is conducted on a real case of residence in Amman. To define the type of system required, a style of yearly energy consumption of the residents needs to be drawn. This can easily be obtained by recording the serial number imprinted on the electrical meter attached to every home and entering the digits into the website of the national electrical distributor. Using this, the study determines the total monthly and annual consumption, what months experience the highest load on the grid, what tariff bracket was used for each month, and the total monetary value of the monthly bill. A 3.5 kW nominal power system is used in this study. Because

Figure 2: System degradation over time



the manufacturer supplies the nominal power for each module. Thus, the only thing needed is to install modules that are enough to produce 3.5 kW.

The next parameter is the assessment of the system's power by providing its location on earth compared to the sun. This will be a purely software-oriented process, as many companies have developed software to track the sun and the expected amount of irradiation energy any spot-on earth will receive from it, so it would be a waste of time and resources for this study to attempt to redevelop this software. A graph of the resulting irradiation obtained from uploading the residential site's geographical location into the program can be easily found.

The second step is to interpret the power produced into fiscal terms, which is related to the tariff of a certain month, which is changed each month. The final step in the feasibility check is to take the continuously changing factors into account. These are split into two categories, the first is an internal system factor, and the second is an external market factor. The internal system factors are the degradation in the cells and the expected eventual failure of investors since the latter is unknown, the study only considered the former, which is the manufacturer's stated degradation of 0.8% per year in the nominal system power output (Table 1). The external factor is the annual increase in tariffs, expected to match inflation at 3.5% per year. Note that the raise in the tariff values will lead to a rise in the amount of produced power as they are relatively linked. Taking into consideration that the raise in the tariff will lead to the rise of the produced power. The study shows that the payback period for this system (3.5 kW h) will be around 9 years.

Table 1: Predicted energy output in kW*hour in the earliest 24 years in service

Years in service	Predicted energy output (kW*hour)	Years in service	Predicted energy output (kW*hour)
1	5825.02	13	5261.31
2	5778.05	14	5214.34
3	5731.07	15	5167.36
4	5684.10	16	5120.38
5	5637.12	17	5073.41
6	5590.14	18	5026.43
7	5543.17	19	4979.46
8	5496.19	20	4932.48
9	5449.22	21	4885.50
10	5402.24	22	4838.53
11	5355.26	23	4791.55
12	5308.29	24	4744.58

For the 3.5 kW*hour system chosen here, we calculated energy production in relation to time in service while taking a reduction in efficiency due to module degradation.

4.4. Higher Consumption Residential Electric Generation Assumptions and Parameters

To demonstrate a preferable situation where a user would get more use out of a PV system and have a shorter payback period, a second simulation was done using the same assumptions used in the previous simulation but with a hypothetical residence. Table 2 shows the expected output degradation and inflation for this hypothetical system. The tariff for this system is set at 0.271 per kW*hour.

4.5. Feasibility of Higher Consumption Photovoltaic Residential Systems

To justify the installation of a higher output PV system and attain the support of government and commercial entities, this study must provide evidence of potential financial gain. The conducted notional case study is for the residents in the west section of Amman. To determine the system's type and its subcomponents, a type of yearly energy consumption of the residential under study must be drawn. This can easily be obtained by recording the serial number imprinted on the electrical meter attached to every home and entering the digits into the website of the national electrical distributor. Note that the study assumed that the use of energy is constant because of no available record. The study determined the total annual and monthly consumption, with all months experiencing the same load on the grid, what tariff bracket was used for each month, and the total monetary value of the monthly bill for a system of power of 10 kW. The next parameter to determine is the expected amount of the produced power based on its location with the sun. This will be a purely software-oriented process, as many companies have developed software to track the sun and the expected amount of irradiation energy any spot-on earth will receive, so it would be a waste of time and resources for this study to attempt to redevelop this software. A graph of the resulting irradiation obtained from uploading the residential site's geographical location into the program can be found.

Table 2: Predicted energy output in kW*hour for initial 24 years in service

Years in service	Predicted energy output (kW*hour)	Values of investment (JD) based on 3.5% of inflation	Years in service	Predicted energy output (kW*hour)	Values of investment (JD) based on 3.5% of inflation
1	18753.26	11,902.50	13	16938.43	17,985.49
2	18602.03	12,319.09	14	16787.20	18,614.99
3	18450.79	12,750.26	15	16635.96	19,266.51
4	18299.56	13,196.51	16	16484.72	19,940.84
5	18148.32	13,658.39	17	16333.49	20,638.77
6	17997.08	14,136.44	18	16182.25	21,361.13
7	17845.85	14,631.21	19	16031.02	22,108.77
8	17694.61	15,143.30	20	15879.78	22,882.57
9	17543.38	15,673.32	21	15728.54	23,683.46
10	17392.14	16,221.89	22	15577.31	24,512.38
11	17240.90	16,789.65	23	15426.07	25,370.32
12	17089.67	17,377.29	24	15274.84	26,258.28

Table 3: Feasibility of 10 kW hour system for initial 24 years in service

Years in service	Total pecuniary value (JD) of produced power based on a 5% rise in tariff	Investment value based on 3.5% inflation	Years in service	Total pecuniary value (JD) of produced power based on a 5% rise in tariff	Investment value based on 3.5% inflation
1	5,336	11,902.50	13	66,014	17,985.49
2	10,629	12,319.09	14	70,791	18,614.99
3	15,880	12,750.26	15	75,525	19,266.51
4	21,087	13,196.51	16	80,216	19,940.84
5	26,251	13,658.39	17	84,863	20,638.77
6	31,372	14,136.44	18	89,468	21,361.13
7	36,450	14,631.21	19	94,030	22,108.77
8	41,485	15,143.30	20	98,548	22,882.57
9	46,477	15,673.32	21	103,024	23,683.46
10	51,426	16,221.89	22	107,456	24,512.38
11	56,332	16,789.65	23	111,846	25,370.32
12	61,195	17,377.29	24	116,192	26,258.28

The final step in the feasibility check is to take the continuously changing factors into account, which are split into two categories, the first is an internal system factor, and the second is an external market factor, as mentioned earlier. For the case of using 1 the 0 kW*hour system chosen here, we calculate energy production in relation to time in service while taking a reduction in efficiency due to module degradation into account. The calculated payback period for this system is around 2.5 years, as shown in Table 3 below:

5. CONCLUSIONS

Although the government of Jordan already supports electrical power to almost all residential users, this is a myopic approach because it is not taking into consideration the influence of drainage on the patriotic budget and do not take an action to alleviate the bill of energy. Considerable progress has been made during recent years in taking on the alternate energy system, specifically on the industrial scale. This has been done through the government's support of business incentives and tax credits. However, the gap in supporting the low energy users compared with those using high energy has led to a delay in the adoption of alternative energies. The other forms of renewable energy, such as using hydroelectric and wind power, are still underused in Jordan, but they can be used to mitigate the instability in the prices of oil and gas. Many points have been observed in this study, such as:

1. Most energy users rely on government subsidies to afford electrical power in their homes
2. Most energy users are lower economic class and thus cannot afford a PV system or a solar heater without assistance and financing
3. The continued rise in energy use by all users is adding to the financial burden on an already strained national budget
4. Lack of clarity on regulations and support for the end user has limited the wider adoption of alternative energy measures.

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