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ECONOMIC MODELING OF HYDROPOWER GENERATION IN LEBANON: IMPLICATION FOR A CLEANER ENVIRONMENT

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Abstract

Water is the main constituent of Earth's streams, lakes, and oceans, and the fluids of most living organisms. It is vital for all known forms of life. It plays an important role in the world economy. Approximately 70% of the freshwater used by humans goes to agriculture. Large quantities of water, ice, and steam are used for cooling and heating, in industry and homes. It is also widely used in industrial processes. Hydropower or hydroelectricity refers to the conversion of energy from flowing water into electricity. It is considered a renewable energy source because the water cycle is constantly renewed by the sun. Electricity is produced using turbines and generators, where mechanical energy is created when moving water spins rotors on a turbine. This turbine *is connected to an electromagnetic generator, which produces electricity when the turbine spins. It is known as the largest contributor of all renewable energy sources and accounts for 6.7% of worldwide electricity production. It is an abundant, low cost source of power and also a flexible and reliable source of electricity compared to other renewable options, as it may be stored for use at a later time. The paper presented here is an identification of costs and benefits associated with the generation of hydropower. Through the utilization of the Net Present Value (NPV) technique which compares benefits and costs. The results of this technique indicated that, after deducting costs from benefits, NPV for hydropower generation amounted to $3,689,661.72 over 10 Year project life cycle. In addition, the Internal Rate of Return (IRR) amounted to 33%, which reinforces the feasibility of any investment in hydroelectricity in Lebanon.*

Keywords: Lebanon, Water, Hydropower, NPV, IRR, Feasibility

INTRODUCTION

Water for all living species is the most important natural resource. The origins of civilization are closely linked to water use and throughout history, people have developed technologies to use water for agriculture, households, and transport, recreation, industry and energy productions.

Energy is a critical factor for economic growth, social development and human welfare in developing countries (Voser, 2012). Hydropower is a renewable energy source that contributes to sustainable development by producing economic, non-polluting and environmentally friendly local inexpensive power from all renewable energy sources. Hydropower reduces the dependence on imported fuels, which carry risks or price volatility, uncertainty of supply and foreign currency. It can also offer multiple benefits, including water storage for drinking and irrigation, preparation for drought, protection against floods, aquaculture and recreation. Hydropower accounts for around 16% of global electricity, a share that is expected to increase. The technical potential of Hydro is five times the current rate of utilization, and there is enormous potential in developing countries. According to the U.S. Energy Information Administration (IEA, 2012), hydropower can contribute up to 16,400 Terawatt-Hour(TWH) per year and by 2050 the total installed hydropower capacity will double, generating 7,100 TWH per year.

In Lebanon, the hydropower capacity is approximately 282 MW, which accounts for nearly 8.7% of Lebanon's total national power (MOEW, 2010). This paper focuses on the prospects of hydropower in Lebanon and recognizes its importance for the future security of power supply in Lebanon.

Background of the Lebanese Electric Situation

Lebanon generates very little electricity from the country's facilities. In fact, 96.8% of the total electricity consumed was imported in 2010, and only 3.2% came from hydroelectric power stations and solar water heaters (TSBL, 2005). Moreover, most of the electricity imported comes from thermal installations. In addition, the electricity sector in Lebanon is facing problems such as load shedding, technical losses and the aging of power plants, which force end users to rely on diesel generators to overcome shortages.

At the UN Framework Convention on Climate Change “Conference of the Parties (COP 15)” meeting, the government made a commitment to develop its renewable energy production capacity to 12 percent. The Council of Ministers has also adopted the National Energy Efficiency Action Plan, which includes 14 energy efficiency and renewable energy initiatives. The national objective would be to implement renewable energy projects producing 767 Tons of Oil Equivalent (TOE) of electricity by 2020 (UNSDG, 2018).

All the hydro power plants in Lebanon were built before 1970 and the total nominal hydropower installed was 280 Megawatts (MW). Electricity produced from hydroelectric power plants accounts for approximately 4.5% of total production (MOEW, 2018).

The government believes that the share of hydro in the electricity mix could be increased by at least 12 MW by maintaining, rehabilitating and replacing existing hydroelectric power plants as well as adding capacity (ibid).

A master plan for the development of the hydroelectric sector identified new sites with a potential of 263 MW at a cost of $667 million and 368 MW at a cost of $772 million. About 25 of these 32 sites are economically viable (ibid.).

Need for the study

Ever since the beginning of the 20th century, from the days of the Ottoman Empire, Lebanon has known electricity. At that time, the electricity network had grown to culminate in the eve of the civil war (1975) in Lebanon, which destroyed many facilities and brought darkness and inactivity to houses and factories (The Monthly, 2018).

During that time, the electricity sector experienced a growing crisis. However, despite the end of the civil war, the return of stability and the disbursement of more than USD 25 billion for projects relating to the construction, restoration and operation of power stations, the crisis continues. Solutions do not appear to come to light soon; the crisis appears to be perpetual because of a conflict of interests. Each president or minister promises that they will provide electricity 24/7 to the power-driven Lebanese, but they never keep their promises (ibid.).

Problem definition

Access to a reliable and continuous supply of electricity is essential for all economic activities as an important element of infrastructure services. It also helps to improve citizens ' living standards and to advance technology and science in societies.

Electricity production in Lebanon decreased from 1494 Gigawatt hours (GWh) in August 2018 to 1362 GWh in September 2018. Lebanon's electricity production averaged 856.41 GWh between 1993 and 2018, reaching an all - time high of 1528 GWh in July 2017, and a record low of 277 GWh in September of 1994 (CDR,2018).

EDL’s combined capacity to generate electricity stands at 1800 MW; leaving a gap with the actual demand of around 1600 MW, currently filled by unregulated private generators (ibid.).

In order to fill this gap, renewable resources such as solar, wind power, hydrogen and fuel cells, geothermal power, and hydroelectric energy wasted could be held as an effective, efficient, and even more rational decision for a long-term environmental sustainability.

LITERATURE REVIEW

Electricity is a key component of modern market economies. Electricity offers light, thermal comfort and the power to consumers and commercial goods on which modern economies depend (Sorrell, S., 2015).

But all choices involve trade-offs. Economists tend to talk about cost and benefit offsets. To evaluate the costs and benefits of different development options, decision makers can choose between different alternatives (ibid.).

The challenge for the region's stakeholders is to understand the economic implications of the different scenarios and the social and environmental implications.

A good understanding at project level is critical because the macroeconomic implications are the result of the cumulative impacts of many projects and activities in an economy.

Introduction to Hydropower

Hydropower, the creation of mechanical energy through the transfer of kinetic energy created by the flow of water, is currently the only large-scale renewable alternative to traditional electricity sources, such as fossil fuels. As economic development spreads throughout the world, so does the demand for electricity, causing global electricity production to double in just the last two decades. Worldwide, 66 countries already generate at least half of their power from hydroelectricity, but only one third of the economically feasible potential of hydroelectric power has been realized (DOE, 2012).

Hydroelectricity, provided through a number of hydropower technologies, all rely on the ability to produce electricity through the force of moving water. The water can come from many sources, from natural flows of the tide or waves, rivers, or man-made conduit projects like impounded reservoirs, dams, or irrigation canals (ibid.).

Hydroelectric energy is operated by requiring a large artificial reservoir of water called the dam. The dam is built with tunnels where water can pass through. The flowing of water creates the energy to turn the turbines which turn the generators, converting energy into electrical energy. However, in generating the energy, the flow of water needs to be controlled. A huge requirement of electricity requires a large amount of water to flow in the turbines otherwise, the turbines are closed and the water flow is slowed down. This system is called the intake system. In many countries where there are fast-flowing rivers and falls, the creation of dams or reservoirs may not be necessary. Since the rush of water cannot be shut off, engineers are finding ways to limit the amount of water that falls on the turbines that generate the hydroelectric power plant. As long as there is plenty of water in the reservoir, a hydroelectric dam can respond quickly to changes in demand for electricity. Opening and closing the intakes directly controls the amount of water flowing through the penstock, which determines the amount of electricity the dam is generating (Sogreah, 2012).

The Economics of Electricity

Electricity market

Lebanon's half absent electricity remains a major source of social and financial distress for the country. Despite the national electricity company's (Electricite Du Liban, EdL) failure to supply enough power since the 1990s, the government's divergent parties could not consent over a rehab or a privatization plan. Instead, the government restricted its role to a draining, indefinite annual financing of more than 90% of EdL's purchases of fuel at a fat bill of $1.8 billion. The market meanwhile was left to its own devices. Between private generators, consolidated electricity generation, sleazy borrowing, and investments in alternative energies, Lebanese citizens are almost getting by, but not without terrible costs on wealth and health (BLOMINVEST, 2106).

The electricity market is generally a heavily regulated market dominated by a small number of firms. Electricity markets are generally divided into three areas:

1. Generation of electricity.
2. Transmission of electricity.
3. Distribution of electricity.

Generation of electricity

- Construction of two combined-cycle power plants in Deir Ammar and Zahrani with a capacity of 435 MW for each plant at a cost of US $575 million, achieved in 1999.
- Rehabilitation of thermal and hydraulic plants at a cost of US $109 million, achieved in 1998.
- Construction of two open-cycle power plants in Sour and Baalback with a capacity of 70 MW for each plant at a cost of US $61 million, achieved in 1996.
- The initiation of supply of a 120 MW of electrical power from Egypt to the new HV transmission plant in Ksara through the Eight Arab connection network (MOE, 2018.).

Transmission of electricity

The Transmission is based on the construction of a network of 220 KV comprising the installation of 339 km of overhead lines. Completely built overhead lines are: Deir Nbouh to Ksara line, Ksara to Aaramoun line, Aaramoun to Zahrani and Sour line and Bahsas to Bsalim line to Halat line (these regions are located on the southern and northern parts of Lebanon) (MOE, 2018).

RESEARCH METHODOLOGY

Capital cost

The Levelized Cost of Electricity (LCOE) is very sensitive to the discount rate used. The difference between a 3 % discount rate and a 10 % discount rate is very significant, with the LCOE increasing by between 85 % and 90 % as the discount rate increases from 3 % to 10 %.

The economics of hydropower is very site-specific, depending on many characteristics of the sites involved, the civil works necessary, the annual flow of water, and other parameters. Table 1 shows new and financially viable hydropower plants in Lebanon, which can be built to increase the available power at competitive pricing. The most effective hydropower plants are those mentioned in Level 1 in Table 1, followed by Level 2 and Level 3 plants, most of which are financially competitive when compared to the current average generation costs of EDL.

Table 1 Economics and Tariffs for New Hydropower Plants in Lebanon

	Level 1 Minimum selling tariff < 8.1 US cents / KWh	Level 2 Minimum selling tariff > 8.1 US cents / KWh and < 12 US cents / KWh	Level 3 Minimum selling tariff > 12 US cents / KWh	Total
Number of sites	13	12	4	
Power (MW)	139	94	17	29
Capital Expenditure-CAPEX (USD million)	273	287	78	250
Annual Production (GWh)	713	413	68	638
Average cost (USD) of installed KW	2,070	3,220	4,310	1,194

Net Present Value (NPV)

Net Present Value is one of many capital budgeting methods used to evaluate potential physical asset projects in which a company might want to invest. Usually, these capital investment projects are large in terms of scope and money, such as purchasing an expensive set of assembly-line equipment or constructing a new building (Peavler,2015).

Net present value uses discounted cash flows in the analysis, which makes the net present value more precise than of any of the capital budgeting methods as it considers both the risk and time variables (ibid.).

A net present value analysis involves several variables and assumptions and evaluates the cash flows forecasted to be delivered by a project by discounting them back to the present using information that includes the time span of the project (t) and the firm's weighted average cost of capital. If the result is positive, then the firm should invest in the project. If negative, the firm should not invest in the project (ibid.).

NPV is the difference between the present value of cash inflows and the present value of cash outflows over a period of time. The following formula is used to calculate NPV:

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{\mathrm{Rt}}{(1+i)^{t}}$$

In this equation:

- Rt = net cash inflow-outflows during a single period (t).
- i = discount rate or return that could be earned in alternative investments.
- t = number of time periods.

The decision rules of NPV are as follows:

- NPV>0 the project should be accepted
- NPV = 0, the decision is indifferent.
- NPV < 0, the project should not be accepted.

The NPV method is usually appointed for projects evaluation because it recognizes the value of money in time, reflects the increase of richness to the investor and depends only on the cash flow and on the capital cost (ibid.).

Internal Rate of Return (IRR)

Internal rate of return is a metric used in capital budgeting to estimate the profitability of potential investments. Internal rate of return is a discount rate that makes the net present value of all cash flows from a particular project equal to zero. IRR calculations rely on the same formula as NPV does.

The Internal Rate of Return, or IRR, is the discount that makes the NPV becomes zero. The IRR is the highest opportunity cost of the capital that the project can hold. The criteria of the Internal Rate of Return establishes that while the value of the IRR is higher than the value of the capital cost, the project must be accepted, that is:

- IRR > i , the project must be accepted.
- IRR = i , accepting or not is indifferent.
- IRR < i , the project should not be accepted.

A characteristic of the IRR is that, most of the times, it brings the same results that the NPV brings, but these can be conflicting in some cases. This method is largely used in practice, but some measurements need to be taken in order to use it in the right way (Brigham, 1999).

Data and the Observed Model

This paper will show if a plan to build a hydropower plant in Lebanon is efficient using a cash flow analysis as a way to determine that. The NPV is expected to be positive since it is known that the economic cost of a hydropower plant can be way less than a thermal power plant like the one currently used in Lebanon.

Table 2 Cost Model for Hydro Power Plant 2 MW, Input Variables Sheet Table

I. Capital Cost	
Feasibility Studies	$50,000.00
Design & Supervision	$375,000.00
Construction Cost	
1. Site Clearance and Setting out	$30,000.00
2. Earthworks	$50,000.00
3. Concrete works for the chute and penstock	$75,000.00
4. Plant Room	$50,000.00

5.	Mechanical Works Piping	$400,000.00
6.	Valves	$60,000.00
7.	Turbines	$40,000.00
8.	Generators	$40,000.00
9.	Speed Regulatory Governors	$100,000.00
10.	Excitation System	$70,000.00
11.	Automatic Components	$50,000.00
12.	Transformers 2x2 MW Complete	$200,000.00
13.	Synchronization Panel	$125,000.00
14.	Cabling and various Items	$50,000.00
The Total Cost does not include distribution, it is only within the plant boundary		
Power Plant efficiency 70%		
Total Capital Cost		$1,765,000.00

Table 2…

Table 2 above shows the actual figures for a real hydropower plant project that can be adopted to start building a hydropower plant. As can be seen, the capital cost includes feasibility study of $50,000, design and supervision of $375,000, and construction cost for a total of $ 1,340,000 that contains the main component to building a hydropower plant.

Table 3 Cash flow Model for Hydro Power Plant 2 MW, Input Variables Sheet Table

I. CASH FLOW ANALYSIS	
Total kwh generated per Annum	12264000 KWh
Electricity sale price (Cents/kwh)	5.00 Cents
Annual Inflation Rate (%)	2.5
Annual electricity price increase (% in addition to inflation rate)	10.0
Discount rate (%) – required investment return	9.5
Maintenance costs	$50,000.00
Ongoing resource consent fees	$30,000.00
Unscheduled maintenance allowance	$25,000.00

Then the values above (table 3) of the cash flow are added i.e. the total KWh generated per annum by a hydropower plant which is 12,264,000 KWh, equivalent to 12,264 MWh. The electricity sale price cent/kwh is 5.00 cents, equivalent to $50/MWh. An annual inflation rate of 2.5% as well as an annual electricity price increase of 10% with a discount rate of 9.5%. Finally, the annual maintenance cost for a hydropower plant consists of $50,000 per year.

Moreover, an annual resource consent fee (the fees of getting a permit to carry out an activity that may contravene a rule in a city or district) which amounts to $30,000 is added. There is also an allowance for unscheduled maintenance in case of breakdown and downtime maintenance which amounts to a total fee of $25,000.

Table 4 Discounted cash flow analysis using the figures stated above

Average cost per kWh over project life	
Expected project life	10 Years
KWh generated per annum	12264000 kWh
Net value of expenses over project life	$2,570,637.55
Total kWh output over project life	122640000 kWh

1. The value of electricity generated is calculated by multiplying the amount of KWh generated per annum by the price/KWh in cents. However, for the following year the value is based on multiplying the number of the previous year by the annual percentage increase which is 10%, and added to the value of the previous year.
2. The discount factor for the first year is= 0, as for the second year it is calculated by the power of [1+ (discount rate 9.5%/100)] the same pattern must be followed for the following years.
3. Present value per generated KWh is calculated by dividing the value of electricity generated in the respective year by the amount of KWh generated per year.

The Expenses include:

1. The initial capital investment applies for the first year of installation which totals to $1,765,000.
2. Maintenance for the installation year is $ 0 , for the second is= $50,000 as it was stated in the input variable sheet ,as for the third year the maintenance expenses will be calculated by multiplying the amount of maintenance in the previous year by (1+annual inflation rate 2.5%/100).
3. Resource content fees for the first year equal to $ 0 for the second year = $30,000 as stated in the input variable sheet for the third year the resource content fees calculated by multiplying the amount of resource consent fees of the previous year by (1+annual price increase 10%/100).

4. Unscheduled maintenance for the first two years is the same which amounts to $25,000 as stated in the input variables, for the third year is calculated by multiplying the amount of the previous year by (1+annual price increase 10%/100)
5. Total expenses are calculated by adding all the expenses in the same year together.
6. Discount factor is the same as in the income section for each year.
7. Present Value of expenses is calculated by dividing total expense/discount factor.
8. Annual NPV of the project: is calculated by deducting in each year the present value of electricity in the income section from the present value of expenses.
9. The Net Present Value of the system is calculated by adding all the amounts of the annual NPV of the project.

Average cost per KWh over project life

The expected project life is for 10 years that generates 12,264,000 kWh with a net value of expenses over project life of $2,570,637.55 which is calculated by adding the present value of expenses from installation year to year 10. The unit cost of electricity generated is $0.02/kwh which is calculated by dividing the amount of net value of expenses over project life by the total KWh output over project life.

RESULTS

The methodology used in this paper revolves around the cash flow analysis with a focus on NPV and IRR. The calculation applied above helps to determine the NPV and IRR to know if the project is profitable. The results of the cash flow analysis and a summary result of the hydro cost model are presented in the table below.

Summary

Capital Cost	$1,765,000.00
Net Present Value of System	$3,689,661.72

Value of electricity generated each year

Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
$613,200.00	$616,016.32	$618,845.58	$621,687.83	$624,543.14
Year 6	**Year 7**	**Year 8**	**Year 9**	**Year 10**
$627,411.56	$730,293.15	$633,187.98	$636,096.11	$639,017.59

Total KWh output over project life	122,640,000 kWh
Average unit cost of electricity generated	$0.02 cents /kWh
Internal rate of return of project	33.12%

The Net Present Value = $3,689,661.72 over 10 year project life. Therefore, the NPV is > 0: The PV of the inflows is greater than the PV of the outflows. The money earned on the investment is worth more today than the costs; therefore, it is a good investment.

CONCLUSION

Hydropower in Lebanon is as important a technology as wind and solar power, yet even more so due to a higher capacity factor and lower economic costs. Yet hydropower is a neglected source of energy in Lebanon. As mentioned earlier, Lebanon generates very little from the country's facilities; in addition, the electricity sector in Lebanon is facing problems such as load shedding, technical losses and many more which forces end users to rely on diesel generators to overcome power shortages.

Hydropower is the leading renewable source for electricity generation globally (supplying 71% of all renewable electricity). Hydropower is the most flexible and consistent of the renewable energy resources; it is capable of meeting base load electricity requirements and with pumped storage technology, it is capable of meeting peak and unexpected demand due to shortages or the use of intermittent power sources.

The energy industry contributes to economic growth by creating jobs. It affects the economy through the use of labor and capital energy for production.

Lebanon's half absent electricity remains a major source of social and financial distress for the country. Despite the national electricity company's (Electricité Du Liban, EDL) failure to supply enough power since the 1990s, the government's divergent parties could not consent over a rehab or a privatization plan.

Hydropower is a proven, mature, and predictable technology that can also be of low-cost. It requires relatively high initial investments, but it has the longest lifetime of any generation plant (with parts replacement) and, in general, low operation and maintenance cost.

Furthermore, the results from the cash flow analysis indicated that establishing a hydroelectric power plant is beneficial to whoever decides to invest in it. Since the NPV is greater than zero and the IRR is 33.12%, it is greatly recommended that the government and the private companies start adopting projects of this sort to better the economy, the environment, and the lifestyle of citizens by providing a continuous supply of electricity through renewable energy which can be a value to Lebanon.

RECOMMENDATIONS

The Lebanese government is recommended to start focusing on adopting renewable energy, as a means to produce electricity instead of relying on thermal power plants that have negative effects on the environment. Furthermore, the country's utility power is not meeting the demand of electricity for the whole population. In addition, adopting these projects can have a positive effect on the Lebanese economy as it can create jobs and limit the brain drain of the country (the exodus of Lebanon's youth to other countries in pursuit of work opportunities). Finally, Adopting renewable energy will be a big step forward in the right direction for a country like Lebanon which has been struggling with the electricity sector for years.

LIMITATIONS

Due to the lack of information on Lebanon concerning this type of research, the researchers were obliged to limit the information to data that dates few years back. The ministries have not made proper data available for such research type, especially, recent figures that are needed to complete this research. Therefore, with the availability of proper data and needed information this project can be implemented on a higher scale.

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