A Renewable Energy System Study of Lebanon

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In this study we investigated the production of about 1000GWh from renewable energy sources, divided to be 750GWh from wind turbines and 250GWh from solar electric modules. For the wind turbine assessment we studied nine different locations in Lebanon and determined that the three best locations to install our wind farms are Marjeyoun, Ksara and Akkar. This selection was based on the cost per unit energy generated in $/kWh and took into consideration the efficiency of energy generation, i.e. total energy generation and corresponding capacity factor, and the cost of installation of wind farms in the chosen location. For solar electricity assessment we investigated several module types and determined the economics of installing solar electricity in Lebanon.

Each of the wind farms is estimated to generate about 250 GWh, with a capacity factor of 0.3 for Ksara, 0.4 for Akkar and 0.49 for Marjeyoun. Based on the economical study we have chosen E82 wind turbines to be used in the three locations rated at 2.05 MW each, which cost about $1350/ kW. The total investment covers 110 wind turbines costing about $309 millions including land. The land requirements were estimated to be 1500 (100x15) m^2 per wind turbine. However, the size of wind-park would be about 10 km2 that would mostly be used for grazing and farming. The annual maintenance and operation cost is estimated to be $7.8 million. The total energy that will be produced by the three farms annually is about 767 GWh, and the average cost of energy is 5.5 ¢/kWh, the lowest being at Marjeyoun at 4.3 ¢/kWh. The total annual revenues from the wind energy project are about $123 millions based on an electricity tariff of $0.16/ kWh, and the total annual costs that include maintenance and capital recovery are about $42 millions. The value of the carbon reduction is estimated based on an emission rate of 525 g/kWh of CO_2 valued at $10 per metric ton of CO_2. The money value of the carbon reduction is estimated to be $4 millions, which gives a simple payback period of 3.6 years including the carbon trade revenues.

For the solar energy system, we did a study on different generators that was also based on the energy output, capacity factor and economic factors and was done on different systems. The energy output from the solar modules was calculated based on solar irradiance and temperature data collected at the American University of Beirut. A model of the solar generator module was developed and used in this calculation. Several types of solar modules were used (e.g. Sharp 230W, GEPV200W, KC200GT), and the results came to be close with a slight edge for the Sharp 230W module. However to be conclusive we need solar data for the Bekaa valley, which was not available to the project team at the moment. The design required about 324 generators each having a capacity of about 500kW and requiring 2160 modules for the 230W module. The area required to install and operate all the generators was about 1.45 km^2 and the overall peak size was 163 MW at a capacity factor of 17.5% thus producing about 250 GWh. The initial investment cost is estimated to be $761 million based on $4500 per kW peak. The operating cost was estimated at $13 per kW peak per year and the price of land was considered to be $25 per m^2. At an interest rate of 10% the cost of electricity generated is estimated to be 0.34 $/kWh, which is clearly uneconomical if the electricity tariff is $0.16/kWh.

[1] This summary is partially based on the final year project report in 2009 entitled "Renewable Energy System in Lebanon", by Amin Kronfol, Rayan Zahr, and Sami Hawi.