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Energy Needs and Sustainable Development of the World Heritage Site: A Proposition in Lumbini

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Abstract: The energy need of people is growing worldwide and the same appears in Nepal. The energy sources apart from petroleum products are hydropower which is in majority and solar are also scattered for household consumption but the use of wind power from traditional methods is evident in the country which is distant from the use of turbines to harness the power of the wind. Focusing on heritage sites with potential such as Lumbini which is a world heritage site faces a lot of problems with energy need as the supply of hydropower and solar are not sufficient enough to fulfill the energy demand. Though the flow of wind is not consistent and high the alternative solution of a low speed wind turbine seems feasible through the preliminary study of wind pressure around the place as the average wind of the place around the year is 4m/s. The speed wind as low as 1.8 m/s could be harvested (Trongtorkarn, M.et.al 2017). The energy need and its sustainable attainability has implications on the involvement of the people for the wellbeing of heritage sites which can be a symbiotic relationship though it has to go through challenges. To reduce the energy demand in heritage areas, in this paper an hybrid solar-wind and hydro-oxygen model is developed. The proposed model is performed using thermodynamic analyses techniques. The result of the model shows, the proposed hybrid approach improves the energy sustainability in heritage areas.

Keywords*: Sustainability, Heritage, Power Consumption, Energy demands, Hydro-Oxygen, Solar Wind.*

Background of Study

Human demand for energy is increasing at a tremendous rate with the explosion of population and urbanization. The requirement of energy needs an appropriate method for harvesting the energy which has a direct or indirect impact on the environment. The method of clean energy is the need of the hour to protect humanity which is possible through sustainable development plans for the future.

Using clean, alternative renewable energy sources to provide energy needs in many industrial and agricultural sectors has received more attention in recent years. Two primary factors are what each trend means and how it might develop: Environmental catastrophes and the need to develop alternative energy sources. Many nations are looking into the development of alternative energy sources, such as peat, oil shale, bitumen, unconventional gas, geothermal energy, solar, wind, ocean, and biosynthesis, due to the slow and steady depletion of basic energy sources, particularly oil and gas, and the limited development of hydro and nuclear power. (Konovalov, 2015)

An example of a sustainable development plan that includes cost-cutting, efficiency and renewable energy are Denmark. As a result, Denmark is currently confronted with two challenges: integrating its large

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proportion of sporadic electricity from renewable sources and involving the transport sector in its long-term strategy. It takes more than simply cost savings, efficiency improvements, and renewable energy to get energy plans to this point. Also, it is crucial to develop integrated energy system solutions and introduce and incorporate flexible energy technology. For future sustainable development, technical change is required. (Lund, 2005).

The goals of conservation and change can be seen as a duality in landscape policy, management, and planning. The Ore Mountains in Saxony, a remnant of the historic German cultural environment, is a recent classic example. 800 years of mining history have formed this mountain range. In response to this, a project was started in the 1990s to preserve the many traces of human influence in landscapes that were listed as part of the World Heritage. The plan was carried out gradually. A list of facilities was compiled after it was put on Germany's UNESCO World Heritage Candidate List in 1998 (Ore Mountains World Heritage Convention, 2015). The designations of 39 components of the history of mining that are dispersed throughout the mountains as possible World Heritage Sites. (Wieduwilt and Wirth, 2018)

The production of clean, renewable energy has grown to be a significant component of the current energy system. Wind and solar energy are prominent examples of renewable energy that have undergone extensive research and widespread use. As a result of the restriction on energy transmission, "energy" is now the primary mode of usage. The safe operation of the large-scale power grid has a considerable detrimental effect on the power system, and renewable energy is extremely subject to external environmental conditions, demonstrating a strong gap and instability. (Wei and Zhang, 2017)

Traditional biomass and imported fossil fuels account for a significant portion of Nepal's total energy source. While the amount of fossil fuels has climbed from 11.5% to 17.2% and the share of renewable energy, including hydropower, has declined from 1.7% to 79.4% in 2014, the share of energy derived from biomass has decreased from 86.7% in 2000 up to 3%. Energy use per person increased from 14.76 GJ in 2000 to 18 GJ in 2014/015. Reliance on biomass is not a practical way to promote growth given Nepal's low per capita energy consumption. Six of the 16 study sites—Jumla, Patan West, Vorleni, Ramechhap, Hansapur, and Baddanda—have promise for small-scale wind farms, while two of the sites—Kagbeni and Thini—are theoretically capable of producing wind farms of a commercial scale. In four areas, however, it is possible to generate electricity seasonally. Take into account the sites' typical wind speed, Tansen, Tarah, Simikot, and Nagarkot. Okaldhunga, Fakhel, Nepalgunj, and Simara aren't good locations for producing wind energy. (Laudari, 2015)

Wind power can be used as a green energy source to generate electricity. Horizontal axis wind power Turbines (HAWT) installed in large power plants are complex and expensive. Small turbines with low wind speed it can be used in the office, home or farm as a new idea for implementing wind energy applications. Vertical axis Wind turbines (VAWT) and permanent magnet synchronous generators (PMSG) can be used on a small scale Overcome starting torque limitations with gradient magnet technology Combining VAWT blades Rotor of Savonius and Darius. The VAWT system was turned on at a wind speed of 1.75 m/s. Operate in a wind tunnel with wind speeds between 1 and 8 m/s. successfully developed the VAWT system and wind turbine. (Trongtorkarn, M.et.al 2017)

The Relationship between temperature and magnet skew angle in PMSG for low-speed wind applications showed that the center coil, as opposed to other places, is where the greater temperatures are produced, even low-speed wind has a high potential for energy. Nonetheless, the wind turbines' blades and generators should be appropriate for low wind speeds. (Trongtorkarn, M.et.al 2020)

Objective:

- To study the sources of energy in Cultural Heritage Sites and their directly connected society
- To identify the potential solution to the energy need a complement for Lumbini
- To improve the energy sustainability an hybrid solar-wind and hydro-oxygen combustor is implemented.

Methodology:

The preliminary study relies on the secondary data provided by weather reports and the wind report of the nearby airport which is 20 kilometers from the site so the equipment to measure the wind potential at the site needs to be implemented for actual data to fetch viability of low wind turbine in the area. Various variable needs to be considered such as purely technical prospect for the turbine and the wind potential and its cost-benefit

analysis as well as the need to attract the community requires expert advice and the community response to the need and utility of the project if implementation needed as well as various stakeholders associated with the site.
In this research work a hybrid model using solar-wind energy and Oxygen-hydrogen component is developed to fulfil the demand in the heritage sites. The main focus of this model is to store extra energy from the natural resources to manage the imbalance situations during night time and prolong cloudy climate. The solar energy is captured from the sun using solar collector and wind energy is collected using wind turbines. The other component utilized in this proposed model to improve the sustainability are hot storage tank, Rankine Cycle, domestic water heater, and vapor compression unit. In order to analyses the efficiency of the proposed model, the complete model is analyzed by implementing thermodynamic laws.

Thermodynamic Analyses

The thermodynamic based analyses includes four steps such as: mass, energy, exergy, and entropy balance equations to analyse the each major and sub systems in the model.

(i) Mass balance equation

This analysis is performed to evaluated the flow of mass during the energy saving process. It is calculated by dividing the net mass flow to the equivalent interval time. It is expressed as:

$$\dot{m}_{in} - \dot{m}_{out} = \frac{dm_{cv}}{dt} \quad (1)$$

$\dot{m}_{in}$, $\dot{m}_{out}$, dt, represent the inlet, outlet, interval time of mass flow rate in the model respectively.

(ii) Energy balance equation

The energy balance is analysed using the first law of thermodynamic, which is evaluated using following equation-2.

$$\sum \dot{Q}_{net} + \sum \dot{W}_{net} + \sum \dot{m}_{in} h_{in} - \sum \dot{m}_{out} h_{out} = 0 \quad (2)$$

Here, q, W, h, and m represent the transferred heat volume, work rate, specific enthalpy ratio, and mass flow rate respectively. After analysing the energy balance value of the hole and sub-system, the entropy balance equation is applied. Because getting an clear understand from the mass and energy balance is not accurate.

(iii) Entropy balance equation

The entropy balance is analysed using second law of thermodynamic, it is expressed using the following equation-3.

$$ex_i = h_i - h_0 - T_0(s_i - s_0) \quad (3)$$

In equation-4, h, T, S, i,0 represents the enthalpy state point, temperature, entropy rate, i^{th} sate point, and ambient conditions respectively. In addition to energy, mass, and entropy analysis, the exergy balance analysis is more required to accurately evaluate the sustainability of the system.

(iv) Exergy balance equation

As per the second law of thermodynamic, the exergy balance equation is expressed as equation -4. It is mainly performed to evaluate the energy loss and quality. Based on the four different forms such as: kinetic, chemical, potential, and physical the quality of the energy in sub-system is analysed.

$$\dot{E}x_{d_i} = \dot{E}x^{Q_i} - \dot{E}x_{W_i} + \sum \dot{m}_{in} ex_{in} - \sum \dot{m}_{out} ex_{out} \quad (4)$$

Where, h, s, e, q, i, $m_{out,}$ and m_{in} denotes enthalpy rate, entropy point, energy rate, heat transfer rate, i^{th} sate point, inlet mass flow and outlet mass flow respectively. In the above equation-4, the $\dot{E}x^{Q_i}$ denotes the heat transfer rate of the exergy balance equation, $\dot{E}x_{W_i}$ indicates the exergy work rate, $\sum \dot{m}_{in} ex_{in}$ *and* $\sum \dot{m}_{out} ex_{out}$ represent the mas flow carried in and out from the system. $\dot{E}x^{Q_i}$ is further expressed as equation-5 to improve the system efficiency.

$$\dot{E}x^{Q_i} = \dot{Q}_i \left(1 - \frac{T_o}{T_{S_i}}\right) \quad (5)$$

Where, $\dot{Q}_i, T_o, T_{S_i}$ represent the heat transfer to the complete system, ambient temperature, and source temperature passed to the boundary of control unit. Then the ratio of exergy destruction is also evaluated using equation-6, to detect the loss in the model.

$$\dot{E}x_{d_i} = T_o . \dot{S}_{gen_i} \quad (6)$$

In the above equation-6, the $\dot{S}_{gen_i}$ denotes the entropy generation rate, which is evaluated using entropy balance equation.

$$\dot{S}_{gen_i} = \sum \dot{m}_{out} s_{out} - \sum \dot{m}_{in} s_{in} - \sum \left(\frac{\dot{Q}}{T}\right) \quad (7)$$

Oxygen-hydrogen rate balance equation

After evaluating the above basic equations, the exergy balance rate of the proposed hydrogen and oxygen are also evaluated using the following equation-(8).

$$ex_i = h_i - h_o - T_o(s_i - s_o) + ex_{ch_i} \quad (8)$$

Forecasting solar and wind energy

Once all the above-mentioned components are evaluated, to improve the energy sustainability now the available wind and solar energy is forecasting using following equations 9 and 10.

$$\dot{Q}_{S,avb} = \dot{I}_S . A_{SC} \quad (9)$$

$$W_{wd,avb} = N_1 . ½ . \rho_{air} . A_r . v_{upstream}^3 \quad (10)$$

Based on the irradiation in the solar panel, the energy received from the sun is calculated, which is denotes as $\dot{Q}_{S,avb}$, $\dot{I}_S$ denotes the cumulative region of the solar collector. The efficiency of the solar collector on storing solar energy is evaluated using the equation (11).

$$Q_{sC,\mathrm{in}} = \eta_{sC} . Q_{s,avb} \quad (11)$$

Then using equation (12), the energy generated by the wind turbine is evaluated.

$$W_{wd,gene} = C_p . \eta_{gene} . \eta_{transmission} . W_{wd,avb} \quad (12)$$

Result and discussion

To evaluate the performance of the model, here two set of public available wind and solar dataset are taken as input. Especially this research work is performed to forecasting the weather conditions in heritage site Lumbini in Nepal. Based on the data available in those dataset, the prediction process is performed by the proposed model. Through thermodynamic balance equations, the various inputs related to solar and wind energy system is evaluated. The preliminary study shows the need for clean energy and its integration with the existing technology is sought and the research for such activities are going on so that clean energy could become part of the daily energy need in an efficient way. This could pave the path for the development of sustainable energy production by the use of clean energy as much as possible.

For such a solution various countries have adopted the way to make clean energy a foundation for resolving solution of energy needs of the population. Various methods and use of GIS and the tools and method of generation of power through nuclear and clean energy had been explored and implemented and they are sighting other opportunities to make it a reliable source of energy solution through integration as well as efficient distribution plan for power solution. Solar and wind energy sources had attracted attention along with other sources. Even various simulations to estimate cost-benefit analysis had been done. (Wieduwilt, P. and Wirth, P. 2018). To overcome these issues and fulfil the demands in the high heritage areas,as mentioned in the above sections, in this paper a hybrid solar and wind energy saving model is developed. The simulation result of the proposed approach on analyzing various attributes related to improve the energy sustainability is discussed in detail. Figure-1 to figure-4 emphasize the average and maximum wind speed and average pressure ratio of wind data.

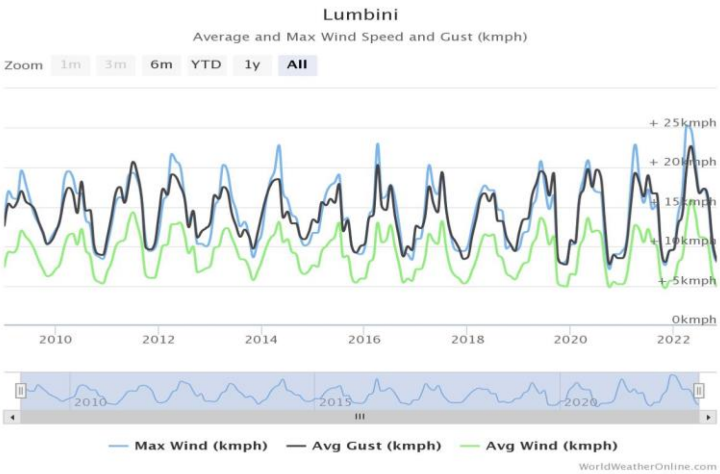

Figure-1 . Average and Max Wind Speed and Gust(Kmph)

(Cited: https://www.worldweatheronline.com/lumbini-weather-averages/np.aspx)

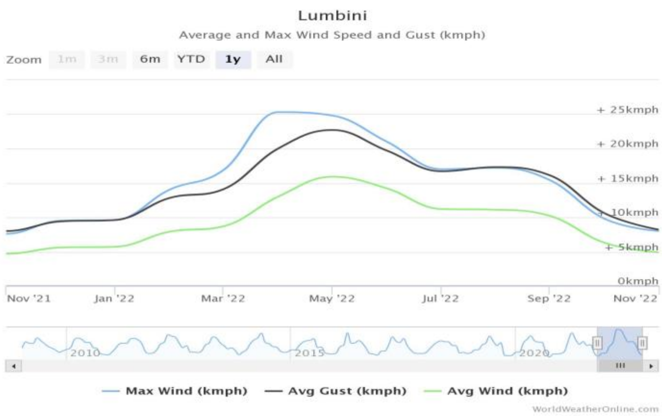

Figure-2. Average and Max wind speed and Gust (Kmphs)

(Cited:Source: https://www.worldweatheronline.com/lumbini-weather-averages/np.aspx) Pressure data of Lumbini

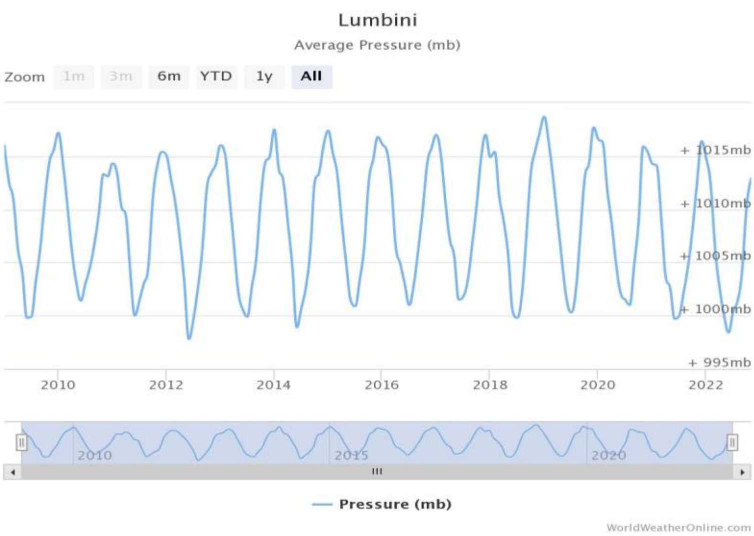

Figure-3. Pressure data of Lumbini

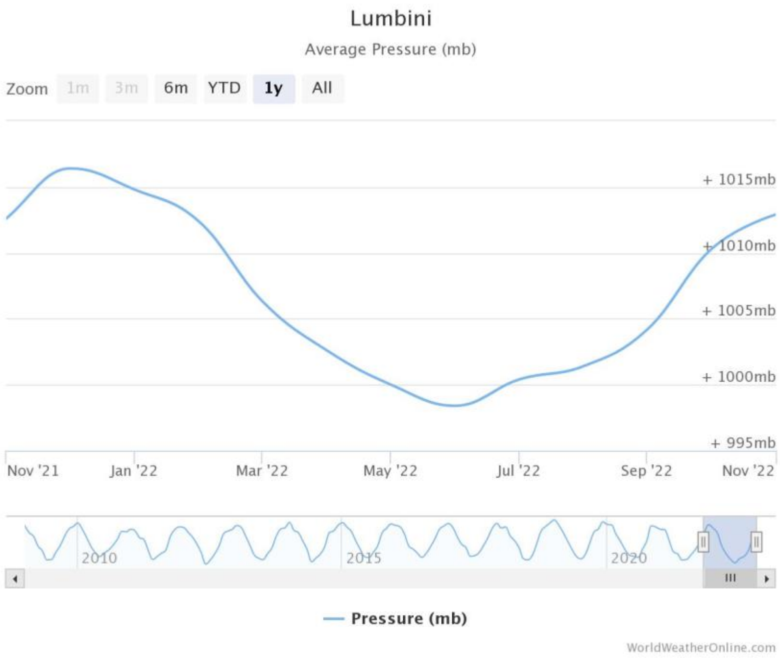

Figure-4. Pressure data of Lumbini

(Cited: https://www.worldweatheronline.com/lumbini-weather-averages/np.aspx)

Lumbini being a heritage site has to suffer power outages at the regular interval which can be minimized through study and implementation of the solutions of harvesting clean energy such as wind which seems feasible to establish solution along with other energy solutions available in the region as we could see the data supporting the conceptual solution. The data from the nearby airport also shows the same average wind speed as taken from internet.

The speed of wind is low on average of about 4 m/s. As per different papers the wind speed as low as 1.8 m/s could be harvested using favorable technology and methods. The wind speed is slow and shows the possibility of low wind speed turbines which seems feasible and could be tested for its viability in the world heritage site Lumbini. To create a sustainable energy during this low wind seasons, the proposed model is evaluated with various parameters and components.

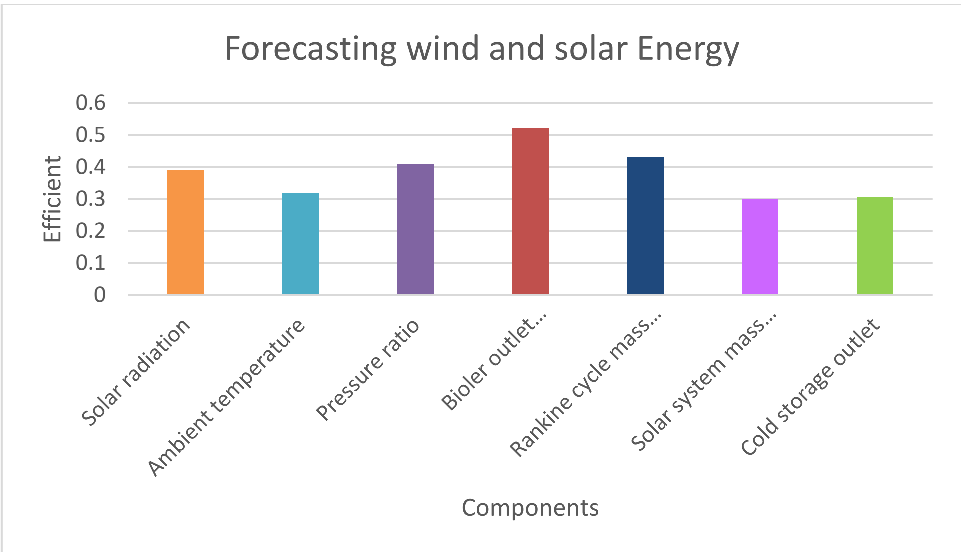

Figure- 5 model efficiency evaluation

Figure-5 depicts the efficiency of the proposed hybrid model on forecasting various parameters on improving the energy sustainability. These parameters are evaluated using various thermodynamic equations. The weather forecasting result of the proposed approach indicates that, the proposed model more efficiently analyse the various parameters to accurately predict the speed of the wind and solar system.

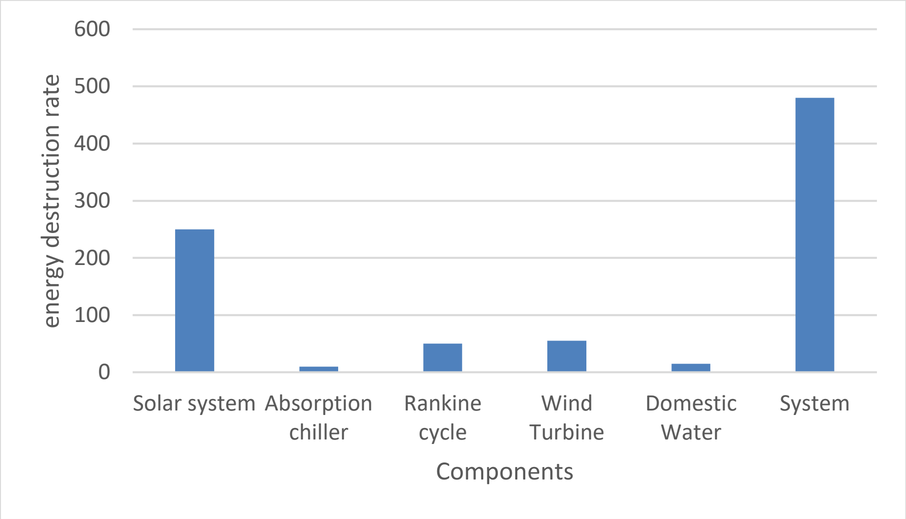

Figure-2 Energy destruction rate prediction

Energy destruction rate of the proposed model on various proposed component is depicted in the figure-2. The result of the analysis shows, the highest destruction rate is analysed from solar system and lowest rate is analyzed in absorption chiller. The overall destruction rate of the proposed model is depicted in the last bar in the figure-2. It is clearly understand from the above evaluation the proposed model is more efficient to adapt in high heritage area to store energy and to create a sustainable environment.

Conclusion:

Nepal with limited resources such as fossil fuel which needs to be imported from other countries leads to dependency on the source of energy which is depleting continuously the earth. The use of biomass cannot cater for the increasing demand for energy so Nepal needs to focus on clean energy which is safe for the environment as well as lead to a self-sustaining economy as a whole by limiting its dependency on energy needs to other countries. To achieve this extensive research is needed to find the viability and feasibility of clean energy and its implication in Nepal. The overall result shows that, the proposed hybrid model has more than 80% efficiency on forecasting weathers condition and stored for future purpose. And the exergy efficiency of the mode is reached to more than 50%. Ans the energy loss ratio analyses shows, very few amount of energy are loss during power generation.

After exploration of the area and the analysis of internet weather sources as well as the data taken from the airport as shown in appendix shows the speed of wind on average per year is 4 m/s which seems feasible to harvest wind energy from low speed wind turbine which could be implemented technically but the viability and the detailed project analysis are needed to adapt it to the heritage site such as Lumbini.

Compliance with Ethical Standards

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Conflict of Interest

The authors declare no conflict of interest.

Ethical approval:

This article does not contain any studies with human participants or animals performed by any of the authors.

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