ASSESSMENT OF RENEWABLE ENERGY SYSTEMS IN NORTHERN PHILIPPINES USING GEOSPATIAL TOOL*KIT*

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ABSTRACT

The Philippines Geospatial Toolkit (GsT) is a map-based renewable energy resource data and used geographic information systems (GIS) for energy resource assessment. Such GsT also developed an optimization software HOMER for distributed hybrid power analysis. The new version of the GsT with contained high-resolution remote sensing data, lend more analytical processing time and could explored for assessment of renewable energy systems. Two case studies were presented to explore how the PGsT can be used to assess renewable energy systems in northern part of the country: (1) a site selection for solar panel installation at government buildings in Dingras was conducted for assessing potential solar energy installation from which ideal sites for solar panel placement on building rooftops were determined.

Geospatial analysis showed that the average solar energy was 5.25 kW/m² and could generate 4,500 kW on large rooftop buildings; and (2) in town of Adams, the energy power generated from the solar and wind energy was assessed for feasible power plant for the area. Weighted overlaid theme maps of solar power density, slope, landuse and elevation showed varying degrees of suitability of solar energy in the area. On wind energy assessment, overlaid theme maps of wind power density, distance to major road network, distance to inclusionary areas, landuse and slope showed delimitation of suitable areas suited for wind power generation.

Using HOMER for optimization of solar-wind hybrid energy systems, revealed shared of 51% for wind and 42% for solar energy production which were feasible with payback periods of 5 years.

1. INTRODUCTION

The northern part of the Philippines was endowed with natural resources, including abundant sources of renewable energy such as biomass, solar and wind energy. One famous and the first in Southeast Asia was the wind farm located in Burgos, Ilocos Norte. The 150MW Burgos wind farm is the biggest wind farm in the Philippines and the first wind project nominated for the Philippine Government's feed-in-tariff incentive scheme. The onshore wind farm was commissioned in November 2014 and was owned and operated by the EDC Burgos Wind Power Corporation (EBWPC), an affiliate of Energy Development Corporation (EDC). Development included the 87MW first phase and the 63MW second phase. The ground-breaking ceremony was held in April 2013 and the construction works began in June of the same year. Burgos consisted of 50 Vestas V90 wind turbines with a rated capacity of 3MW each. The first phase included the installation of 29 wind turbines and the construction of a wind farm substation, access roads and a 42 km overhead transmission line. The remaining 21 turbines were installed in the second phase. Each wind turbine rested on a tubular steel tower, had a 75 m hub height and 9 0m rotor diameter and offered a swept area of 6,326 m². The wind turbine generators were expected to have an average life period of 20 years. The wind farm was expected to generate approximately 370 GWh of electricity a year, which used to power more than two million households, while offsetting approximately 200,000t of CO_2 emissions annually.

In February of 2015, USAID and the Philippine Department of Energy launched two state-of-the-art tools focused on renewable energy development: the 2014 Wind Energy Atlas for the Philippines; and the Geospatial Toolkit (GsT). Through the U.S. Enhancing Capacity for Low Emission Development Strategies (EC-LEDS) Program, the U.S. and Philippines were partnering to accelerate the achievement of Philippines' national renewable energy goals. The Philippine officials and investors used these powerful new tools to advance the development of clean and renewable power sources.

The Philippines Renewable Energy Program began in 2011, setting an ambitious target to triple the country's renewable energy output by 2030. Officials aimed for wind to constitute about 24 percent of the renewable portfolio, resulting in 2,345 MW from wind by 2030. With wind generation potential in the Philippines estimated to be 76,600 MW, there was plenty of resource availability that was poised for development. Energy experts from the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) provided the technical assistance to develop the tools. The 2014 Wind Atlas employed sophisticated modeling programs and high performance computing to analyze very large quantities of up-to-date wind resource data and provide accurate maps outlining areas for ideal wind power development. The GsT consolidated all renewable energy data in one place, providing a one-stop source of information on resources like biomass, hydro, solar and wind around the country. The GsT mapped the resources in relation to key infrastructure like roads and transmission lines, providing the government and private sector important information for investments in new generation.In the present world, every country is giving important place on energy security and sustainable development; hence role of renewable energy has become ever more significant. Ensuring energy security, energy resources used in the country in the future need to be diversified. Also to ensure the continuity of supply, energy mix need to be rationalized considering important factors, such as economic cost, environmental impact, reliability of supplies and convenience to consumers.

The hybrid renewable power generation was a system aimed at the production and utilization of the electrical energy stemming from more than one source, provided that at least one of them was renewable. Through this research, it was expected to give concern about development of the wind-solar hybrid power generation systems where wind solar potential was high in northern provinces in the country. Under this case study, solar energy and wind energy potentials were investigated at geographically different locations in northern Philippines (in the towns of Dingras and Adams, Ilocos Norte using NREL's Geospatial Toolkit. Selected located wind and solar energy systems were analyzed using Hybrid Optimization Model for Electric Renewables (HOMER) software with technical and socioeconomics data. The software was a micro-power optimization model for both off-grid and grid connected power systems in a variety of applications.

2. MATERIALS AND METHODS

Initially, literature review was done to get better understanding about the energy situation and problems of energy sector in the country. Designing wind-solar hybrid system was relatively new concept in the Philippine context. Hence, related literatures were reviewed in order to get more insights in design and selection of models to identify wind and solar potentials in northern Philippines, as a case study and previous studies were analyzed that has been carried out in the country and elsewhere.

2.1 The Case Studies

Two case studies on renewable energy assessment were conceived in the northern part of the Philippines, namely, in the town of Dingras located in the northeastern part and in the indigenous northern town of Adams in the province of Ilocos Norte. In Dingras, selected government buildings rooftops were geographically located to estimate the solar energy power for photovoltaic lighting systems using the combined use of the NREL's Geospatial Toolkit solar energy data and GIS spatial analysis techniques.In Adams, suitability of stand-alone solar, wind and hybrid systems was evaluated using the NREL's Geospatial Toolkit solar and wind energy data and applying HOMER software to optimize the feasible renewable energy mix coupled with engineering economy indicators (net present value, internal rate of return and payback period; and greenhouse gases emission reduction.

2.2 The Geospatial Toolkit

The Geospatial Toolkit (GsT) was a map viewer developed by the National Renewable Energy Laboratory (NREL). The toolkit helped energy planners, project developers, researchers and others identify areas of a country that showed good potential for renewable energy projects. The toolkit displayed renewable energy data along with information about the geography, location of population centers, borders, and transportation and power infrastructure. The toolkit was integrated with HOMER, a power system simulation and optimization model, originally developed at NREL and currently owned by HOMER Energy LLC. HOMER integration with the toolkit makes it possible to automatically populate HOMER inputs using weather data from the toolkit to get started with HOMER analysis. Geographic data in the country came from different sources, including NREL's renewable resource database, resource assessment programs in each country, and government ministries and research institutions responsible for maintaining geographic datasets for the country. For a list of available

2.3 The HOMER Software

HOMER simulated the operation of a system by making energy balance calculations in each hourly time step of the year. For each time step, HOMER compared the electric demand in that time step to the energy that the system can supply in that time step. Then, it calculated the flows of energy to and from each component of the system. HOMER performed these energy balance calculations for each system configuration that wants to be considered. It then determined whether a configuration is feasible, i.e., whether it could met the electric demand under the specified conditions, and estimates the cost of installing and operating the system over the lifetime of the project.After simulating all of the possible system configurations, HOMER displayed a list of configurations sorted by net present cost (NPC), i.e. lifecycle cost, which could be used to compare the different system design options. The NPC of a component was the present value of all the costs of installing and operating that component over the project lifetime, minus the present value of all the revenues that it earns over the project lifetime. HOMER calculated the NPC of each component in the system, and of the system as a whole. For information about HOMER, see http://www.homerenergy.com/.

2.4 Wind-Solar Hybrid Power Generation System

The hybrid power generation concept was a system aimed at the production and utilization of electrical energy coming from more than one source within an integrated arrangement. The hybrid system studied in Adams town is one combining solar PV and wind turbines with power conditioning units such as inverters. Hybrid wind turbine and solar PV modules offer greater reliability than any one of them alone, because local energy supply cannot depend entirely on any one of these sources.In addition to *this, as well as* being indigenous and free, renewable energy resources also contributed to the reduction of pollution emissions.In this case study, the proposed hybrid power generation system made use of solar PV and wind turbine to produce electricity and supply the load by connecting to the grid. A schematic of a typical grid connected wind-solar hybrid system is shown in Figure 1.

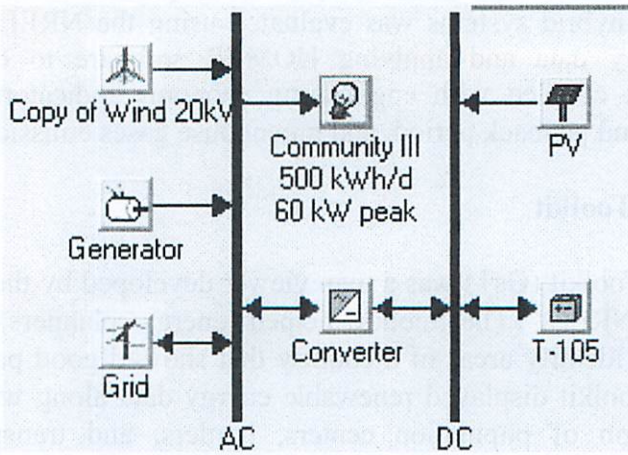


Figure 1. Wind and solar hybrid system design using HOMER software.

2.5 Designing and Modeling of Hybrid System with HOMER

The Hybrid Optimization Model for Electric Renewables (HOMER), which was copyrighted by the Midwest Research Institute (MRI) was a computer model developed by the US National Renewable Energy Laboratory (NREL) to assist the design of power systems and facilitate the comparison of power generation technologies across a wide range of applications [HOMER, ver. 2.81 Beta]. HOMER was used to model a power system physical behavior and its life-cycle cost, which is the total cost of installing and operating the system over its life time. HOMER performed three principal tasks, simulation, optimization and sensitivity analysis based on the raw input data given by user. In the simulation process, the performance of a particular power system configuration for each hour of the year was modeled to determine its technical feasibility and lifecycle cost. HOMER simulated wide variety of power system configurations, comprising any combination of PV array, wind turbines, run-off-river hydro turbines, generators and battery bank systems with grid connection or off grid that can serve electrical loads and thermal loads. The simulation process served two purposes. First, it determines whether the system is feasible. Second, it estimated the lifecycle cost of system, which was the total cost of installing and operating the system over its lifetime

3. RESULTS AND DISCUSSION

3.1 Location of the Study Area

The case study area is located in the northern part of the Philippines. For the first case study area was situated in Dingras, Ilocos Norte while the second site was in the indigenous town of Adams (Fig. 2). The only state university in the province is the Mariano Marcos State University (MMSU) located in Batac City. Figures 2 and 3 show also the wind and solar energy of the area.

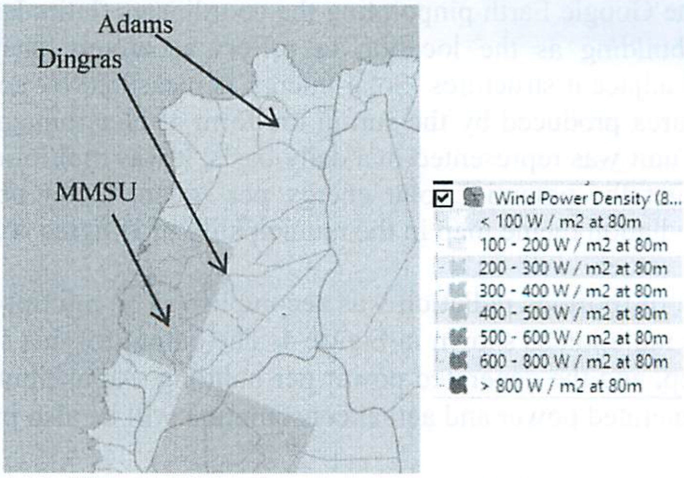


Figure 2. Location of study sites overlaid with wind power density.

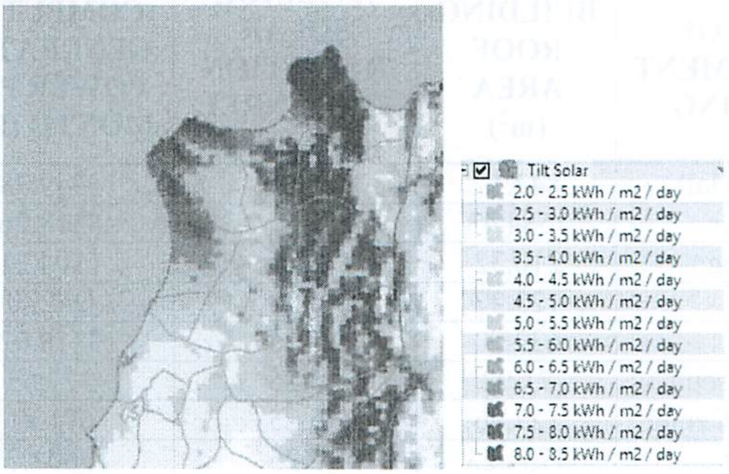


Figure 3. Tilt solar power density in the study sites.

3.2 Solar Energy Case Study in Dingras

Dingras is a second class municipality and known as "The Rice Granary of Ilocos Norte" due to its vast agricultural lands. It lies on the southeast part of the province, 20 kilometers south of Laoag City, 85 kilometers north of Vigan, 250 kilometers from Baguio City and 466 kilometers north of Manila. The municipality of Dingras had a total land area of 17,962 hectares, ranks 8th in size among the 23 municipalities including Laoag city. It accounted for practically 5.2% of the total land area of Ilocos Norte and corresponding percentage to the municipal area composed of thirty one barangays. Six were on the poblacion and twenty five in the rural area. The government buildings around the municipality of Dingras (Poblacion Area) namely: (Municipal Hall, Evacuation Center, Civic Center, Old and New Public Market, RHU, BFP, ABC Hall, JosefaLlanesEscoda Museum, Women's Training Center, BalayDingras, and Mothering Center) and the 31 Multi-Purpose Hall in each barangay.

To develop a process for solar panel placement site selection, the micro-scale area analysis was carried out for building rooftops only. The focus of this case study was on the development of an approximation of total roof area. Represented buildings were accurately located using the Google Earth pinpointing the coordinates (latitude and longitude) using the center of the building as the location to reflect accurately shape of the rooftop, roof orientation, and adjacent structures. Solar energy is measured by solar irradiance. It was the power per unit area produced by the sun in the form of electromagnetic radiation. Since the solar irradiance unit was represented in a daily basis, it was multiplied by the *number of days* in a month to get the potential solar energy per square meter per month (Table 1). The monthly solar radiation theme map in the municipality of Dingras was made.

Extraction of rooftops radiation was accomplished by multiplying the rooftop area and the annual solar radiation as shown in Figure 4. The output for this step was the building area and location map, and the generated power per building. An attribute table per building with the tables for generated power and actual consumption will be also produced.

Table 1. Summary of the estimated solar energy on some building in Dingas, IlocosNorte.

NAME OF GOVERNMENT BUILDING	BUILDING ROOF AREA (m^2)	AVERAGE SOLAR RADIATION FROM NREL ($kw/m^2/day$)	COMPUTED GENERATED POWER PER MONTH (kW)	ACTUAL GENERATED POWER PER MONTH (kW)
Municipal Hall	847.57	5.25	4449.78	5382.00
Civic Center	1584.43	5.25	8318.26	1248.00
DA Building	210.32	5.25	1104.21	261.00
PNP	123.27	5.25	647.20	213.00
Balay Ti Ili	632.00	5.25	3318.02	37.00
Escoda Museum	71.92	5.25	377.63	41.00
Mothering Center	127.96	5.25	671.81	120.00
Old Market	3734.23	5.25	19604.71	896.00
New Market	1263.92	5.25	6635.58	2435.00
RHU	232.69	5.25	1221.67	205.00
Bemonc	236.20	5.25	1240.07	80.00
BFP	115.16	5.25	604.62	224.00
Brgy. Albano	209.13	5.25	1097.93	150.00
Brgy. Madamba	107.22	5.25	562.92	130.00
Brgy. Dancel	149.33	5.25	784.00	40.00
Brgy. Espiritu	384.34	5.25	2017.78	65.00
Brgy. Bacsil	205.04	5.25	1076.48	75.00
Brgy. Capasan	49.017	5.25	257.34	53.00
MPH Suyo	87.87	5.25	461.34	48.00
MPH Bungcag	29.48	5.25	154.76	35.00
MPH Peralta	134.19	5.25	704.48	44.00
MPH Puruganan	66.35	5.25	348.35	48.00
MPH Guerrero	101.42	5.14	521.31	20.00

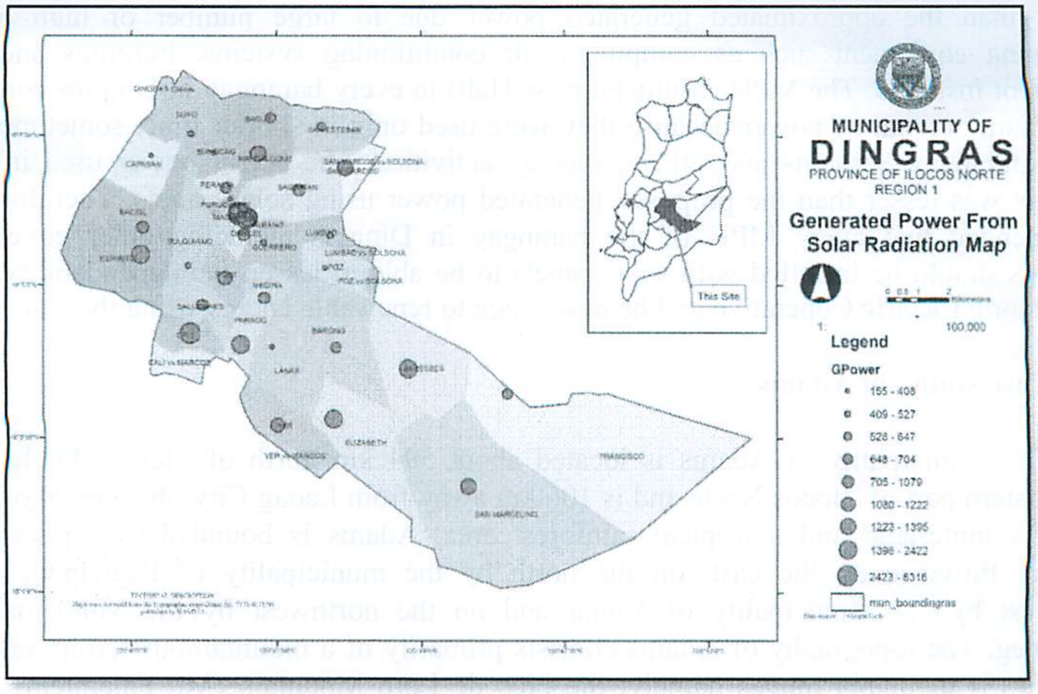


Figure 4. Generated solar energy density in some building rooftops in Dingras, Ilocos Norte.

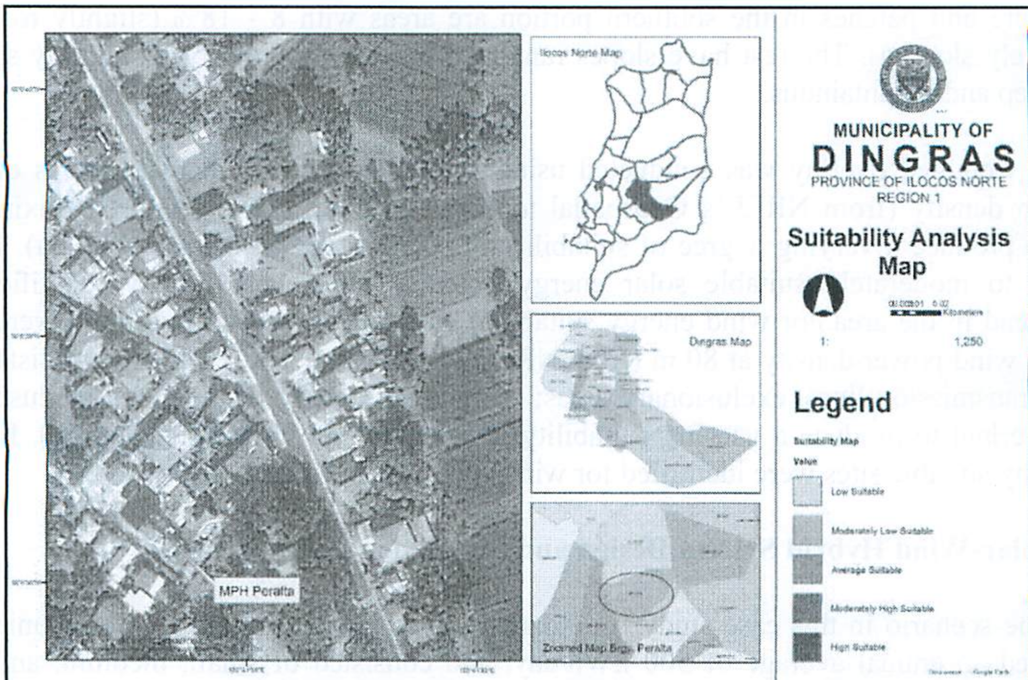


Figure 5. Suitability of solar energy of some building rooftops in Dingras, Ilocos Norte.

The most suitable building to the installed with solar panels were the buildings with greater building roof area with solar radiation estimates ranging from 5.25 to 5.14 kW/m², in the entire municipality of Dingras. The greatest building roof based from the table was the Civic Center with an area of 1,584.43 m² and if installed with solar panels, it generated an approximately 1,248 Kw which was greater than the actual power consumed by the said building. The Municipal had a building roof area of 847.877 m² and can generate a power of 4,449.78 Kw. However, the average monthly energy consumption in the said building was greater than the approximated generated power due to large number of high electric consuming equipment such as computers, air conditioning systems, lightings and other equipment installed. The MPH (Multi-Purpose Hall) in every barangay in Dingras consumed a minimum amount of power because they were used only in shorter time, sometimes only during Barangay Sessions and other barangay activities. The actual power used in every barangay was lesser than the proposed generated power using solar panels. Therefore, it is recommended that every MPH of the barangay in Dingras including other government buildings should be installed with solar panels to be able to lessen the dependability in the Ilocos Norte Electric Coperative and be more open to renewable energy using the sun.

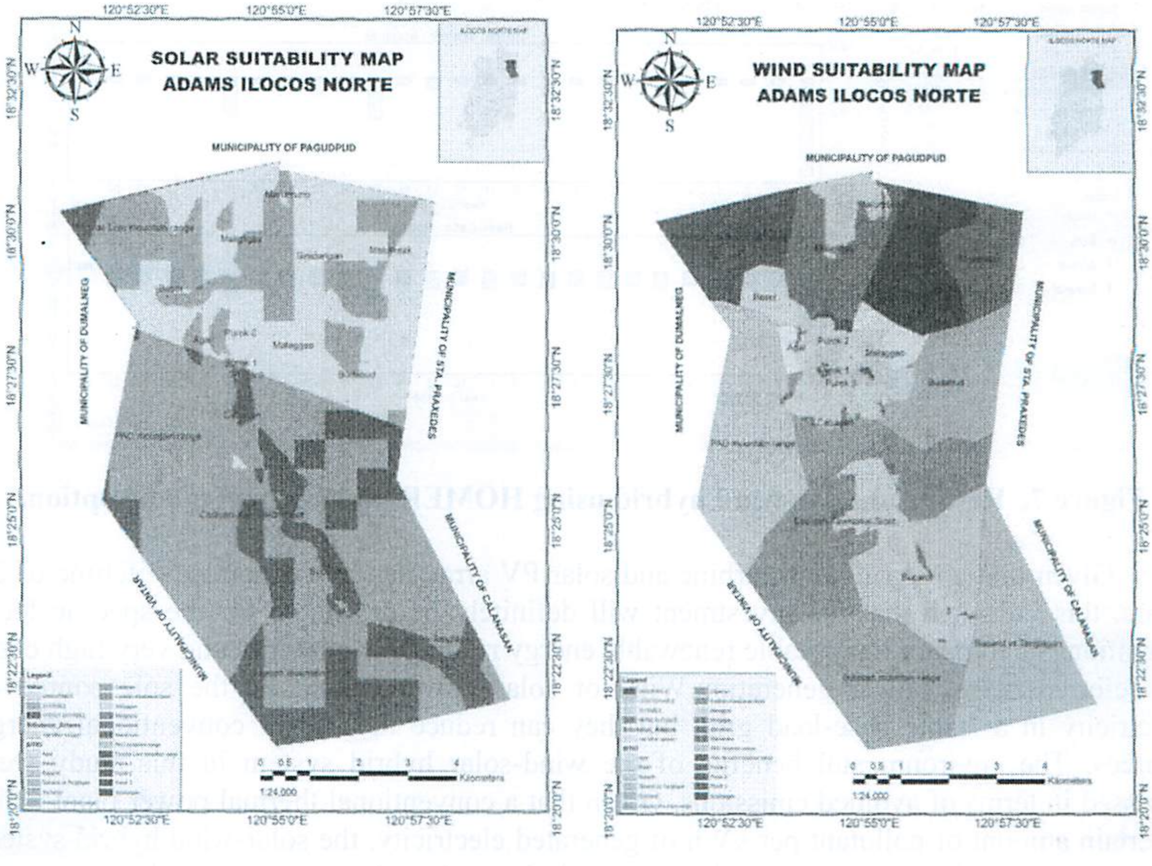
3.3 Case study in Adams

The municipality of Adams is located about 594 km north of Metro Manila at the Northeastern part of Ilocos Norte and is 106 km away from Laoag City, the capital of Ilocos Norte. A hinterland and a tropical rainforest area, Adams is bounded by Apayao and Cagayan Province on the east, on the north by the municipality of Pagudpud, on the southwest by the Municipality of Vintar and on the northwest by the Municipality of Dumalneg. The topography of Adams consists primarily of a mountainous terrain encircled by three (3) mountain ranges namely: the Pico de Loro Mountain (Mt. Palemlem) on the northwest; Mt. Pao on the southwest; and Mt. Mangnas on the southeast. Elevation is as high as 4,300 feet above sea level; and with lowest elevation at 1,500 feet above sea level is the urban core (poblacion) with 0-8% slope (nearly level to gently rolling). Northward from the urban core and patches in the southern portion are areas with 8 - 18% (slightly rolling to moderately sloping). The rest have slopes ranging from 18% to over 50%, slightly steep to very steep and mountainous.

A weighted overlay was conducted using spatial analysis of thematic maps of solar radiation density (from NREL's Geospatial toolkit, elevation, slope, landuse, proximity to roads to produce a varying degree of suitability of solar energy in Adams (Fig. 6a). Highly suitable to moderately suitable solar energy potential sites were mostly identified and widespread in the area.For wind energy suitability assessment, seven (7) criteria were used, namely, wind power density at 80 m (from NREL's Geospatial Toolkit); location distance to power transmission lines, exclusionary areas; population density; slope; and landuse maps were overlaid to produce a varying suitability of wind energy in Adams (Fig. 6b). Limited and spotty suitable sites were identified for wind energy in the area.

3.4 Solar-Wind Hybrid System Design and Simulation Using HOMER

The scenario in this case study in Adams was under the option of Community III - consumed an annual average of 500 kWh/day, and consisted of small, medium, and large houses, two stores, and a primary school. The distribution system required about 20 km of wire. The load profile had one daytime peak in the early morning and an evening peak between sundown and sunset. The daytime load was flatter than that of the small village because of the cumulative effect of varying loads of the larger number of different sized houses. For each time step, HOMER compared the electric demand in that time step to the energy that the system could supply in that time step. Then, it calculated the flows of energy to and from each component of the system. HOMER performed these energy balance calculations for each system configuration that wanted to be considered. It then determined whether a configuration was feasible, i.e., whether it could meet the electric demand under the specified conditions, and estimated the cost of installing and operating the system over the lifetime of the project. After simulating all of the possible system configurations, HOMER displayed a list of configurations sorted by net present cost *(NPC), i.e. lifecycle* cost, which could be used to compare the different system design options. The NPC of a *component* was the present value of all the costs of installing and operating that component over the project lifetime, minus the present value of all the revenues that it earned over the project lifetime. HOMER calculated the NPC of each component in the system, and of the system as a whole.



(a) Solar energy **(b) wind energy**

Figure 6. Suitability of (a) solar and (b) wind energy in Adams, Ilocos Norte.

Figure 7 shows the categorized HOMER optimization results at a grid model scenario. In each category of different design types, it showed only the lowest net present cost (NPC) configuration. It also showed overall HOMER optimization results were presented. It can be seen that four, 20 kW wind turbines and ten, 20 kW PV module with 1000kW converter gave the cheapest configuration. This configuration has COE of US$0.64 kWh; NPC value of US$1.74million; IRR of 18.7%; and payback period of 5 years.

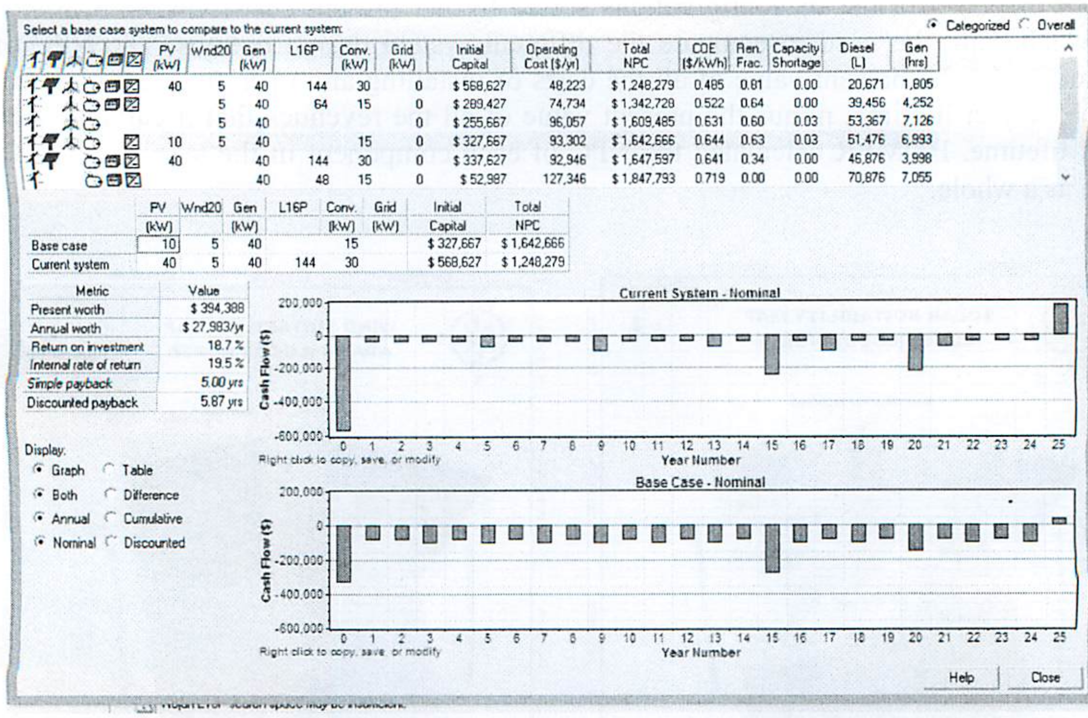


Figure 7. Results of solar-wind hybrid using HOMER under a grid model option.

Given that a typical wind turbine and solar PV array had an economical lifetime of 25 years, this indicated that the investment will definitely be profitable for the specific local conditions of comparatively stable renewable energy resource availability and very high costs of deferred diesel power generation.Wind or solar power cannot be the sole source of electricity in a stable base-load grid, but they can reduce the use of conventional energy sources. The environmental benefits of the wind-solar hybrid system in this study were assessed in terms of avoided emissions. Given that a conventional thermal power plant emits a certain amount of pollutant per kWh of generated electricity, the solar-wind hybrid system can be considered to cause an avoidance of emissions, since it generates the electricity with nearly zero pollutant emissions. Although there are many types of emissions related to electricity production, only CO_2 emission was considered in this study. CO_2 is the largest component of the emissions from conventional electricity production and may be considered as the greatest environmental impact caused by the established power industry. The amount of CO_2 produced by conventional diesel fuel is 0.6kg for 1 kWh. Hence, the reduction of CO_2 from energy saving would be 65,165 kg of CO_2 annually.

4. CONCLUSION

Wind-solar hybrid system has numerous advantages. One of the advantages was reliability, when solar and wind power production resources were used together, reliability was improved and the system energy service was enhanced. What this mean was that in the absence of one type of energy, another would be available to carry out the service. Other advantages were the stability and lower maintenance requirements, thus reducing downtime during repairs or routine maintenance. In addition to these, as well as being indigenous and free, renewable energy resources contributed to the reduction of pollution emissions. Solar, wind, and biomass energy could be seen as suitable alternatives to conventional power as shown using GsT for resource assessments in the study area and could be duplicated in other areas in the country.

However, the following should be considered in using GsT:

- The GsT does not contain data on available rooftop space for photovoltaic installations. However, the "Built-Up Area" land cover classification can be used as a proxy for areas with available rooftop;
- The tilt solar layer was the most appropriate dataset for analyzing resource availability for PV systems. Tilt solar represents the solar resource when a flat panel was titled at an angle equal to the location's latitude, which improved the efficiency of PV systems; and
- Alternatively, global solar data could be used to analyze resource available for PV panels that are oriented horizontally, with no tilt.

5. ACKNOWLEDGEMENT

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