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CORRELATION BETWEEN SUNLIGHT INTESITY AND WIND SPEEDS OF A COASTAL LOCATION

School of Technology

2015

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ABSTRACT

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Title	Correlation between Sun Light Intensity and Wind Speeds of a Coastal Location.
Year	2015
Language	English
Pages	38 + 12 Appendices
Name of Supervisor	Niemelä Riitta

This research is focused on conducting case studies of two coastal cities namely; Vaasa in Finland and Keta in Ghana. A one year historical data of these cities were analyzed at a monthly level to establish whether or not a coastal location with a good solar energy potentials could also have good wind energy potential.

The analysis in the two case studies using Karl Pearson coefficient of correlation shows that high solar energy potentials of the coastal cities do not necessarily translate into high wind energy potentials.

The study suggest that, there is a need to independently assess solar and wind energy resources of a coastal location in a solar and wind energy hybrid energy project.

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1 INTRODUCTION

1.1 Background

Throughout history the harnessing of energy in various forms around the world has presented great intellectual challenges and fueled many scientific and technological advancements. The technologies there are today were as a result of years of gradual advancements. /2/

Over the past centuries, human civilization, population and demand for energy have increased significantly. The main energy source that powered civilization was and still is fossil fuel. Fossil fuels such as crude oil, natural gas and coal are the backbone of today's economy.

However, the world is experiencing an increase in the use of renewable energy resources such as solar energy, wind energy, hydro energy, biomass energy, geothermal energy, tidal energy and ocean thermal energy. This increasing demand for alternative energy is a result of recent improvements in renewable energy technologies and the need to reduce greenhouse emissions (CO2, CO, NOx, and SOx.) /11/.

For millions of years the sun has been the earth's primary energy source. The sun is a nearly spherical star at the center of the solar system and radiates energy to the earth and the rest of the solar system in the form of light and heat.

The earth receives 174,000 terawatt (TW) of incoming solar radiation in the upper atmosphere. Approximately, 30 % of the sun's radiation is reflected back to space while the rest is absorbed by the clouds, the oceans and landmasses. The total energy absorbed by the earth's atmosphere, oceans and landmasses is 3,850,000 exajoules (EJ) per year. In 2002, this was more energy in one hour than the world used in one year /23/.

Solar energy in the earth's atmosphere results to other indirect energy resources such as wind energy, hydro energy and biomass energy.

1.1.1 Wind Energy as an Indirect Solar Resource

During the day, the sun rays heat different surfaces on the earth differently. Land masses get heated faster than water bodies in the day and in the night, the land masses loose their heat faster than water bodies.

The temperature difference between different surfaces on the earth causes the air on their respective surfaces to be unevenly heated. This inequality in air temperature causes the air to be in motion creating wind /2/.

The intensity of wind speeds varies from one place to another depending on the intensity of the factors necessary for wind formation.

1.1.2 Hydro Energy as an Indirect Solar Resource

Hydro energy refers to the potential energy in moving water. The sun energy is necessary to create the hydrological cycle needed to sustain the potential energy in water bodies. /2/

The sun energy heats the water bodies on the earth's surface causing them to evaporate in to the atmosphere. The water vapour then condenses in the cloud and fall as rain to replenish water the bodies.

This repetitive cycle of rain water replenishing water bodies is the mechanism by which hydro dams are maintained.

1.1.3 Biomass Energy as an Indirect Solar Resource

Biomass energy is the type of energy that is generated from plant and animal material.

During the day, green plants absorb sunlight by the help of chlorophyll in their leaves. Green plants also absorb carbon dioxide through their stomata and water from the ground by their roots through the stem to the leaves. The energy from the sun, the carbon dioxide and the water are used by the green plant in a process known as photosynthesis to make starch which is further converted into other plant materials.

In the earth's ecological system, the food chain comprises of both plants and animals that depend on each other for sustenance. Basically green plants absorb energy from the sun to grow and becomes food for other organisms like animals and micro bacteria /2/.

These plant and animal materials can be processed to create biomass energy for various uses.

1.2 Research Objectives

Firstly, this research is focused on the correlation between the primary solar energy (sunlight intensity) and wind energy (wind speeds which is an indirect energy from the sun) in coastal locations.

Secondly, this research is not only taking in to consideration the correlation between the sunlight intensity and the wind speeds in a costal location but also how this correlation could result in the selection of sites for solar and wind energy hybrid projects.

Finally, case studies were conducted on two coastal locations namely Vaasa-Finland and Keta-Ghana in order to statistically illustrate the correlation between the sunlight intensity and wind speeds of coastal location.

1.3 Research Questions

This research focuses on answering the following questions:

1. Is there a correlation between sunlight intensity and wind speeds at coastal locations?

2. Could the correlation between sunlight intensity and wind speeds at a coastal location be used in site selection for solar and wind energy hybrid projects?

1.4 Research Methodology

This research is exploratory in purpose and has adapted a multiple case study strategy /13/. There is a total of two cases that will be considered in this research.

The first case takes in to consideration the correlation between sunlight intensity and wind speeds in Vaasa-Finland from January to December based on historic data.

The second case also takes in to consideration the correlation between sunlight intensity and wind speeds in Keta-Ghana from January to December based on historic data.

2 RELATIONSHIP BETWEEN SOLAR AND WIND ENERGY

Studies have shown that, the sun energy is the most abundant energy source of the earth. The sun energy is the highest at the equator and lesser at the North Pole and the South Pole. This difference in solar energy radiations on the earth's surface results in a convective flow of air between the North and South Poles and the equator of the earth to create a global wind pattern /2/.

2.1 Key Concept

The original source of wind energy is radiation from the sun. The sun radiation heats the clouds, the land masses, oceans and other water bodies in a different way. These different bodies on the earth intends heat their surrounding air to create temperature gradients. The temperature gradient created causes convection and pressure changes which result in winds. An example is the land breeze that occurs at night in coastal areas, caused by the sea retaining the heat from the sun better than the land.

On the global scale, the earth near the equator receives more of the sun energy than the north and south poles. This causes warm air to rise up from the equator and cooler air to flow in from the north and south poles. The direction of wind is traditionally taken to be where it comes from, so in the northern hemisphere the warm air rising up from the equator would give rise to a northerly wind at the ground level.

An enormous amount of power resides in the wind as about 1- 2% of the incident solar power of 1.37 KW/M2 is converted into winds /2/.

Winds are variable both in time and in location, with some parts of the earth exposed to frequent high winds and some to almost no wind. The higher intensity of solar radiation at the equator would have set up a north- south convective flow of air without the rotation of the earth on its axis. The earth's rotation causes a point on the earth to have a velocity towards the east that is highest at the equator, decreasing towards the poles and thereby creating global wind patterns /15/. Figure 1 shows a diagram of the global wind patterns /8/.

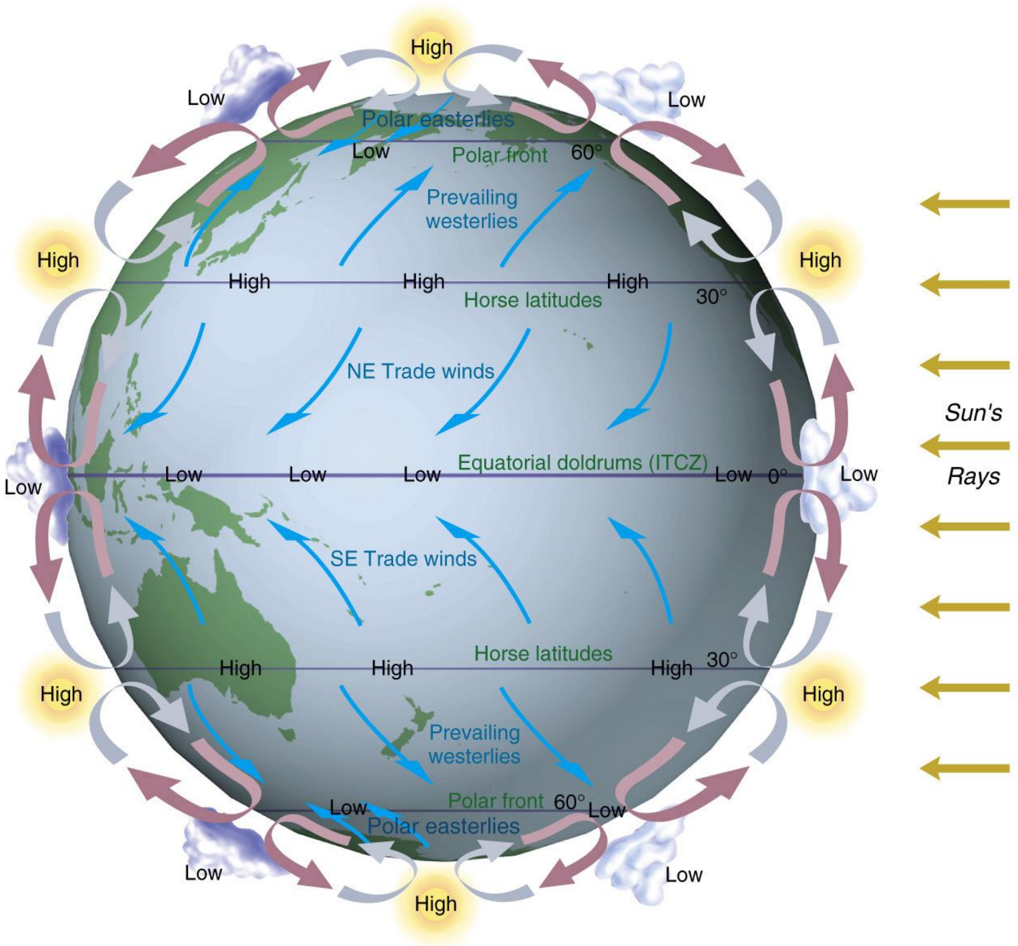


Figure 1. Global wind patterns.

2.2 The Concept of Solar and Wind Energy in a Coastal Location

As discussed in the earlier chapters, the energy in wind comes from the sun (indirect solar energy). During the day, some parts of the earth absorb more solar energy than the others, some parts reflect more of the sun ray back to space. Light-coloured surfaces and water reflect more sunlight compared to darker surfaces. This then causes land and sea breeze.

As the name depicts, the two breezes occurs along coastal areas or areas with large water bodies. Water and land have different heating abilities, water takes more time to warm up and is able to retain the heat better than land.

During the day, the land heats up faster and the air above it warms up a lot more than the air over the water. The warmer air over the land is less dense and begins to rise and thereby creating low pressure /16/.

The air pressure over the water is higher with cold dense air, which moves to occupy the space created over the land. The cold air that comes along is called a sea breeze. Figure 2 explains briefly how sea breeze works /4/.

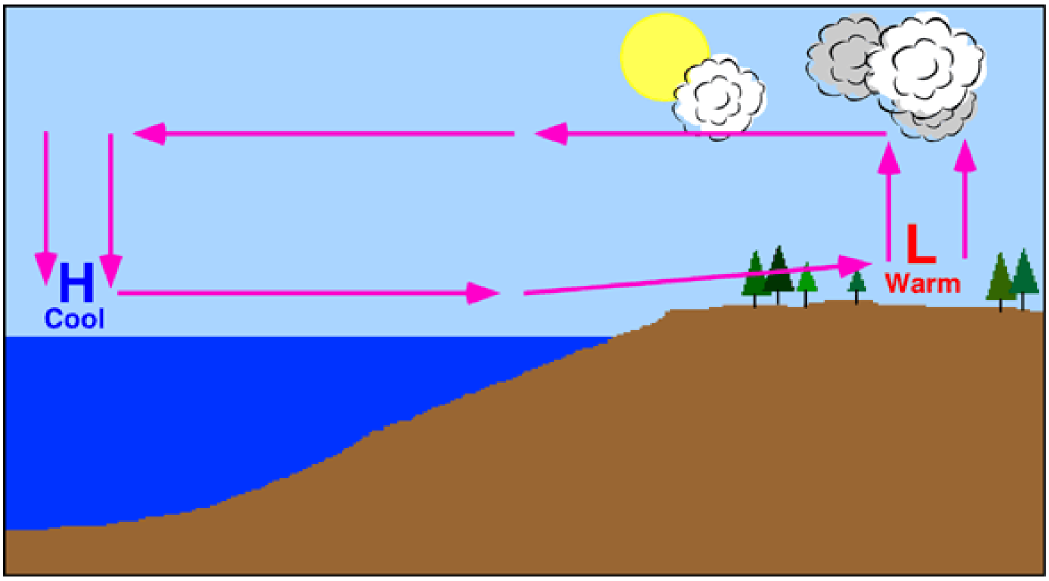


Figure 2. Sea breeze.

During the night, the reverse takes place. The land quickly loses its heat while the water retains its warmth. This means the air over the water is warmer, less dense and begins to rise, thereby creating low pressure over the water. Cold and dense air over the land begins to move to the water surface to replace the warmer rising air. The cool breeze from the land is called land breeze. Figure 3 explains briefly how land breeze works /4/.

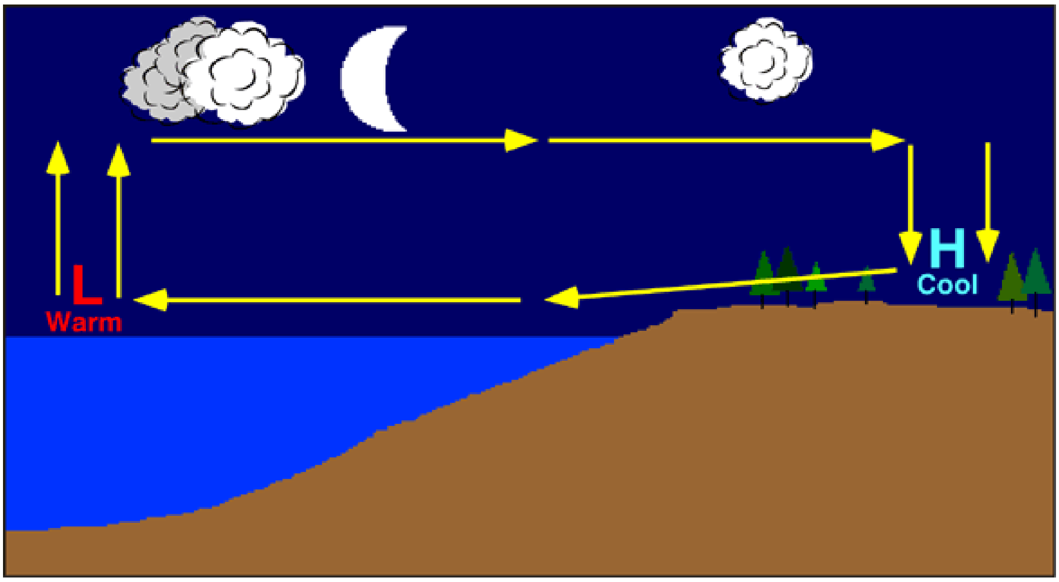


Figure 3. Land breeze.

3 METHODS OF DETERMINING SOLAR AND WIND ENERGY RESOURCES

Any energy project, such as solar and wind energy projects involve huge financial commitments and investments. Therefore, there is a need to assess the viability of the resources in order to establish accurate evidence to justify the necessary financial commitments.

The method of resources assessment varies from one type of energy resource to another. The methods may even vary with an individual energy resource.

3.1 Solar Energy Resource Assessment

Starting a solar energy project requires assessment of the characteristics of solar radiations at the chosen site. The various solar energy technologies are influenced by the characteristics of the radiations, such as /3/:

(a) The directional nature of the radiations which explains whether the sunlight radiations are direct or diffuse and its angle of incidence on the collector surface.

(b) The spectral nature of the radiations which shows what specific wavelengths of sunlight radiations there are effectively in the incident rays.

(c) The variability characteristics in the span of a few minutes; for instance how clouds will affect power production. Seasonal characteristics; for instance how climate pattern will affect the solar resource. Interannual characteristics; for instance how the resource will vary from year to year. Even decadal characteristics; for instance how climate change could affect the resource.

There are two main ways by which solar resource assessment data can be obtained namely ground-based measurement and satellite-derived measurement

In ground-based measurement, different types of instruments, such as active cavity radiometers, thermopile pyrheliometer and rotating shadowband pyranometer are mounted on site to collect data over a period of time. Ground-based measurements are known to be more accurate compared to satellite-derived measurements. Below in Figure 4(a, b and c) are the pictures of active cavity radiometers, thermopile pyrheliometer and rotating shadowband pyranometer respectively /9/.

(a) (b) (c)

Figure 4. Ground-based measurement instruments (a) active cavity radiometers (b) thermopile pyrheliometer (c) rotating shadowband pyranometer.

On the other hand, satellite-derived measurements are obtained from satellites in space. Imagery from satellites of cloud cover and ground conditions now permit the estimation of incoming direct and diffuse solar radiation reaching the earth at any location.

3.2 Wind Energy Resource Assessment

Correct estimation of the wind energy available at a particular location can make or break the economics of a wind energy project. A typical wind resource assessment of a site starts with preliminary assessment by utilization of existing data from national wind resource maps, nearby airports and other weather measurement sites to estimate the project's viability /12/.

Furthermore, a detailed on site assessment is initiated once the preliminary evaluations show that the project is promising. The detailed assessment is done by deploying a meteorological tower on site for at least a year. The meteorological tower must have the following instruments: an anemometer, a wind direction vane, a thermometer and a barometric pressure sensor for measuring wind speeds, wind direction, temperature and pressure respectively /12/.

Long-term validation of the wind data obtained from the site is needed to establish how consistent the on-site data will be in a long term, for example over a period of ten or more years. This is done by comparing the on-site data with historical data taken from a meteorological facility or airport closer or miles away from the site /12/. Figure 5 shows the diagram of a meteorological tower /18/.

Figure 5. Meteorological tower.

However, computer models are now available that can be used to estimate wind resources of a selected site /24/. These models are based on many years of historical weather data and can stand on their own or complement data taken by a meteorological towers with instrumentations at a project /12/.

4 SOLAR AND WIND ENERGY TECHNOLOGIES

Renewable energy technology is becoming increasingly important in today's energy market. This increase in demand for renewable energy has led to many scientific and technological researches aimed at improving the efficiency and effectiveness of renewable energy technologies.

Solar and wind energy technologies have also received attention in terms of research and development. The various solar and wind energy technologies there are today are as a result of many years of research and development commissioned by many governments and private institutions worldwide.

In this twenty first century, solar and wind energy contributes a significant amount of energy to the world's energy supply. Figure 6 shows the world's energy resource usage /7/.

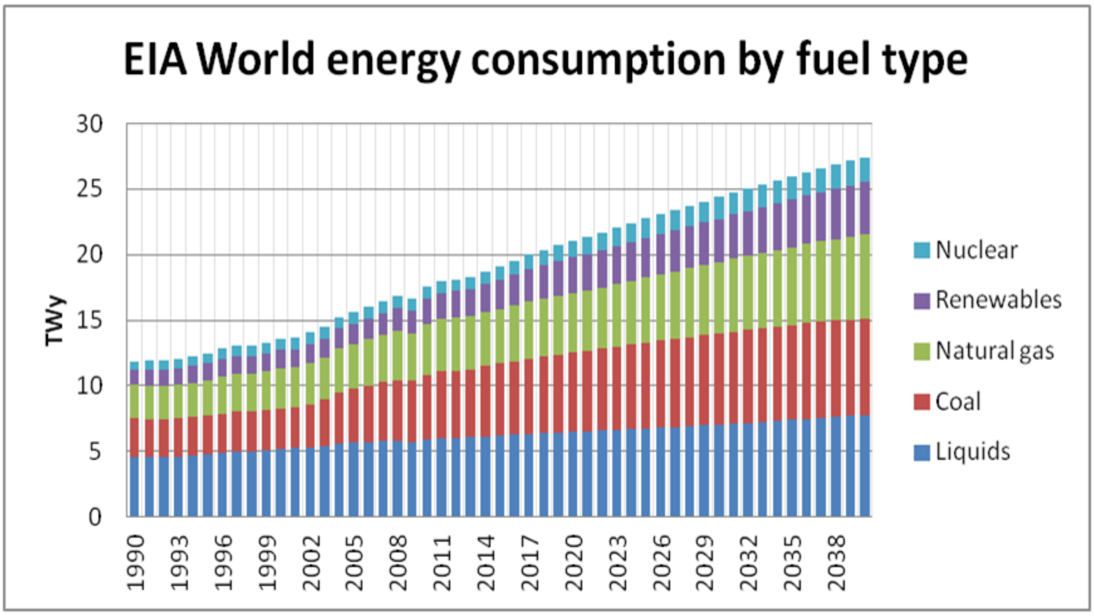


Figure 6. The world's energy usage.

4.1 Solar Energy Technologies

There are two main types of solar energy technologies namely photovoltaic technology and solar thermal technology.

Photovoltaic technologies use materials, such as semi-conductors and other amorphous materials to convert the sun's energy or photons into electrical energy. Semi-conductors are made into individual solar cell by doping with the appropriate impurities, such as boron and phosphorus to create a complete cell. The individual cells are arranged in arrays to make a solar panel. The most common semi-conductor used in manufacturing photovoltaic cell is silicon /3/. Figure 7 explains the working principle of photovoltaic technology /5/.

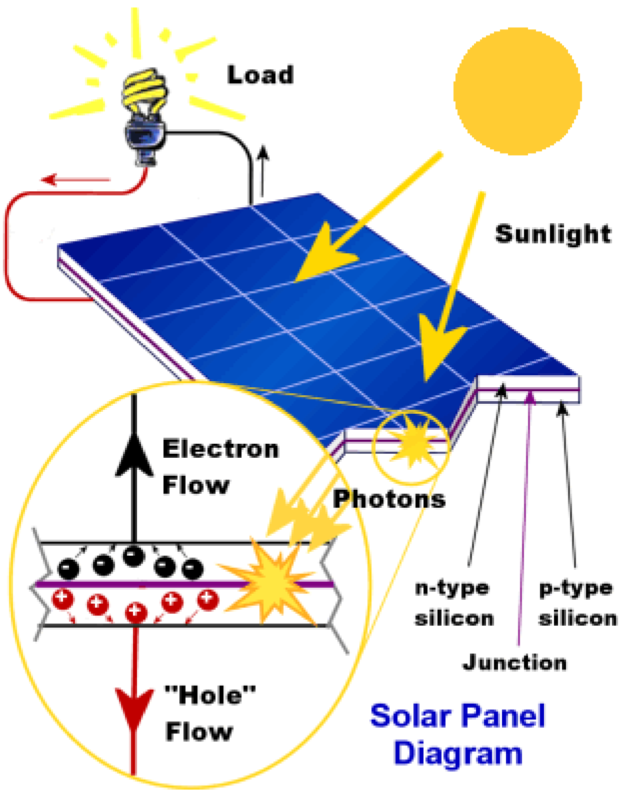


Figure 7. The working principle of photovoltaic technology. /5/

On the other hand, solar thermal energy uses various types of mirror and heat absorption technologies to concentrate or convert the sun's energy to heat energy which can be used to produce hot water, steam and other products.

These products can further be used in other processes such as electric power generation using steam turbines, hot water for factory processes and hot water for domestic use /3/. Figure 8 shows a typical working principle of a solar thermal energy system /6/.

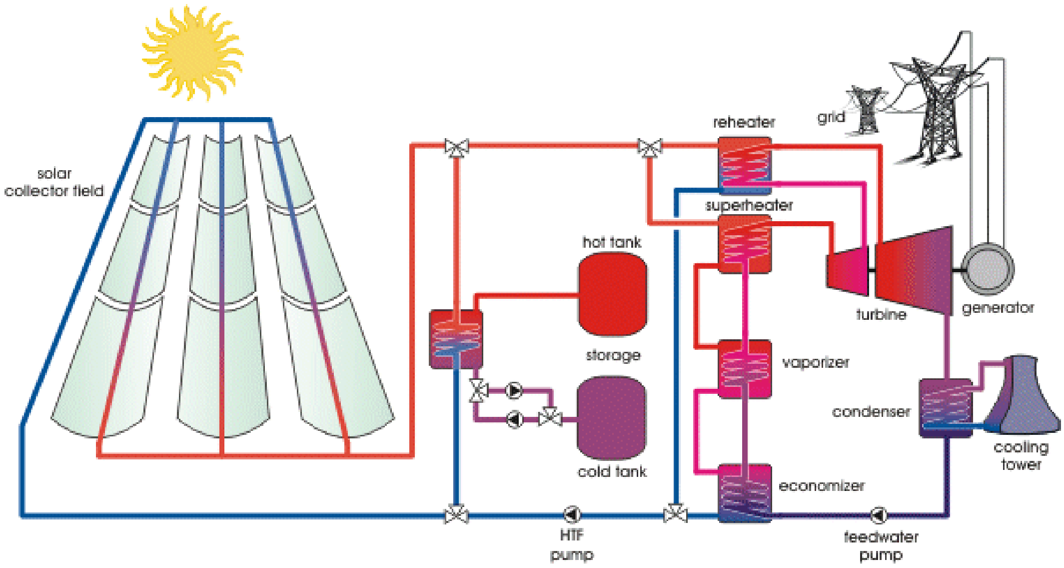


Figure 8. The working principle of a solar thermal energy system. /6/

However, there are newer solar energy technologies that are still at research and developmental stage. These newer technologies such as artificial photosynthesis may improve the way solar energy is harnessed in the nearest future /3/.

4.2 Wind energy technologies

Wind energy technology is divided into two main groups, namely horizontal axis and vertical axis wind turbines. Wind turbines are designed to convert the kinetic energy in wind into electrical energy /15/. Some of the common parts of a wind turbine are:

(a) The blade; is the part of the wind turbine that converts the kinetic energy in the wind into rotary motion in the main rotor shaft.

(b) The rotor shaft; it is the shaft that receives the low speed rotary motion of the blades through the hub to the gearbox.

(c)The gearbox; is a device that takes the low speed rotary motion from the main shaft and converts it into high speed rotary motion to drive the generator.

(d) The generator; it is the part of the wind turbine that takes high speed rotary motion from the gearbox and converts it to electrical energy. The generator is basically made of coper wire windings moving in magnetic fields and generates electricity by electron displacement due to magnetic field cutting effect on the coper wire windings during motion.

Horizontal axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower or a mast, and must be pointed into the wind. Smaller horizontal axis wind turbines are simply pointed by a wind wane while larger turbines generally use a yaw control system to point the turbine into the wind /15/.

The number of blades of a wind turbine varies for different types of horizontal axis wind turbine depending on their design, purpose and efficiency. Figure 9 shows a diagram of a typical horizontal axis wind turbine /10/.

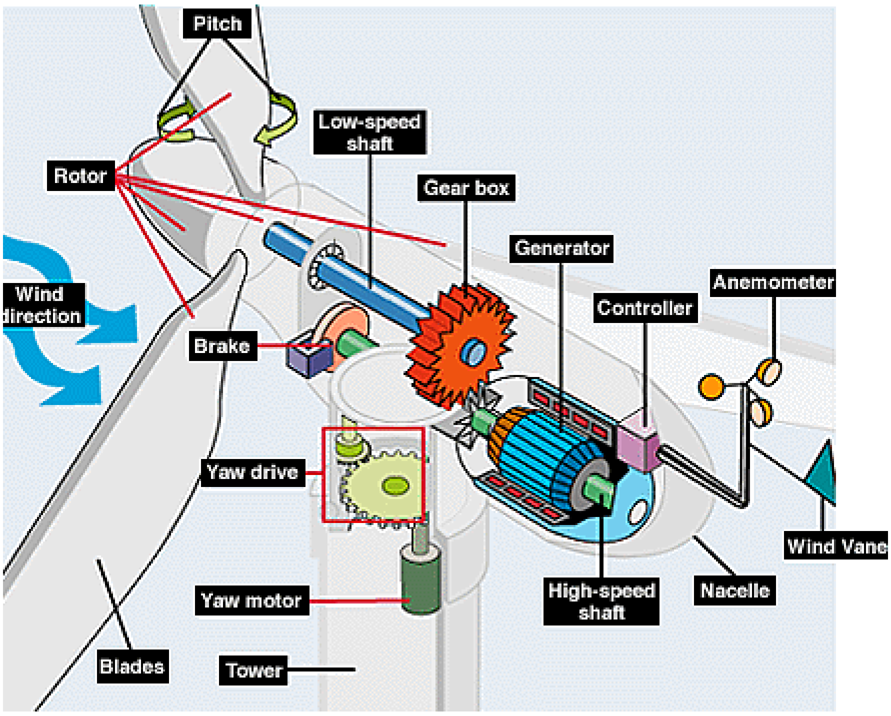


Figure 9. Horizontal axis wind turbine. /10/

Vertical axis wind turbines (VAWTs) have the main rotor shaft arranged vertically. One advantage of this type of arrangement is that the turbine does not need to be pointed into the wind to be effective /24/. This is also advantageous for sites where the wind direction is highly variable /15/.

There are different types of vertical axis wind turbines such as Darrieus wind turbine, Giromill and Savonius wind turbines. Figure 10 shows a typical vertical axis wind turbine /22/.

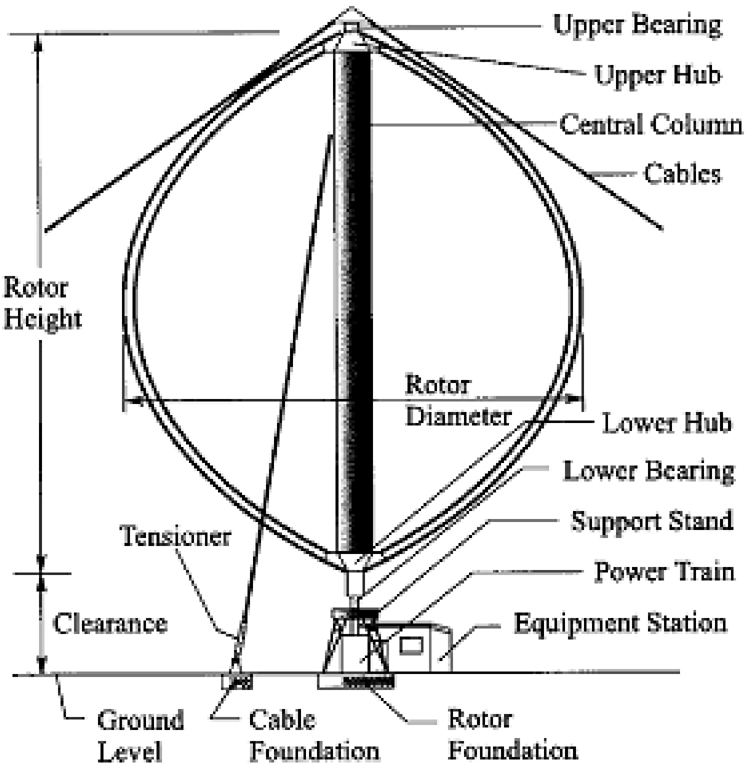


Figure 10. Vertical axis wind turbine. /22/

Also, there are some newer wind turbines technologies, such as airborne wind turbine that have great potentials and may dominate the future of wind turbine technologies.

An airborne wind turbine is a design concept for a wind turbine with a rotor supported in the air without a tower or a mast. They have the advantage of floating to altitudes higher than the conventional wind turbine can ever reach; this enables the airborne wind turbines to assess higher speed winds at higher altitudes. They also do not need expensive crane systems during installation since they do not need a tower or a mast /1/.

5 SOLAR AND WIND ENERGY IN COASTAL LOCATIONS

In this chapter, the research is aimed at statistically studying and analyzing the correlation between sunlight intensity and wind speed at two coastal locations namely Vaasa in Finland and Keta in Ghana.

Coastal locations were selected for this analysis. This is because, coastal locations have all the necessary parameters to create land and sea breeze. The surface of the sea and the surface of the shores (the land surrounding the sea) both absorbs sunlight differently and therefore creates the conditions necessary for wind formation (land and sea breeze).

5.1 Solar and Wind Energy Resource Data and Analysis Tool

This research deployed an international web-based tool known as Solar and Wind Energy Resource Assessment (SWERA).

The SWERA initiative brings together solar and wind energy resource data sets and analysis tools from a number of international organizations, such as National Aeronautic and Space Administration (NASA), National Renewable Energy Laboratory, German Aerospace Center (DLR), Risoe National Laboratory for Sustainable Energy, Brazil's national Institute for Space Research (INPE), State University of New York (SUNY), United Nations Environment Programme (UNEP), Global Environment Facility (GEF) and Risoe DTU in a dynamic user-oriented environment. The information and data provided on the site are freely available to the public and intended to support the work of policy makers, project planners, research analyst and investors /17/.

5.2 Units of Measurement

The solar and wind energy data obtained are in the form of direct nominal irradiance (DNI) and wind speeds respectively.

Direct nominal irradiance (DNI) is the amount of solar radiation received per unit area by a surface that is positioned perpendicular to the incident rays in a straight line from the direction of the sun at its current position in the sky. It is measured in kWh/sqm /24/.

On the other hand, the speed of the wind is the rate of change in the position of the air. It is also referred to as the velocity of the wind and it is measured in m/s /12/.

5.3 Case Vaasa-Finland

Vaasa is a coastal city at the south-western part of Finland and is the sunniest city in Finland /21/. Sea breeze occurs in Finland especially strongly in spring and early summer (March/April till July), and some later in the summer (August) but practically non-existent in September-February.

In autumn the sea might be warmer than land and in winter snow or ice cover is the same everywhere. Figure 11, 12 and Table 1 shows the solar and wind data of Vaasa /17/.

Table 1. Monthly average solar and wind data of Vaasa.

Months	**DNI (kWh/sqm)**	**Speed (m/s)**
January	0.48	6.85
February	1.5	6.63
March	2.89	6.06
April	5.2	5.82
May	7	5.62
June	7.46	5.36
July	6.89	5.4
August	4.73	5.52
September	3.48	6.12
October	1.79	6.86
November	0.89	6.82
December	0	6.85

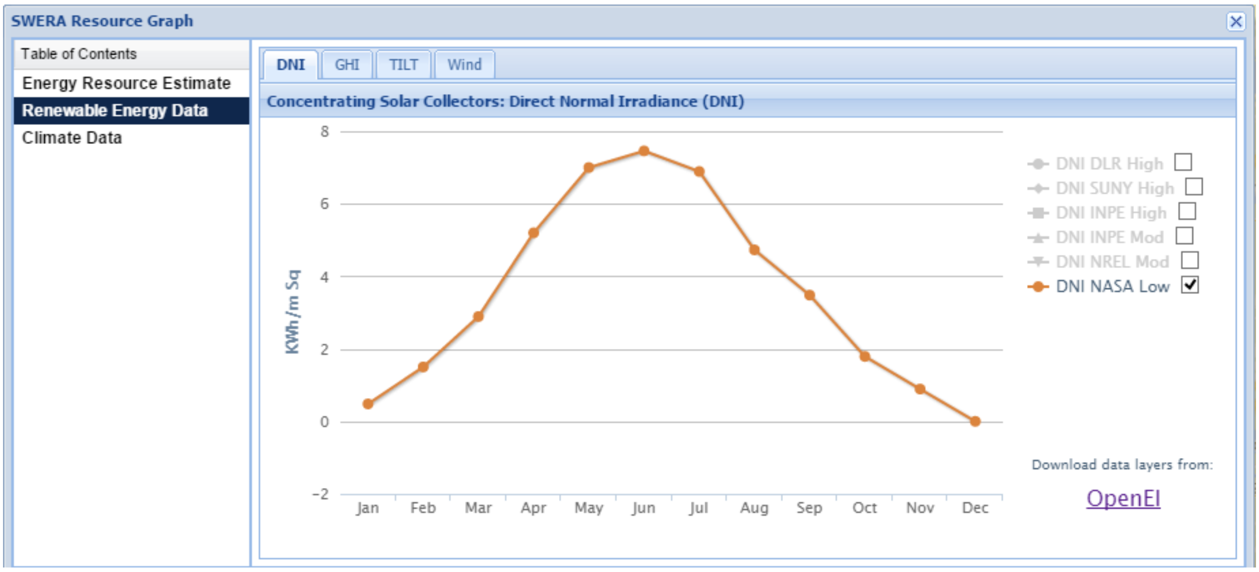


Figure 11. Monthly average DNI of Vaasa.

Figure 12. Monthly average wind speeds of Vaasa.

5.3.1 Correlation Analysis of the Solar and Wind Data of Vaasa

Table 2 shows the Karl Pearson coefficient of correlation analysis between monthly average direct nominal irradiance (DNI) and monthly average wind speeds in Vaasa. The Excel scatter graph is used in Table 3 to show the graphical distribution of the data.

Karl Pearson coefficient of correlation is denoted by the symbol r. It is one of the very few symbols that are used universally for describing the correlation analysis. /14/

Table 2. Karl Pearson coefficient of correlation analysis of solar and wind data of Vaasa.

Months	**DNI (X)**	**(X- $\bar{X}$) x**	**x^2**	**Wind speeds (Y)**	**(Y- $\bar{Y}$) y**	**y^2**	**xy**
January	0.48	-3.04583333	9.27710069	6.85	0.69083333	0.47725069	-2.10416319
February	1.5	-2.02583333	4.10400069	6.63	0.47083333	0.22168403	-0.95382986
March	2.89	-0.63583333	0.40428403	6.06	-0.09916667	0.00983403	0.063053472
April	5.2	1.674166667	2.80283403	5.82	-0.33916667	0.11503403	-0.56782153
May	7	3.474166667	12.069834	5.62	-0.53916667	0.29070069	-1.87315486
June	7.46	3.934166667	15.4776674	5.36	-0.79916667	0.63866736	-3.14405486
July	6.89	3.364166667	11.3176174	5.4	-0.75916667	0.57633403	-2.55396319
August	4.73	1.204166667	1.45001736	5.52	-0.63916667	0.40853403	-0.76966319
September	3.48	-0.04583333	0.00210069	6.12	-0.03916667	0.00153403	0.001795139

October	1.79	-1.73583333	3.01311736	6.86	0.70083333	0.49116736	-1.21652986
November	0.89	-2.63583333	6.94761736	6.82	0.66083333	0.43670069	-1.74184653
December	0	-3.52583333	12.4315007	6.85	0.69083333	0.47725069	-2.43576319
	ΣX= 42.31	Σx= 2.5E-08	Σ x^2 = 79.29769	ΣY= 73.91	Σy= -4E-08	Σ y^2 = 4.144692	Σxy= -17.29594165

Karl Pearson coefficient of correlation calculation:

$r = (\Sigma xy) \div (\sqrt{(\Sigma x^2) . (\Sigma y^2)})$

r = (-17.29594165) ÷ (√(79.29769) . (4.144692))

r = (-17.29594165) ÷ (√328.664501)

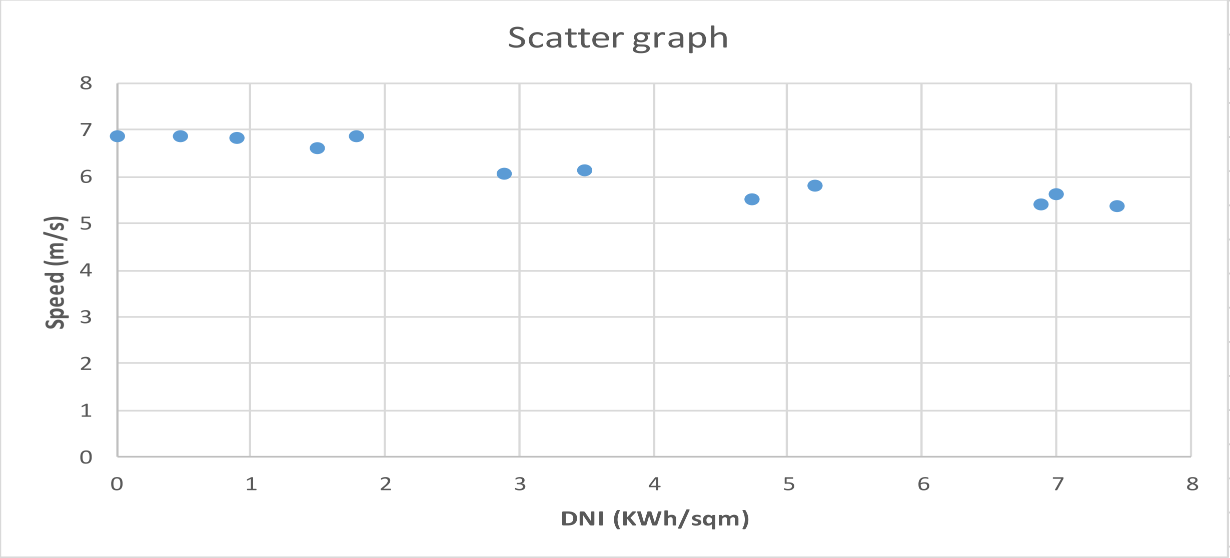
r = (-17.29594165) ÷ (18.1291065)

r = -0.9540427

In case Vaasa, the Karl Pearson correlation coefficient analysis shows a strong negative correlation of -0.9540427 between the direct nominal irradiance (DNI) and the wind speeds of Vaasa. This means that when direct nominal irradiance (DNI) increases, then wind speeds decrease or when wind speeds increase then direct nominal irradiance (DNI) decreases.

Table 3. Excel scatter graph of solar and wind data of Vaasa.

DNI (KWh/sqm)	Speed (m/s)
0.48	6.85
1.5	6.63
2.89	6.06
5.2	5.82
7	5.62
7.46	5.36
6.89	5.4
4.73	5.52
3.48	6.12
1.79	6.86
0.89	6.82
0	6.85



5.4 Case Keta-Ghana

Keta is a coastal town in the Volter region of Ghana. The settlement of Keta is between the Gulf of Guinea and the Keta lagoon; this makes the settlement one of the few coastal locations in Ghana with high wind speeds.

However, the geographical location of Keta between the Gulf of Guinea and the Keta lagoon makes it a good place for land and sea breeze occurrence and also a good choice for this research. Figure 13, 14 and table 3 shows the solar and wind data of Keta /17/.

Table 4. Monthly average solar and wind data of Keta.

Months	**DNI (kWh/sqm)**	**Speed (m/s)**
January	6.48	3.72
February	6.35	3.99
March	5.5	4.05
April	5.05	3.6
May	4.72	3.18
June	3.92	3.25
July	4.67	4.47
August	4.52	4.63
September	4.34	4.60
October	5.33	3.71

November	6.11	3.96
December	6.29	3.33

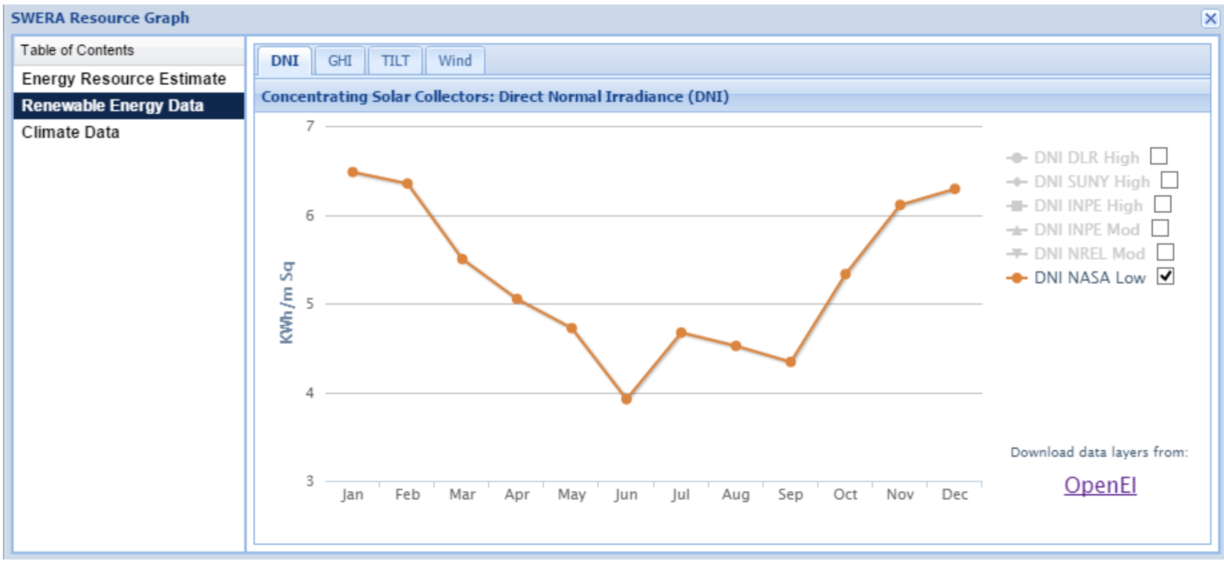


Figure 13. Monthly average DNI of Keta.

Figure 14. Monthly average wind speeds of Keta.

5.4.1 Correlation Analysis of the Solar and Wind Data of Keta

Table 5 shows the Karl Pearson's coefficient of correlation analysis between monthly average direct nominal irradiance (DNI) and monthly average wind speeds in Keta. The Excel scatter graph is used in Table 6 to show the graphical distribution of the data.

Table 5. Karl Pearson coefficient of correlation analysis of solar and wind data of Keta.

Months	**DNI (X)**	**$(X-\bar{X})$ x**	**x^2**	**Wind speeds (Y)**	**$(Y-\bar{Y})$ y**	**y^2**	**xy**
January	6.48	1.206666667	1.45604444	3.72	-0.15416667	0.02376736	-0.18602778
February	6.35	1.076666667	1.15921111	3.99	0.115833333	0.01341736	0.124713889
March	5.5	0.226666667	0.05137778	4.05	0.175833333	0.03091736	0.039855556
April	5.05	-0.22333333	0.04987778	3.6	-0.27416667	0.07516736	0.061230556
May	4.72	-0.55333333	0.30617778	3.18	-0.69416667	0.48186736	0.384105556
June	3.92	-1.35333333	1.83151111	3.25	-0.62416667	0.38958403	0.844705556
July	4.67	-0.60333333	0.36401111	4.47	0.595833333	0.35501736	-0.35948611
August	4.52	-0.75333333	0.56751111	4.63	0.755833333	0.57128403	-0.56939444
Septem-ber	4.34	-0.93333333	0.87111111	4.6	0.725833333	0.52683403	-0.67744444
October	5.33	0.056666667	0.00321111	3.71	-0.16416667	0.02695069	-0.00930278
Novem-ber	6.11	0.836666667	0.70001111	3.96	0.085833333	0.00736736	0.071813889

December	6.29	1.016666667	1.03361111	3.33	-0.54416667	0.29611736	-0.55323611
	ΣX= 63.28	Σx= 8.88178E-15	Σx^2 = 8.393666667	ΣY= 46.49	Σy= -3.9968E-15	Σy^2 = 2.798291667	Σxy= -0.828466667

Karl Pearson coefficient of correlation calculation:

$r = (\Sigma xy) \div (\sqrt{(\Sigma x^2). (\Sigma y^2)})$

$r = (-0.828466667) \div (\sqrt{(8.393666667) . (2.798291667)})$

$r = (-0.828466667) \div (\sqrt{23.4879275})$

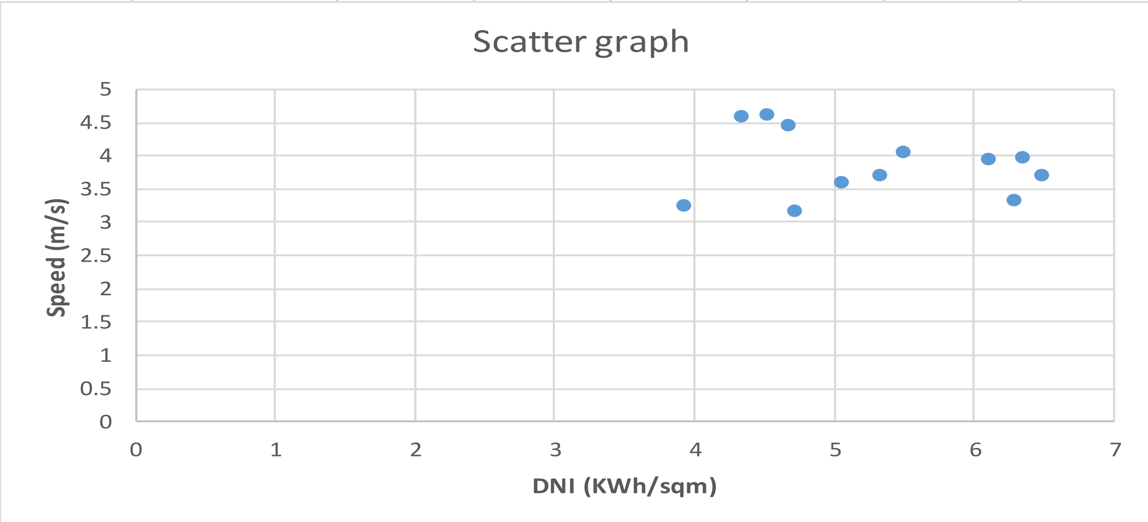
$r = (-0.828466667) \div (4.84643451)$

$r = -0.1709435$

In case Keta, the Karl Pearson correlation coefficient analysis shows a weak negative correlation of -0.1709435 between the direct nominal irradiance (DNI) and the wind speeds of Keta. This means that when direct nominal irradiance (DNI) increases then wind speeds decreases or when wind speeds increases then direct nominal irradiance (DNI) decreases.

Table 6. Excel scatter graph of solar and wind data of Keta.

DNI (KWh/sqm)	Speed (m/s)
6.48	3.72
6.35	3.99
5.5	4.05
5.05	3.6
4.72	3.18
3.92	3.25
4.67	4.47
4.52	4.63
4.34	4.6
5.33	3.71
6.11	3.96
6.29	3.33



6 CONCLUSIONS

In this research, the correlation analysis of the data in case Vaasa-Finland and case Keta-Ghana gave rise to correlation co-efficient of -0.95404 and -0.17094 respectively.

It appears that, there is a strong negative correlation between direct nominal irradiance (DNI) and wind speeds in case Vaasa-Finland while case Keta-Ghana has a weak negative correlation between direct nominal irradiance (DNI) and wind speeds.

However, the analysis shows that high solar energy potentials of a coastal location does not necessarily translate into high wind energy potentials through land and sea breeze.

When embarking on a solar and wind energy hybrid project at a coastal location; it is necessary to assess both solar and wind energy potentials independently in order to ascertain the viability of the hybrid project instead of assuming that once the coastal location has a good solar energy potentials it will also have a good wind energy potentials through land and sea breeze alone. This is because the wind speeds of a coastal location is not only due to land and sea breeze but also largely influenced by global wind patterns.

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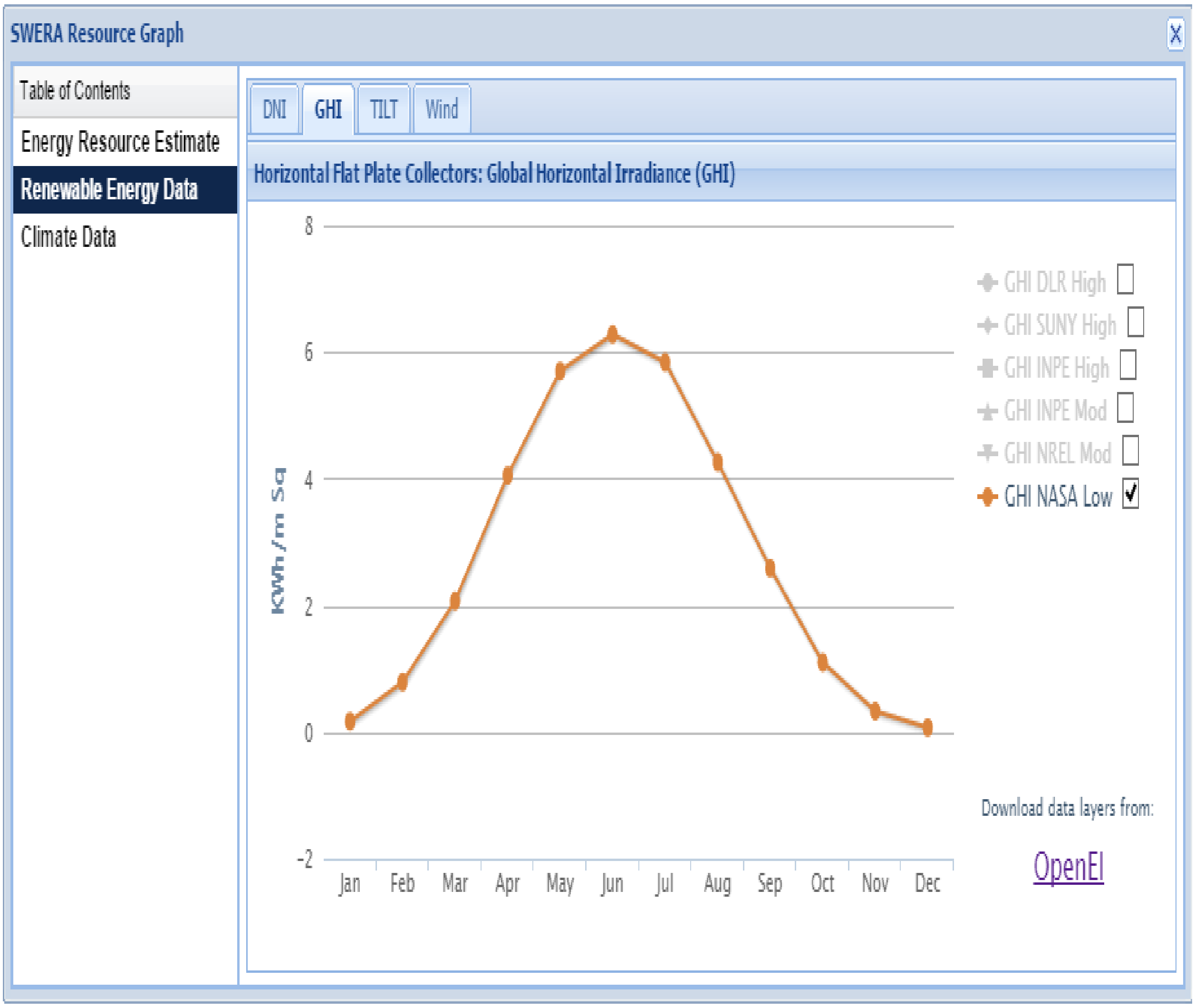
APPENDICES

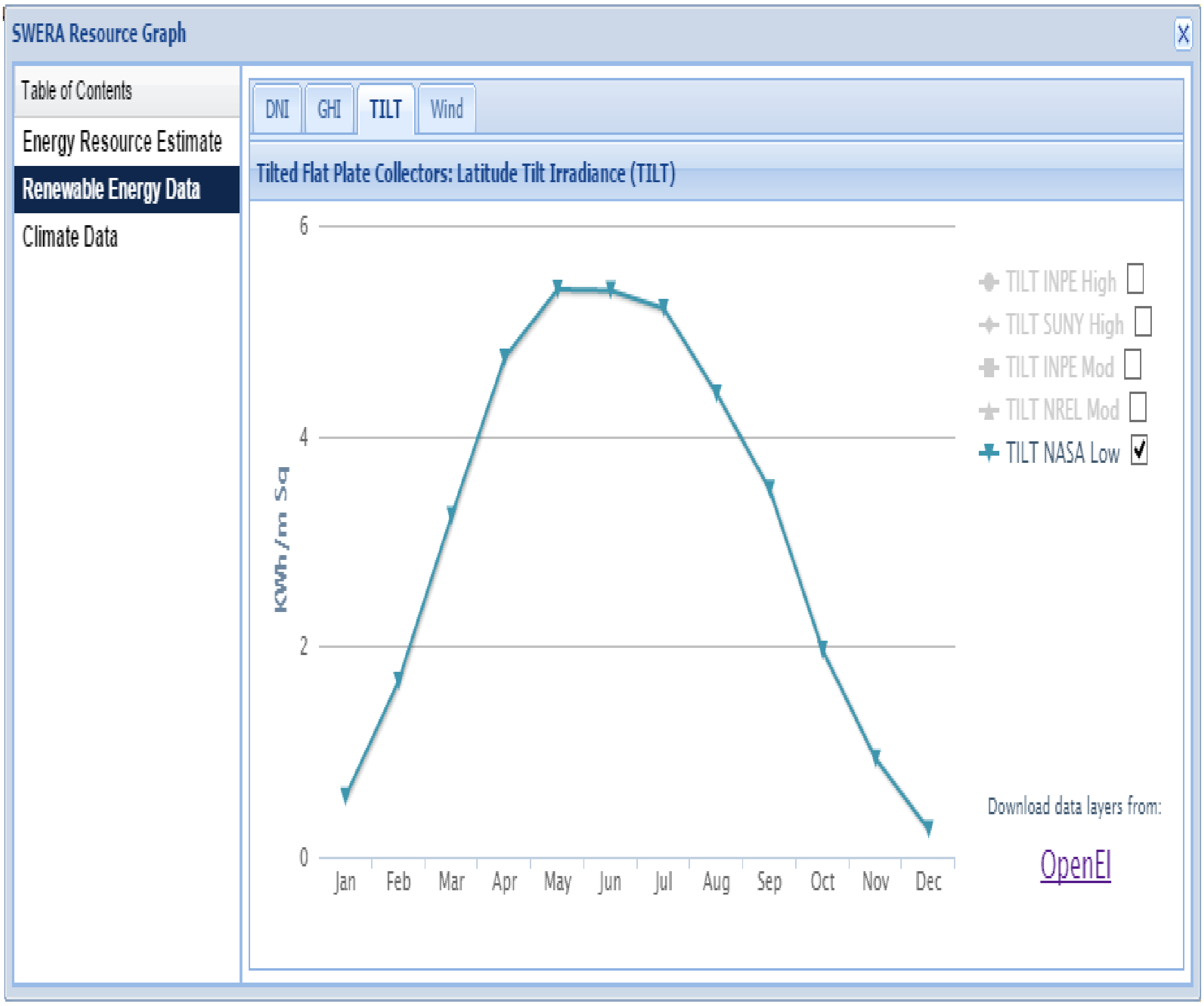
APPENDIX 1. THE MAP OF FINLAND /20/

Vaasa

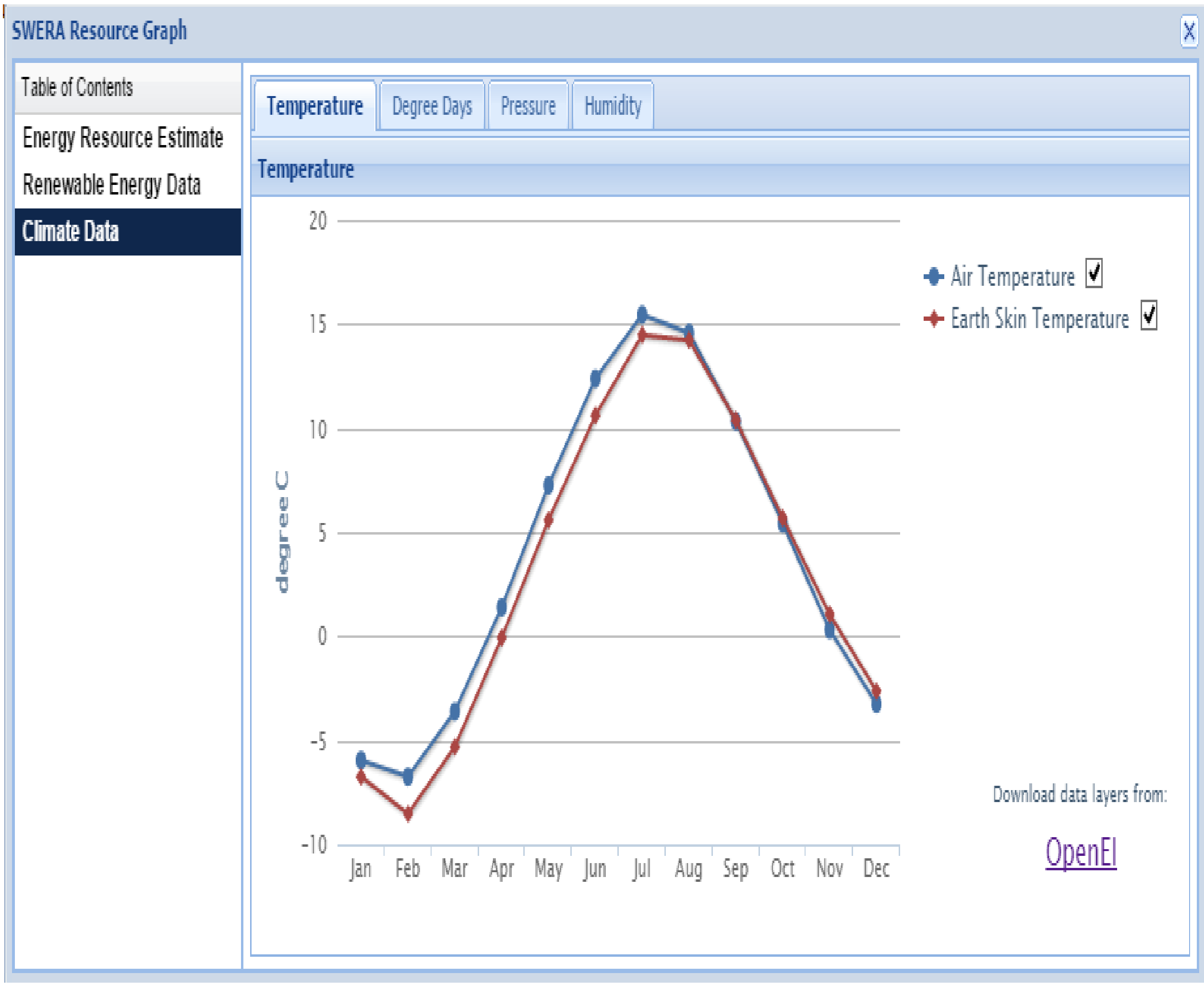
APPENDIX 2. THE MONTHLY AVERAGE GLOBAL HORIZONTAL IRRIDIENCE OF VAASA /17/



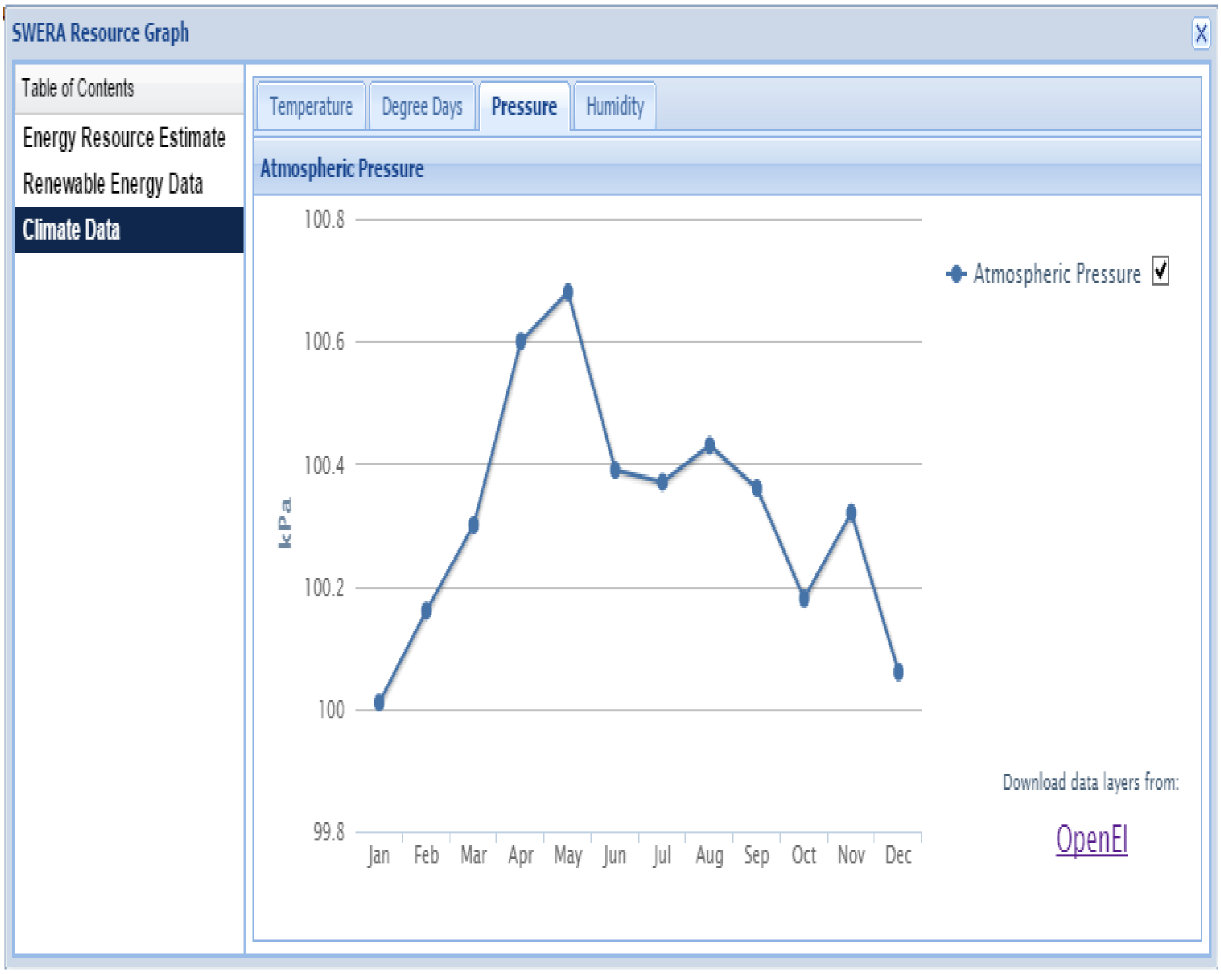
APPENDIX 3. THE MONTHLY AVERAGE LATITUDE TILT IRRIDIENCE OF VAASA /17/



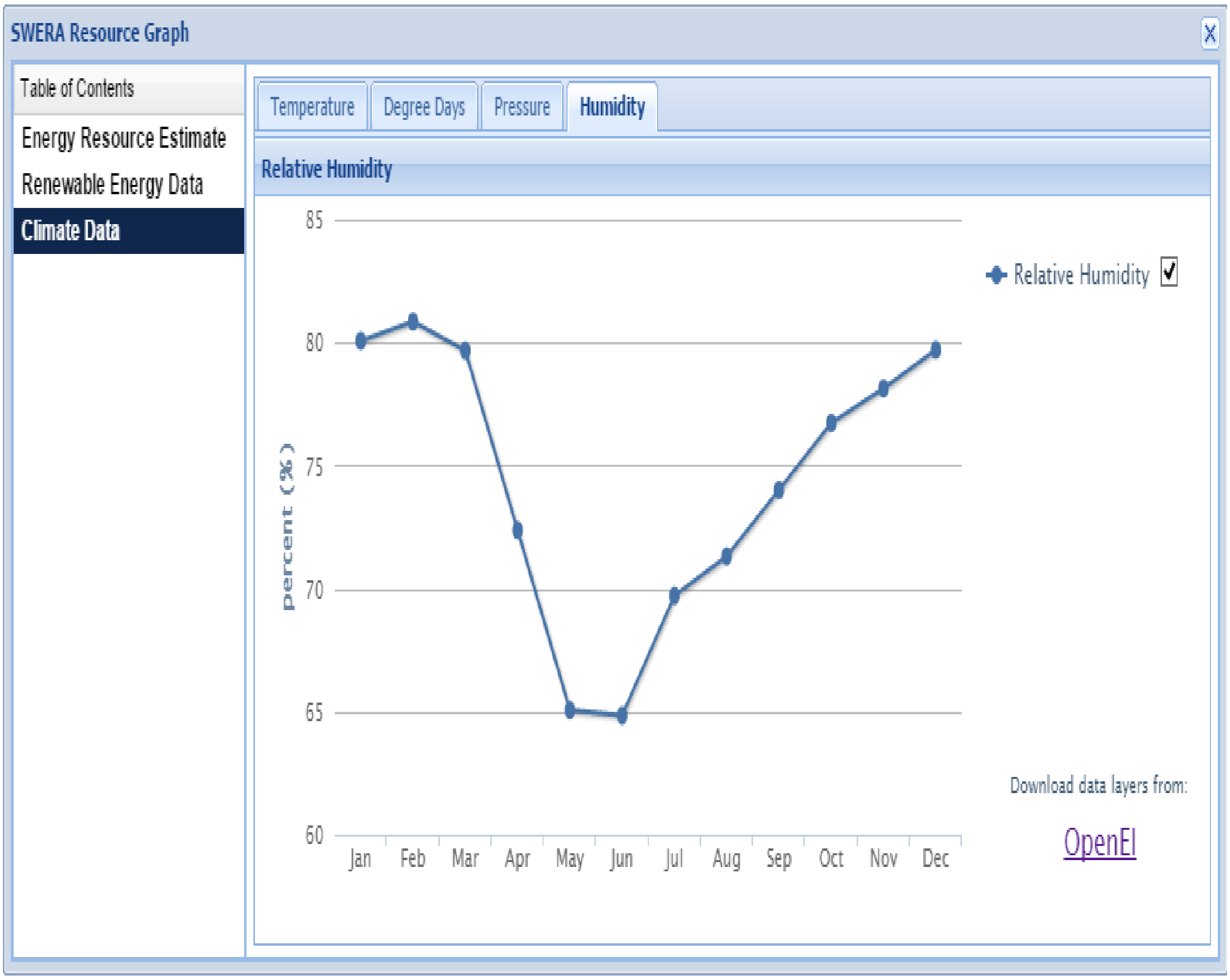
APPENDIX 4. THE MONTHLY AVERAGE TEMPERATURE OF VAASA /17/



APPENDIX 5. THE MONTHLY AVERAGE PRESURE OF VAASA /17/



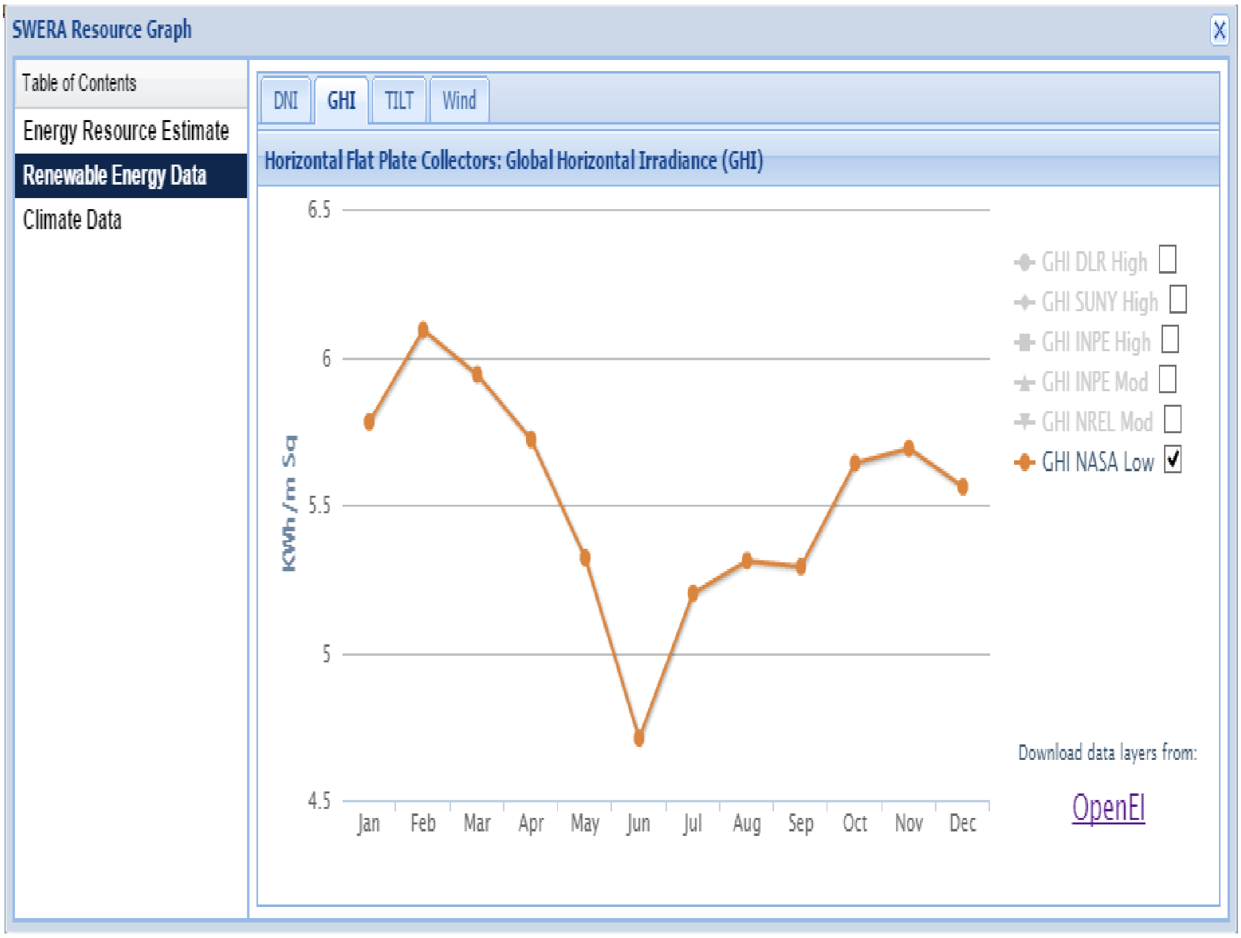
APPENDIX 6. THE MONTHLY AVERAGE HUMIDITY OF VAASA /17/



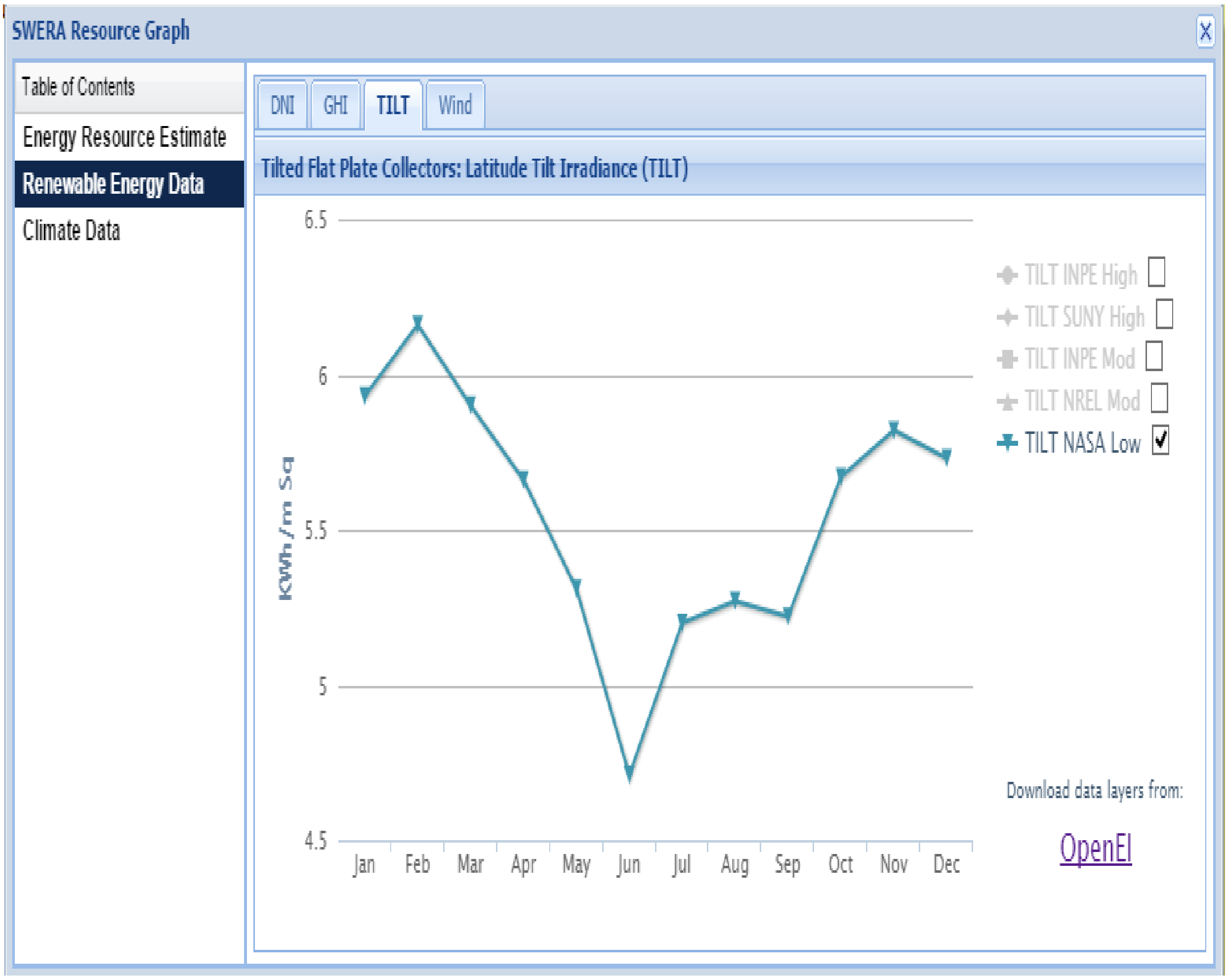
APPENDIX 7. THE MAP OF GHANA /19/

Keta

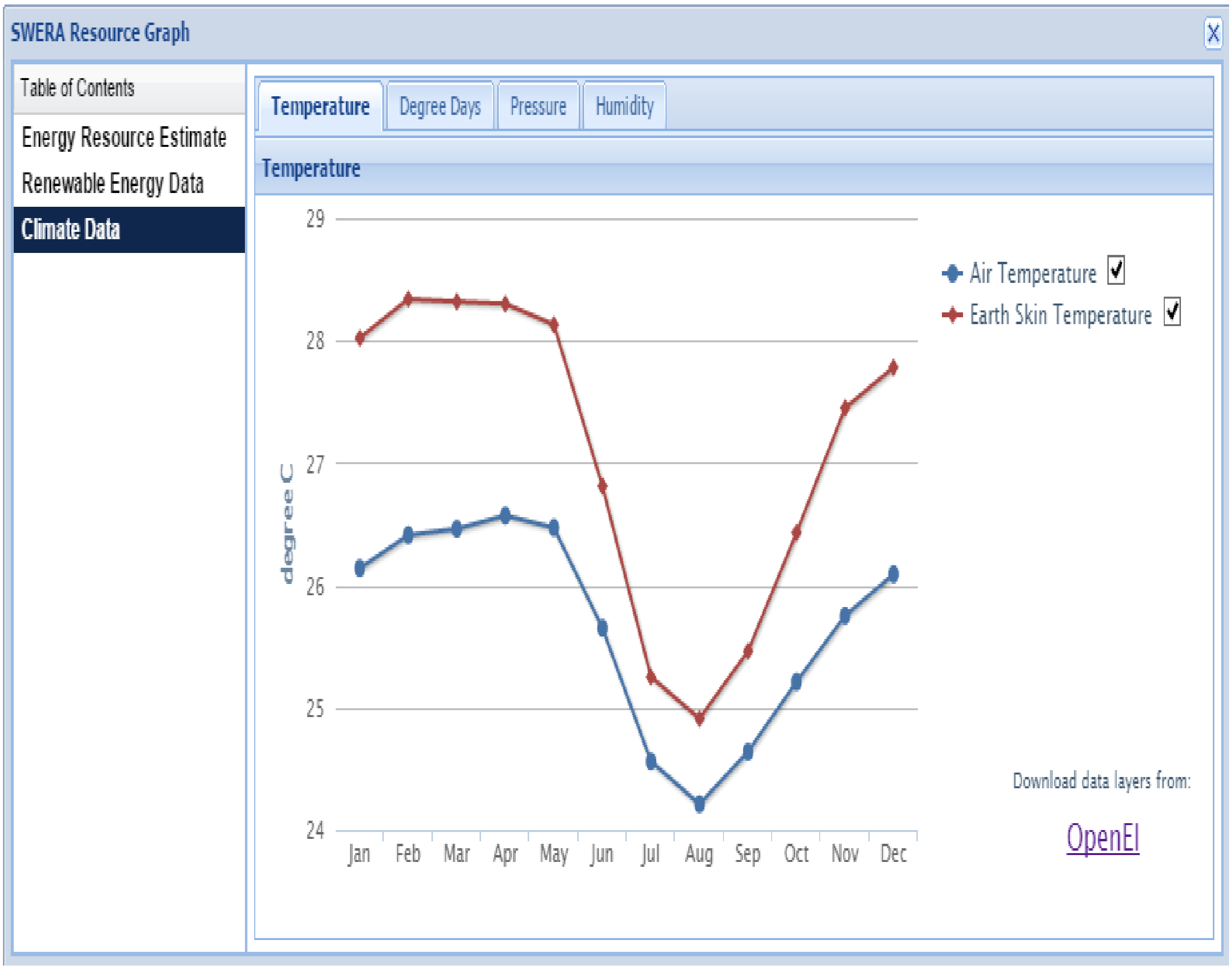
APPENDIX 8. THE MONTHLY AVERAGE GLOBAL HORIZONTAL IRRIDI-ENCE OF KETA /17/



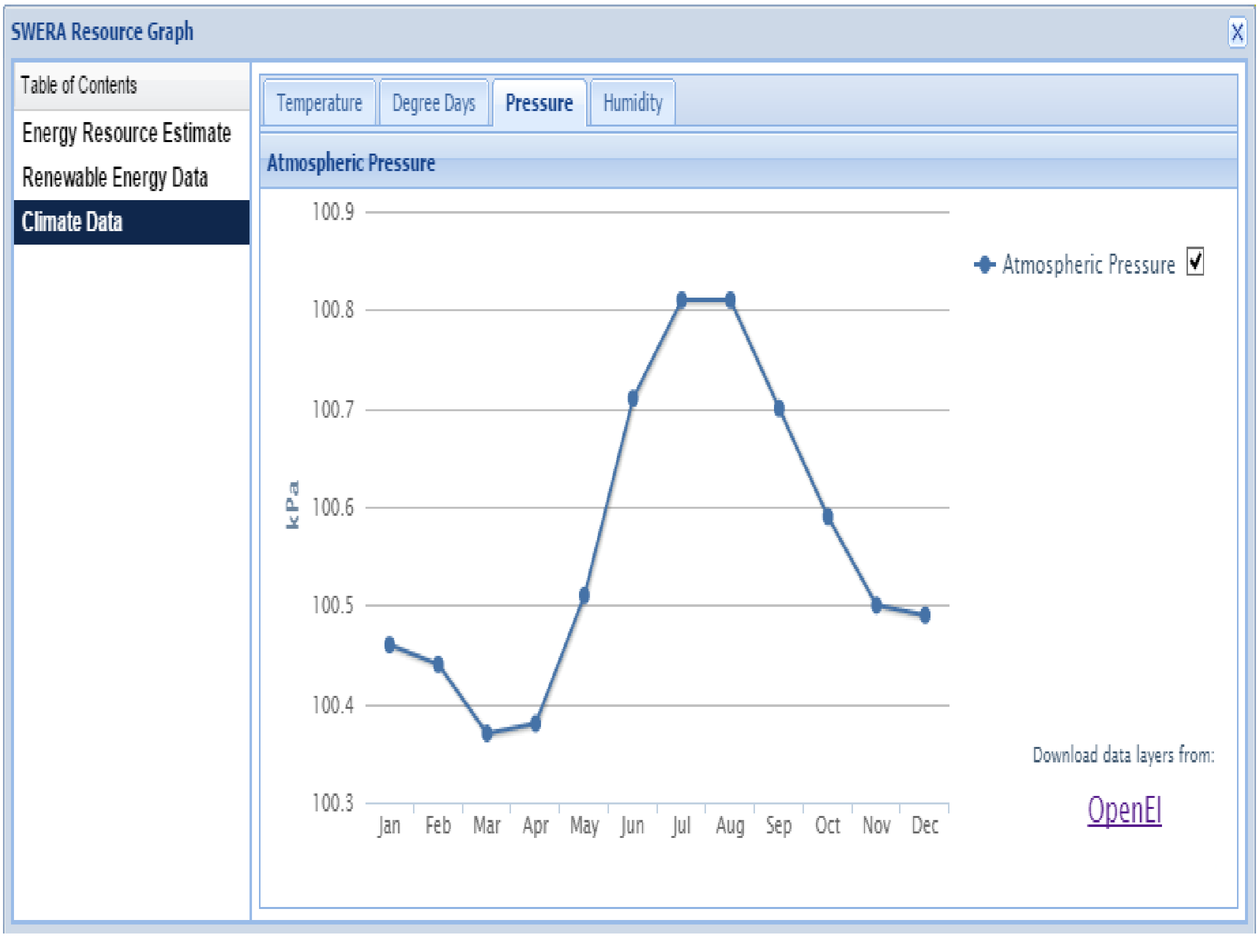
APPENDIX 9. THE MONTHLY AVERAGE LATITUDE TILT IRRIDIENCE OF KETA /17/



APPENDIX 10. THE MONTHLY AVERAGE TEMPERATURE OF KETA /17/



APPENDIX 11. THE MONTHLY AVERAGE PRESURE OF KETA /17/



APPENDIX 12. THE MONTHLY AVERAGE HUMIDITY OF KETA /17/