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ECONOMIC FEASIBILITY STUDY OF SOLAR PV AND WIND TURBINES IN MOROCCO APPLYING MONTE CARLO SIMULATION

Report and appendix

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Abstract

In this work, an economic feasibility study has been conducted on solar PV and wind turbine in Morocco using Monte Carlo simulation. By using historical measured data of solar irradiance and wind speed on different cities across Morocco and taking into account other factors that may affect the results on the economic profitability of the previously mentioned renewable plants, many different outcomes were computed to help interested parties take decisions on this type of activity. First, a review on the regulatory framework of the country has been done. Later, using solar irradiance and wind speed data of each city, probability distribution functions were assigned on each city, which allowed to consider the meteorological uncertainties in the calculations. The tools used to discuss the results are the net present value (NPV) and the levelized cost of electricity (LCOE). A comparison has been done between the solar PV with different tracking configurations and the onshore wind turbine at different levels of power capacity. The results reveal that regions close to the desert are more suitable to implement solar PV related projects, and the southern coastal regions are better befitting for wind turbines. This work is an academic research and results are computed using theoretical methods.

Keywords: *Solar PV, wind turbines, Monte Carlo simulation, probability distribution, NPV, LCOE, Anderson-Darling, unimodal distribution, bimodal distribution, Morocco, solar tracking system.*

Resumen

En este trabajo se ha realizado un estudio de viabilidad económica para instalaciones solares fotovoltaicas y turbinas eólicas *onshore* en Marruecos utilizando la simulación de Monte Carlo. A partir de datos históricos de la radiación solar y de la velocidad del viento en varias ciudades de Marruecos y teniendo en cuenta otros factores que afecten los resultados económicos de las plantas renovables mencionadas anteriormente, varios escenarios se han calculado, obteniendo así resultados diversos. Para empezar, se presentará el marco regulatorio marroquí en cuanto a las energías renovables. Posteriormente, a partir de los datos de radiación solar y de la velocidad del viento, se han generado varias funciones de probabilidad para diferentes intervalos de tiempo para cada ciudad. Se ha calculado el valor actual neto (VAN) y el coste nivelado eléctrico (LCOE) para realizar comparaciones entre varios sistemas de seguimiento solar fotovoltaico y las turbinas de viento para distintos niveles de potencia. Los resultados indican que para la energía fotovoltaica las zonas cercanas al desierto son las que tienen condiciones más favorables, y las zonas costales en el sur del país son las más beneficiosas para la energía eólica. Este es un trabajo académico y todos los resultados se obtuvieron aplicando cálculos teóricos.

Palabras clave: *Solar fotovoltaica, turbinas eólicas, simulación de Monte Carlo, distribución de probabilidad, VAN, LCOE, Anderson-Darling, distribución unimodal, distribución bimodal, Marruecos, sistema de seguimiento solar.*

Resum

En aquest treball s'ha realitzat un estudi de viabilitat econòmica per a instal·lacions solars fotovoltaiques i turbines eòliques *onshore* al Marroc utilitzant la simulació de Monte Carlo. A partir de dades històriques de la radiació solar i de la velocitat del vent en diverses ciutats del Marroc i tenint en compte altres factors que afectin els resultats econòmics de les plantes renovables esmentades anteriorment, diversos escenaris s'han calculat, obtenint així resultats diversos. Per a començar, es presentarà el marc regulador marroquí quant a les energies renovables. Posteriorment, a partir de les dades de radiació solar i de la velocitat del vent, s'han generat diverses funcions de probabilitat per a diferents intervals de temps per a cada ciutat. S'ha calculat el valor actual net (VAN) i el cost anivellat elèctric (LCOE) per a realitzar comparacions entre diversos sistemes de seguiment solar fotovoltaic i les turbines de vent per a diferents nivells de potència. Els resultats indiquen que per a l'energia fotovoltaica les zones pròximes al desert són les que tenen condicions més favorables, i les zones costals en el sud del país són les més beneficioses per a l'energia eòlica. Aquest és un treball acadèmic i tots els resultats es van obtenir aplicant càlculs teòrics.

Paraules clau: *Solar fotovoltaica, turbines eòliques, simulació de Monte Carlo, distribució de probabilitat, VAN, LCOE, Anderson-Darling, distribució unimodal, distribució bimodal, el Marroc, sistema de seguiment solar.*

Contents

Glossary

I_T^{β}	Total radiation on a surface plane [W/m^2]	ir	Interest rate [%]
I_b	Beam radiation [W/m^2]	v	Wind speed [m/s]
I_d	Diffuse radiation [W/m^2]	h	Wind turbine hub height [m]
I_G	Global radiation [W/m^2]	α	Wind shear exponent
I_{r90}	Reflected radiation on a 90º tilted surface [W/m^2]	E_{pv}	Output solar energy [kWh]
I_o	Extraterrestrial radiation [W/m^2]	P_{nom}	Nominal power capacity [kW]
A_i	Anisotropy index	G_{dt}	Solar radiation on the surface panel [W/m^2]
R_b	Ratio of beam radiation	G_{stc}	Solar irradiance under standard conditions [W/m^2]
β	Surface inclination [º]	PR	Performance ratio [%]
ρ_g	Surface albedo	Δt	Time interval
θ	Incidence angle [º]	AD	Anderson-Darling statistic
θ_Z	Zenith angle [º]	NPV	Equity net present value [€]
G_{sc}	Solar constant	CF_i	Cash flow in year I [€]
ϕ	Latitude angle [º]	r	Real discount rate [%]
δ	Declination angle [º]	D	Nominal discount rate [%]
ω	Hour angle [º]	g_i	Inflation rate in year i [%]
h_t	Local time [hours]	Eq	Owner's equity share [%]
α_s	Solar elevation angle [º]	I	Total installation cost [€]
γ	Azimuth angle [º]	N	Economic lifetime of the project [Years]
γ_s	Solar azimuth angle [º]	$degr$	System degradation rate [%]
EBT_i	Earnings before taxes in year i [€]	$marg$	Percentage of profit margin [%]
TX_i	Total taxes in year i [€]	$INCOME_i$	Gross income in year i [€]
LP_i	Annual loan payment in year i [€]	$COST_i$	Total costs in year i [€]
DEP	Depreciation value [€]	CO	Capital outstanding in year i [€]
LF	Annual loan fee [€]	OM_i	Operational and maintenance cost in year i [€]

State of the art

When making an economic feasibility study, most of the times it is hard to predict an average value of some parameters with a considerable weight in the final results, that is, a slightly variation of such parameters may change radically the outcome of the result. Monte Carlo simulations are a method to counter this often common problem in feasibility studies. Some research has already be done in some locations around the world, while others are yet to be done. One of these countries is the Kingdom of Morocco, where many studies about economic feasibility of renewable projects have been done in this location. However, at the time of writing this work, there is none that takes into account unpredictable factors such as meteorological and financial ones. In this work, a feasibility study for solar PV and wind energy has been done in several locations across the north African country using Monte Carlo simulation to help guide interested parties when deciding which technology has the highest potential in which location in Morocco.

1. Introduction

As days pass by, the world is leaning more to a future free of carbon emissions with the help of renewable energies as one of the solutions when it comes to energy supply. Major economies in Western countries and Asia are investing more and more in these type of energies while preparing for the time when fossil fuels will become more expensive and harder to come by. This is a goal that countries with developing economies must also take part in, but have difficulties due to not having enough research about green sources of energy such as solar and wind, despite the huge potential some of these countries have. One of these countries is Morocco.

Located in the north of Africa, its land enjoys a considerable solar and wind energy source due to its latitude and the 2.310 km of Atlantic coast [1]. However, 91% of energy supply comes from imported fossil fuels [2]. With a growing population, and thus, an increasing energy demand, the Ministry of Energy, Mines and sustainable Development in Morocco presented in 2009 an energy plan to reduce the dependency of fossil fuels and increase the renewable energy mix by 42% in 2020, with an installed solar power capacity of 2000MW of solar energy and 2000MW of wind energy. The objective was updated in 2015 to a 52% of renewable share in the energy mix by 2030. At the time of writing this work, the renewable share in Morocco is about 35% (2018), which means that the remaining 7% is expected to be installed during 2019 and 2020 [Figure 1] [3] [4].

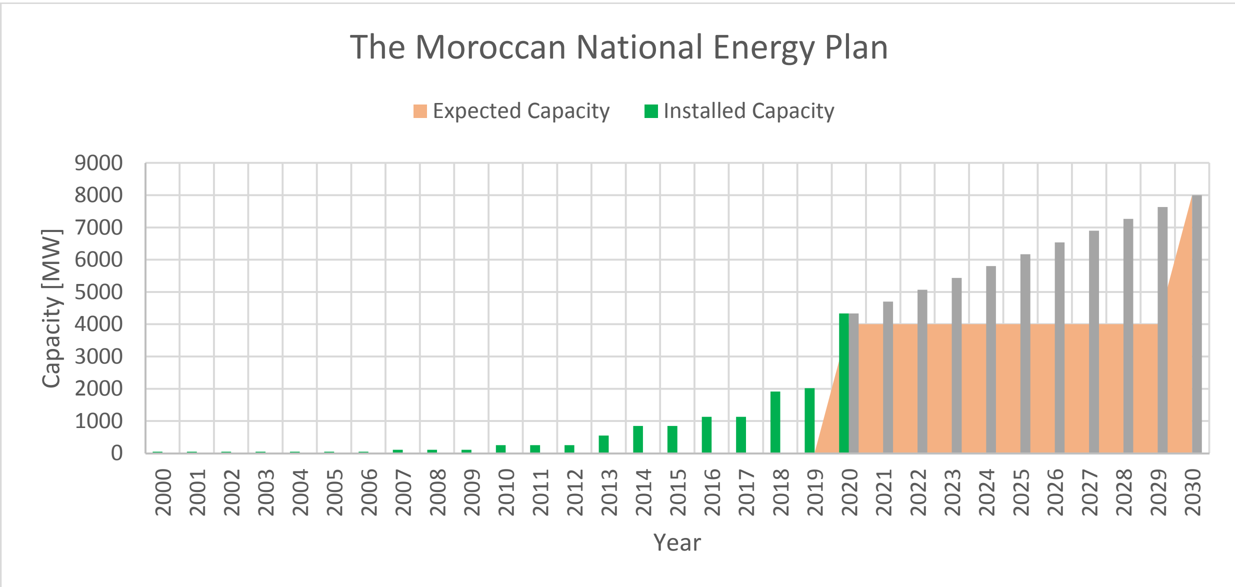

Figure 1. Evolution of installed capacity of wind a solar energy in Morocco. Source [own elaboration]

1.1 Regulatory framework

In order to face this challenge, the Moroccan government has adopted a series of laws throughout the years for the pursuit of reducing foreign energy dependence and promoting renewable energy integration in the electrical market. Sorted in chronological order, the legislation that shaped the Moroccan energy market as it is today is the following [3] [5] [6] [7] [8]:

- **Law 16-08 (2008):** This law was created in order to promote self-generation and it allows for private entities to produce their own energy if the following conditions are met:

Prior authorization by the government.

- Capacity does not exceed 50MW.
- The energy is consumed solely by the producer.
- No disruption of the power supply of the area concerned.
- In case of surplus of energy, it must be sold to ONEE (“*Office Nationale de l’Eau et l’Electricité”*).

Many large industrial facilities took advantage of this law to reduce electricity dependency from the national grid.

- **Law 13-09 (2010):** Private entities were allowed to produce renewable energy either to their own consumption or for selling it to the national grid. However, there are certain limitations to his right: renewable plants can only be connected to a medium-voltage, high-voltage or very-high-voltage grid. Excluding the hydro power plants, if the capacity of the plant is higher than 2 MW an authorization is required for installation, as well as any changes to be done to the plant. If the capacity does not exceed 2 MW but it is higher than 20 kW a license is needed in this case. Any capacity lower than 20 kW do not require going through the former administrative procedures to produce electricity.

- **Law 57-09 (2010):** In the same year, the Moroccan Agency for Solar Energy (MASEN) was created. Law 57-09 declares that MASEN will oversee the Solar Plan in Morocco, by managing all solar related projects.

- **Law 16-09 (2010):** This law was created to establish the National Agency for the Promotion of Renewable Energy and Energy Efficiency (AMEE), and its main purpose was to establish and developing the regulatory framework related to renewable energy and energy efficiency.

- **Law 58-15 (2015):** This law complements law 13-09 and it introduced the possibility for private entities to connect to the low-voltage grid, allowing private individuals and small companies to produce their own renewable energy. Any surplus of energy can only be sold to ONEE and it cannot exceed 20% of the yearly production. This law was established to encourage more parties to make the transition from conventional energy production to renewable production. However, the implementing decree is not ready yet, so at the time of writing this article decentralized production is not yet possible.

- **Law 48-15 (2016):** The national regulatory authority of electricity (ANRE) was created, and it meant the liberalization of the energy sector. This law establishes the activities that the institution is responsible for. The main role of ANRE is to guarantee the stability of the national grid by regulating new self-producers and overseeing the energy market in the country.

- **Law 37-16 (2016):** This law complements the law 57-09, and it introduced some changes. The Moroccan Agency for Solar Energy is now called the Moroccan Agency for Sustainable Energy, and it is now responsible for managing solar, wind and hydro projects across the country. The main mission of this institution is to achieve Morocco's renewable energy goals for 2020 and 2030.

- **Law 38-16 (2016):** The "*Office National de l'electricité"* is created, and its main purpose is the control of the electric energy except renewable energy production, which MASEN is now responsible for. All renewable energy projects, documentation and staff is now transferred to MASEN. This law separated renewable energy activities from conventional ones.

- **Law 39-16 (2016):** Some changes to law 16-09 were introduced with this law. The main change is that AMEE will now be called the Moroccan Agency for Energy Efficiency, and its main purpose is the establishment of the regulatory framework and its implementation of energy efficiency in all sectors, leaving aside everything related to renewable energy.

Attracting investors will make achieving the aforementioned goals a not so distant future. Therefore, it is necessary to prove that a profitable business project will arise when investing in these green energies in the country. Despite the clear intention on the part of the Moroccan government, many studies need to be done in order to demonstrate the energy potential of this location. At the time of writing this paper, many studies have been done about this topic when it comes to Morocco. However, these do not take into account the unpredictability of some factors that play a key role when making an economic feasibility study. In this work, the Monte Carlo simulation method is used to take into account in these uncertainties, as it is a reliable tool used in the business and engineering field when it comes to these kind of studies.

In the following sections the solar PV and wind onshore energy resources will be reviewed, and it's economic potential in different locations across Morocco to compare and help guiding investors about which technology is more profitable for different scenarios.

2. Methodology

Morocco is a country with many kilometers of coastline and high altitude mountains which makes its climate conditions such as sun radiation and wind speeds vary considerably depending on the region. Therefore, it is necessary to perform the study in different locations, as the results may be different in each region. Twenty-three cities across the country have been chosen in this work in order to analyze how different the profitability of solar PV plants and wind farms are in those locations. The chosen cities are the following [9]:

City	Latitude [degrees]	Longitude [degrees]
Agadir	30.383	-9.567
Al Hoceima	35.180	-3.850
Beni Mellal	32.360	-6.400
Casablanca	33.567	-7.667
Er-Rachidia	31.930	-4.400
Essaouira	31.517	-9.783
Fes	33.933	-4.983
Ifrane	33.500	-5.167
Kenitra	34.300	-6.600
Laayoune	32.683	-4.733
Larache	35.180	-6.130
Marrakech	31.617	-8.033
Meknes	33.883	-5.533
Midelt	27.160	-13.210
Nador	35.150	-2.910
Ouarzazate	30.933	-6.900
Oujda	34.793	-1.933
Rabat	34.050	-6.767
Safi	32.283	-9.233
Sidi Ifni	29.360	-10.180
Tanger	35.733	-5.900
Taza	34.217	-4.000
Tetouan	35.580	-5.330

Table 1. Latitudes and longitudes of the Moroccan selected cities. Source [9]

2.1 Data collection

2.1.1 Solar data

There are many resources where solar data is available on the Internet. In this study, historically measured data are necessary to be able to define a solar resource probabilistic function. In this case, the data was collected from the PVGIS site, which offers a variety of tools for PV related projects. The longest period of time for which solar radiation data is available is from January 2005 to December 2016 at an hourly interval, obtained from the PVGIS-SARAH database.

The PVGIS site also offers the possibility to have solar radiation data for different panel surface inclinations and for different solar tracking devices, which uses the anisotropic model developed by (Muneer T. 1990) [10] . In this study, however, the radiation components for the different panel surface configurations are being calculated using the anisotropic sky-model of Hay-Davis-Klucher-Reindl (HDKR-Model) (Duffie/Beckmann, 1991) [11].

Seven different panel surface configurations are studied to compare and determine which one has the highest profitability depending on the region. The seven configurations include: horizontal surface, sloped surface at the optimal inclination according to PVGIS for each location and at chosen inclination close to that of the city's altitude, horizontal east-west tracking surface, horizontal north-south axis tracking surface, sloped surface with a vertical axis tracking system and a two-axis tracking surface.

The inclinations of the panel surfaces for the sloped surfaces inclination for each city are listed below:

City	Optimal Slope [PVGIS] [degrees]	Chosen Slope [degrees]
Agadir	31	30
Al Hoceima	34	35
Beni Mellal	31	30
Casablanca	32	30
Er-Rachidia	33	30
Essaouira	31	30
Fes	32	35
Ifrane	31	30
Kenitra	31	35
Laayoune	27	30
Larache	32	35
Marrakech	31	30
Meknes	32	30
Midelt	32	30
Nador	34	35
Ouarzazate	32	30
Oujda	33	35
Rabat	31	35
Safi	31	30
Sidi Ifni	30	30
Tanger	32	35
Taza	33	35
Tetouan	31	35

Table 2. Optimal and selected panel inclination angels for each Moroccan city. Source [own elaboration]

The expression used to obtain the total radiation [W/m^2] for the different panel surfaces configurations is the following:

$$I_T^{\beta} = (I_b + I_d A_i) R_b + I_d (1 - A_i) \left(\frac{1 + \cos(\beta)}{2}\right) \left(1 + f * \left(\sin\left(\frac{\beta}{2}\right)^3\right)\right) + I_G \rho_g \left(\frac{1 - \cos(\beta)}{2}\right) \quad (1)$$

A_i is the anisotropy index and is expressed as the ratio between the beam radiation on the surface panel (I_b) and the extraterrestrial beam radiation (I_o).

$$A_i = \frac{I_b}{I_o} \quad , \quad (2)$$

R_b is the ratio of beam radiation on a tilted surface and it is the ratio between the cosine incidence angle on the surface ($\cos(\theta)$) and the zenith angle ($\cos(\theta_Z)$).

$$R_b = \frac{\cos(\theta)}{\cos(\theta_Z)} \quad , \quad (3)$$

and f is expressed as

$$f = \sqrt{\frac{I_b}{I_G}} \tag{4}$$

where I_G is the global radiation received by the panel.

The value of albedo (ρ_g) has been estimated with the following expression [12]:

$$\rho_g = \frac{2}{I_G * (1 - \cos(90º))} * I_{r90} \tag{5}$$

To use this expression, radiation data for a 90º tilted surface are also obtained from PVGIS. Although the albedo is best determined using ground measurements, in this paper Eq. (5) is used to have an approximate value of this parameter.

The extraterrestrial radiation on a horizontal surface (I_o) is calculated using the following formula:

$$I_o = \frac{12 * 3600}{\pi} G_{sc} \left(1 + 0.033 * \cos\left(\frac{360n}{365}\right)\right) * \left[\cos(\phi)\cos(\delta)\left(\sin(\omega_2) - \sin(\omega_1)\right) + \frac{\pi(\omega_2 - \omega_1)}{180}\sin(\phi)\sin(\delta)\right] \tag{6}$$

where G_{sc} is the solar constant. The value used in this paper is 1367 W/m^2, as adopted by the World Radiation Center (WRC) (Duffie/Beckmann, 1991). The extraterrestrial radiation will depend on the day of the year (n).

The hour angle (ω) is calculated as

$$\omega = (h_t - 12) * 15 \quad , \tag{7}$$

where h_t is the hour at the instant *t*. The expression $\omega_2 - \omega_1$ refers to the time interval between two hour angles, in this case, a period of one hour.

The declination angle depends on the day of the year and it is calculated as

$$\delta = 23.45 \sin\left(360\left(\frac{284 + n}{365}\right)\right) \tag{8}$$

The data downloaded from PVGIS also offers the sun elevation (α_s) at each hour. Therefore, the zenith angle can be calculated as

$$\theta_z = 90 - \alpha_s \tag{9}$$

The incidence angle (θ), the tilt angle (β) and the surface azimuth angle (γ) methods of calculations depends on the panel surface's configuration. The formulas are also obtained from (Duffie/Beckmann, 1991) [11] and the formulas used are listed below.

- For slopped surfaces, the tilt angles for each city are shown in Table 2 and the surface azimuth angle is considered to be 0º. The incidence angle is calculated as

$$\cos(\theta) = \cos(\theta_z)\cos(\beta) + \sin(\theta_z)\sin(\beta)\cos(|\gamma_s - \gamma|) \quad (10)$$

- For the horizontal north-south axis tracking, the expressions are the following.

$$\cos(\theta) = (\cos^2(\theta_z)\cos^2(\delta)\sin^2(\omega))^{1/2} \quad (11)$$

$$\tan(\beta) = \tan(\theta_z)\,|\cos(\gamma - \gamma_s)| \quad (12)$$

$$\gamma = \begin{cases} 90º & if\ \gamma_s > 0 \\ -90º & if\ \gamma_s \leq 0 \end{cases} \quad (13)$$

- For the horizontal east-west axis tracking, the expressions are

$$\cos(\theta) = (1 - \cos^2(\delta)\sin^2(\omega))^{1/2} \quad (14)$$

$$\tan(\beta) = \tan(\theta_z)\,|\cos\gamma_s| \quad (15)$$

$$\gamma = \begin{cases} 0º & if\ |\gamma_s| > 0 \\ 180º & if\ |\gamma_s| \leq 0 \end{cases} \quad (16)$$

- For the sloped surface with a vertical axis tracking systems, the formulas used are:

$$\cos(\theta) = \cos(\theta_z)\cos(\beta) + \sin(\theta_z)\sin(\beta) \quad (17)$$

$$\beta = const \quad (18)$$

$$\gamma = \gamma s \quad (19)$$

- For the two-axis tracking, the next expressions are used

$$\cos(\theta) = 1 \tag{20}$$

$$\beta = \theta_z \tag{21}$$

$$\gamma = \gamma_s \tag{22}$$

The expression to determine the solar azimuth angle (γ_s) for each instant in all configurations is the following:

$$\gamma_s = sign(\omega)\left|\cos^{-1}\left(\frac{\cos(\theta_z)\sin(\phi) - \sin(\delta)}{\sin(\theta_z)\cos(\phi)}\right)\right| \tag{23}$$

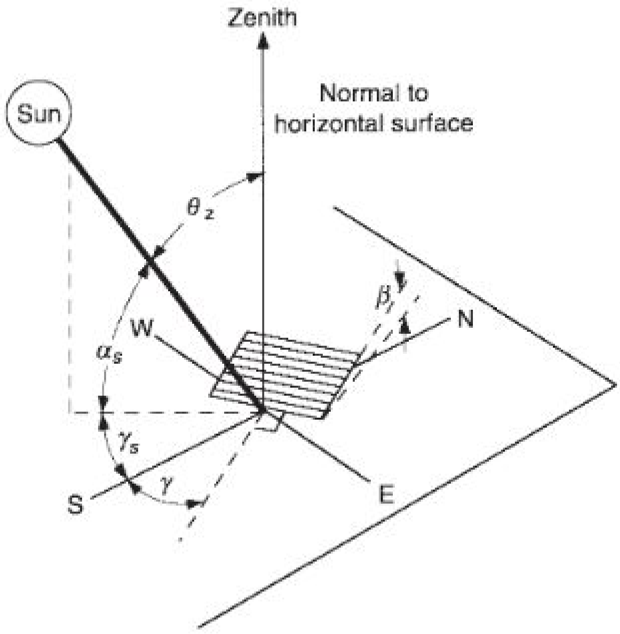

Figure 2. Illustration of all angles used in the model. Source [Duffie/Beckmann, 1991] [11]

2.1.1 Wind data

In the case of wind data collection, Windographer [13] is a software that allows you to obtain historical wind speed data from any part of the Earth. The data worked for the wind farm study are hourly data from January 1980 to December 2018 for all the 23 cites mentioned. The altitude of wind speed in which this data is available is of 10m above the ground surface. This altitude is not suitable to perform the analysis, as the hub height of most wind turbines are above 40m. Therefore, it is necessary to calculate wind speeds at higher altitudes [14].The expression used to determine the wind speed at an altitude h_2 is called the Weibull wind speed distribution extrapolation [15].

$$\frac{v_2}{v_1} = \left(\frac{h_2}{h_1}\right)^{\alpha} \qquad (24)$$

where v_1 is the wind speed [m/s] at reference height h_1 [m] and v_2 is the wind speed at the wanted height h_2. The wind shear exponent α is calculated as

$$\alpha = \frac{0.37 - 0.0881\ln(v_1)}{1 - 0.0881\ln\left(\frac{h_1}{h_r}\right)} \qquad (25)$$

where h_r is a reference height which value is 10m.

2.2 Energy conversion

Following the hourly data calculation for solar radiation and wind speed, the energy conversion computation will take place.

In the case of solar energy, the output energy is expressed as:

$$E_{pv} = P_{nom}\left(\frac{G_{dt}}{G_{stc}}\right)PR \cdot \Delta t \qquad (26)$$

where P_{nom} is the nominal capacity in kW, G_{dt} is the radiation on the panels' surface in W/m^2, G_{stc} is the solar irradiance under standard conditions, with a constant value of 1000 W/m^2. The performance ratio (PR) is a variable that takes into account other factors that can affect the performance of the PV panels, such as environmental conditions and solar equipment (inverter, etc.) [16].

For wind energy, three power curves of three different wind turbines are used. The nominal powers of those turbines are 100kW, 3MW and 5MW. The wind turbines models are NPS 100C [17], the Vestas V90-3.0 [18]and the Gamesa G128-5.0MW [19], respectively.

Once all calculations are done, the hour intervals will be changed to monthly intervals. An hourly time scale is necessary when assessing specific projects for a duration that takes no longer than a year. In this case however, working with a long-term energy production plan will not be a good choice, since it will avoid increasing the random error of the data [20].

2.3 Probability distribution calculation.

It can be observed that for each month interval, the energy output can vary each year. Therefore, it is uncertain (and also not probable) to have the same energy output each year for a specific month. This calls for a method to fit the sample data of each month into a distribution curve so that the monthly energy output value in each year will be similar to the recorded ones.

In this study, 10 different distributions are chosen to have the data samples fit into. For these distributions, the probability distribution function (PDF) and the cumulative distribution function (CDF) are presented in the following table [Table 3]:

Distribution name	PDF [f(x)]	CDF [F(x)]
Beta	$\frac{x^{\alpha-1}(1-x)^{\beta-1}}{B(p,q)}$	$\frac{\int_0^z (t^{p-1}(1-t)^{q-1}dt)}{B(p,q)}$
Chi-square	$\frac{e^{-\frac{x}{2}}x^{\frac{v}{2}-1}}{2^{\frac{v}{2}}\Gamma\left(\frac{v}{2}\right)}$	$\frac{\gamma\left(\frac{v}{2},\frac{x}{2}\right)}{\Gamma\left(\frac{v}{2}\right)}$
Exponential	$\frac{1}{\beta}e^{-\frac{x-\mu}{\beta}}$	$1-e^{-\frac{x}{\beta}}$
Extreme Value	$\frac{1}{\beta}e^{\frac{x-\mu}{\beta}}\ e^{-e^{\frac{x-\mu}{\beta}}}$	$1-e^{-e^{x}}$
Gamma	$\frac{x^{(\gamma-1)}e^{-x}}{\Gamma(\gamma)}$	$\frac{\int_0^x (t^{\alpha-1}e^{-t}dt)}{\Gamma(\gamma)}$
Lognormal	$\frac{e^{-\left(\frac{\left(\ln\left(\frac{x-\theta}{m}\right)\right)^2}{2\sigma^2}\right)}}{(x-\theta)\sigma\sqrt{2\pi}}$	$\Phi\left(\frac{\ln(x)}{\sigma}\right)$
Normal	$\frac{e^{-\frac{(x-\mu)^2}{2\sigma^2}}}{\sigma\sqrt{2\pi}}$	$\int_{-\infty}^{x} e^{-\frac{x^2}{2}}/\sqrt{2\pi}$
Rayleigh	$\frac{x}{\sigma^2}\ e^{-\frac{x^2}{2\sigma^2}}$	$1-e^{-\frac{x^2}{2\sigma^2}}$
T	$\frac{\left(1+\left(\frac{x^2}{v}\right)\right)^{-\frac{v+1}{2}}}{B(0.5,0.5v)\sqrt{v}}$	$\frac{1}{2}+\frac{1}{2}\left[I\left(1;\frac{1}{2}r,\frac{1}{2}\right)-I\left(\frac{r}{r+t^2},\frac{1}{2}r,\frac{1}{2}\right)\right]sgn(t)$
Weibull	$\frac{\gamma}{\alpha}\left(\frac{x-\mu}{\alpha}\right)^{\gamma-1}\ e^{-\left(\frac{x-\mu}{\alpha}\right)^{\gamma}}$	$1-e^{-(x^{\gamma})}$

Table 3. Distributions considered with their respective PDF and CDF. Source: [21] [22] [23]

The next step is to define the probability curve for each interval for all cities and cases. There are many probability distribution tests that help scientists fit a sample of data into a suitable probability curve, such as the chi-square test and the Kolmogorov-Smirnov test. The probability distribution test used in this paper will be the Anderson-Darling test, as it is considered a more powerful tool than the ones mentioned before, since it gives more weight to the tails than other tests [24]. The Anderson-Darling test statistic (AD) is defined as:

$$AD^2 = -N - \sum_{i=1}^{N} \frac{2i-1}{N} [\ln(F(Yi)) + \ln(1 - F(Y_{N+1-i}))] \quad (27)$$

Where N is the number of samples, F is the cumulative distribution function of a specified distribution and Yi is the data sorted in an ascending order. The data sorted in a descended order is then Y_{N+1-i}.

One of the limitations of this probability distribution test has is that is does take into account the modality of the distribution. Therefore, it is necessary to conduct another test to see whether the solar and wind data have an unimodal distribution for each interval. In this work, only unimodal and a bimodal distributions are considered.

Just like the probability distribution tests, there are many bimodal distribution tests. In this study the Hartigan's dip test is the one used to determine if the sample follow an unimodal distribution, since it is more reliable than other bimodal tests [25].

The calculations done are the same as the ones done by J. A. Hartigan and P.M. Hartigan in their paper [26]. From the calculations we can obtain the Hartigan's dip statistic, where its values can range from 0 to 1. If the statistic is less than 0.1 it means that the sample has a significant bimodal behavior, which is the criteria used.

If the bimodality of the data sample is confirmed, the sample will be split into two samples of equal length and the Anderson-Darling test will be applied in each sample. If not, the Anderson-Darling test is applied on the entirety of the sample. To determine which probability distribution fits for each sample, the AD statistic is calculated assuming it follows a specified distribution. The AD statistic is calculated again for the all the remaining distributions in Table 3. If the AD statistic for a certain distribution has the lowest value amongst the rest, the sample data is best fitted into the distribution in question [27]. For bimodal distributions, it is possible to have different probability distribution for each sample.

The power outputs are not the only parameters in which the probability factor will be applied to. Other financial related parameters might have the uncertainty factor applied, as it will be shown in the following sections.

2.4 Economic analysis

The tools that will be used to carry on the analysis are the net present value (NPV) and the levelized cost of electricity (LCOE). Both of these are common and useful when it comes to economic analysis of power plants. Other criterion used in economic analysis are the payback period and the internal rate of return (IRR). However, the latter pair will not be covered in this study, as these tools are not so frequently employed in literature as the NPV and the LCOE. This work aims to orient investors when deciding what technology to use and in which location in the country.

The expression used to calculate the NPV is the following [28]:

$$NPV = \sum_{i=1}^{N} \frac{CF_i}{(1+r)^i} - (Eq \cdot I) \quad (28)$$

where Eq is the owner's equity of the total installation cost, I is the total installation cost and N the economic lifetime. The real discount rate (r) depends on the inflation (g) and the nominal discount rate (D), and it is expressed as:

$$r = \frac{D - g_i}{1 + g_i} \quad (29)$$

Note that the value of inflation might change every year. Thus, the real discount rate will be different if the inflation value is changed. It should be noted that the equity NPV is calculated (instead of the project NPV). The D is considered to be equal to the weighted-average capital costs, expressed as:

$$D = WACC = \frac{EV}{EV + DV} k_E + \frac{DV}{(EV + DV)} k_D \quad (30)$$

The EV is the equity value, DV is the debt value, k_E is the cost of equity and k_D the cost of debt. The combination of these last two parameters will be one that will keep the WACC value between 5% and 10%.

The cash flow (CF) will vary in each year and it depends on 4 variables: the earnings before taxes (EBT), the total taxes (TX), the annual loan payment (LP) and the depreciation value (DEP).

$$CF_i = EBT_i - TX_i - LP_i + DEP \quad (31)$$

The depreciation value will be constant each year. Therefore it can be expressed as:

$$DEP = \frac{I}{N} \quad (32)$$

The annual loan payment depends on the loan fee (LF) and the interest payments (IP). It can be expressed as:

$$LP_i = LF - IP_i \tag{33}$$

where the loan fee is calculated using the French amortization method, which considers the loan fee constant for all the loan lifetime, in this case considered the same as the economic lifetime of the project. Given a fixed interest rate (ir), the loan fee is expressed as:

$$LF = \frac{(1 - Eq) \cdot I \cdot ir}{1 - ((1 + ir)^{-N})} \tag{34}$$

The interest payment will vary each year, and it depends on the remaining borrowed money at the end of each year. It can be expressed as:

$$\begin{cases} IP_i = \big((1 - Eq) \cdot I\big) \cdot ir & if\ i = 1 \\ IP_i = (CO_{i-1} - LP_{i-1}) \cdot ir & if\ i > 1 \end{cases} \tag{35}$$

where CO_{i-1} can be interpreted as the capital outstanding in the year i-1. The capital outstanding in year is expressed as:

$$CO_i = CO_{i-1} - IP_{i-1} \tag{36}$$

The variables used to calculate the earnings before taxes can be split into two categories: income and costs. In the case of the income, it will mainly depend on the energy sold at each year (E_{pv}). Other variables that determine the income is the systems degradation rate ($degr$) and the price in which the energy is sold. The price will be determined as the product of the LCOE and the profit margin ($marg$). The income is then expressed as:

$$INCOME_i = E_{pv_i} \cdot (1 - degr)^i \cdot LCOE \cdot (1 + marg) \tag{37}$$

The costs will consist mainly on the yearly operational costs of the plant (OM), the depreciation and the interests for each year. It can be expressed as:

$$COST_i = OM_i - DEP - IP_i \tag{38}$$

Thus, the earnings before taxes for each year is calculated as:

$$EBT_i = INCOME_i - COST_i \tag{39}$$

The total taxes in each year can be positive in the years where the earnings before taxes has a positive value and zero when it does not (the possibility of compensating negative EBTs with future positive EBTs is therefore not considered, which could be regarded as the worst case) . The tax rate (tr) will be constant throughout the economic life time of the project.

$$\begin{cases} TX_i = EBT_i \cdot tr & if\ EBT_i > 0 \\ TX_i = 0 & if\ EBT_i < 0 \end{cases} \tag{40}$$

For the LCOE, the formula commonly used is the simple LCOE [29]:

$$LCOE = \frac{I + \sum_{i=1}^{N} \frac{OM_i}{(1+r)^i}}{\sum_{i=1}^{N} \frac{E_{pv_i}}{(1+r)^i}} \quad (41)$$

However, this formula will not be useful since it does not take into account taxes and other financial concepts. Instead, the formula used is the Leveraged LCOE formula [29]:

$$LCOE = \frac{I - \sum_{i=1}^{N} \frac{DEP}{(1+r)^i} \cdot tr + \sum_{i=1}^{N} \frac{LP_i}{(1+r)^i} - \sum_{i=1}^{N} \frac{IP_i}{(1+r)^i} \cdot tr + \sum_{i=1}^{N} \frac{OM_i}{(1+r)^i} \cdot (1-tr)}{\sum_{i=1}^{N} \frac{E_{pv_i}(1-degr)^i}{(1+r)^i}} \quad (42)$$

Once the formulas have been defined, the parameters shall be inserted to carry out the simulations, as it will be explained in the next section.

3. Simulation model

The Monte Carlo simulation model is a tool used in many fields such as engineering and finance to assess the different outcomes of an event that can have many results due to the uncertainty of prediction of some variables involved in the studied model. Factors like atmospheric conditions and finance related concepts can be hard to predict due to their randomness. It can be a very useful technique to guess the most probable outcome of a business model when some unpredictable variables can have a huge impact on the final result if they have their value slightly changed [30]. In the case studied, solar radiation and wind speed are examples of variables that are hard to predict. Other financial parameters might affect the outcome of the results. Therefore, it will deem necessary to carry out a sensitivity analysis in order to know which parameters are worthy of adding the randomness feature.

To start off, the parameters involved in the NPV calculation will have a fixed value. Afterwards, the NPV will be computed several times, each one after increasing and decreasing the parameter's value by 20%. The rate at which the NPV's original value for solar and wind generation will change is shown in the following graph.

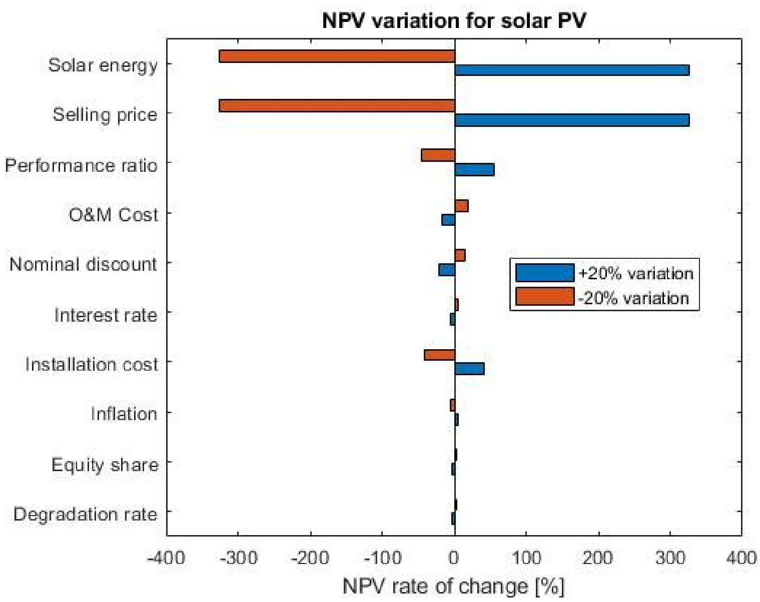

Figure 3. Sensitivity analysis results performed for solar PV for a fixed capacity. Source [own elaboration]

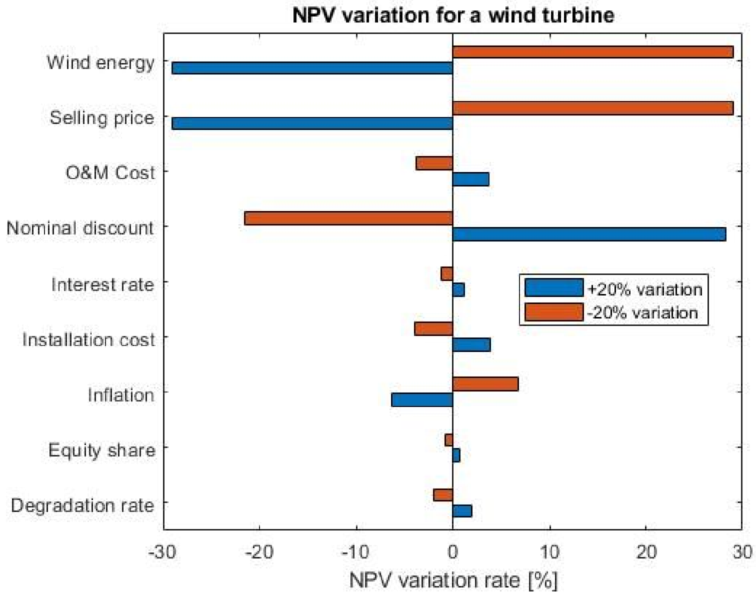

Figure 4. Sensitivity analysis performed for wind energy for a fixed capacity. Source [own elaboration]

It will be convenient to know the probability distribution function of these variables to have it model a realistic scenario and, thus, having more realistic results. Fortunately, some papers have already studied the rate at which some of the technical parameters value change in a physical experiment. These are the yearly system's degradation rate and the performance ratio. In the case of the financial parameters, recorded inflation rate of the Moroccan economy have been used [31]. The rest of the parameters will have a uniform distribution.

The total installation costs for the solar PV will vary between 1000 €/kW and 2000 €/kW and between 1000 €/kW and 2500 €/kW for wind turbine [32]. Depending on the tracking system in the case of solar PV, additional costs will be added to the total installation costs, as shown in Table 6 [33]. The yearly operational and maintenance costs for solar PV will vary between 10 €/kW·year and 18 €/kW·year. For wind turbines, the value will be between 40 €/kW·year and 60 €/kW·year [32]. Other parameters that will have a constant value are the interest rate and the owner's equity, assumed in this paper to have a value of 6% and 30% respectively. For the nominal discount rate, this can have a value from 5% to 10%, as mentioned in previous sections. In Morocco, private producers generally will have to sell their energy to the network operator (ONEE) and a power purchase agreement (PPA) has to be established. Information about whether the selling price might change during the economic lifetime of the project is not clear. Therefore, the price at which ONEE will purchase the electricity produced will be constant throughout the economic lifetime and this has to be negotiated with the network operator [34] .The profit margin can then be between 4% and 10% of the LCOE [35]. The inflation rate will be a random value each year and it will follow a probability distribution as shown in Table 4 [31]. Finally, the economic life time of the project will be 25 years, concurring with the duration of the power generation authorization mentioned in law nº 13-09 [6] .

For the technical parameters, degradation rate and performance ratio will have a distribution function assigned to them, as shown in Table 5 [36] [37] [38].

	Solar PV		Wind turbine	
Financial parameter	**Distribution**	**Value**	**Distribution**	**Value**
Installation costs	Uniform	[1000,2000] €/kW + Tracking system price	Uniform	[1000,2500] €/kW + Tracking system price
O&M costs	Uniform	[10 €/kW, 18 €/kW]	Uniform	[40 €/kW, 50 €/kW]
Interest rate	Constant	6%	Constant	6%
Owner's equity	Constant	30%	Constant	30%
Profit margin	Uniform	[4%,10%] of LCOE	Uniform	[4%,10%] of LCOE
Inflation rate	Lognormal	μ=0.33% σ=0.58%	Lognormal	μ=0.33% σ=0.58%
Nominal discount	Uniform	[5%, 10%]	Uniform	[5%, 10%]
Economic lifetime	Constant	25 years	Constant	25 years

Table 4. Financial parameters used in the simulation model. Source: [own elaboration]

	Solar PV		Wind turbine	
Technical parameter	**Distribution**	**Value**	**Distribution**	**Value**
Degradation rate	Gamma	a=1.67% b=40.58%	Uniform	[0.2%, 0.4%]
Performance ratio	Lognormal	μ=4.35% σ=0.16%	Lognormal	μ=4.35% σ=0.16%

Table 5. Technical parameters used in the simulation model. Source: [own elaboration]

Tracking system	Price [€/kW]
No tracking system	0
Horizontal axis tracking	240
Vertical axis tracking	360
Two axis tracking	520

Table 6. Additional installation costs for solar tracking. Source [33]

In the sensitivity analysis the wind turbine power capacity has quite the impact on the NPV value. In this paper the Monte Carlo simulation will be applied for 3 different levels of power capacity: 100kW, 3MW and 5MW. This will allow to compare between solar PV and Wind turbines and decide which option is more profitable in all scenarios. Usually, installation cost tend to decrease when the power capacity is higher. In this study however, this will not be considered, as not analyzing optimistic scenarios can erase doubts about whether the practical application does not concur with the theory presented in this paper.

Once all the parameters are introduced, it remains to define the number of simulations to be done in each case. Ideally, the number should be large enough until no notable variation happens to the rolling average [Figure 5]. In this paper, 20 sets of 500 simulation will be carried on for each city, configuration, technology and power capacity.

Once the simulations are done, a 95% confidence interval has been calculated for each case using the Matlab software [39]. The results will be discussed in the following section.

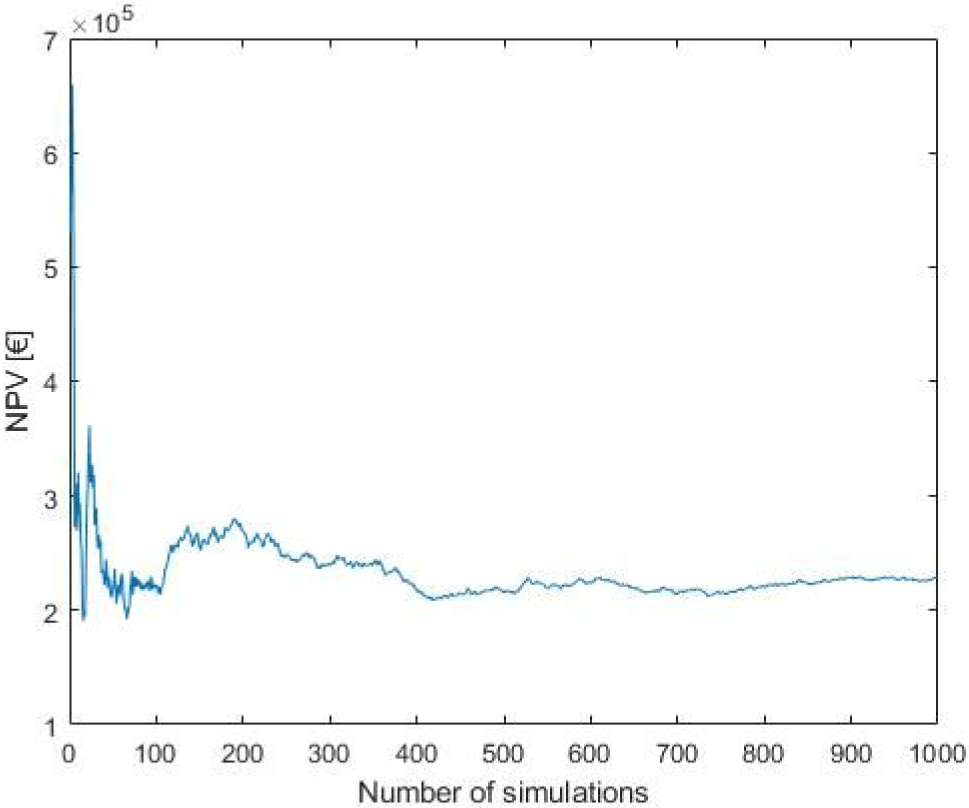

Figure 5. Rolling average of the NPV as the number of simualtions increase. Source [own elaboration]

4. Results and discussions

In Monte Carlo simulations, the results are usually presented in confidence intervals (usually at 95%) where the outcome will most likely fall into. In this section however, the mean value of these intervals will be presented in a bar graph for better visualization of the obtained results. The confidence intervals for each case can be reviewed in the appendix.

The results will be reviewed in two parts. The first part will separately discuss the results separately for each solar PV tracking system and wind turbines in each level of power capacity. The best technology and the location where it's best applied will be decided in each of these levels. In the second part, found in the conclusion section, we will discuss the overall summary of the study and all three levels of power capacity will be compared. We will also review the overall study and mention some considerations about the study done.

- Results of the 5MW capacity power plant:

From the graph [Figure 6], it can be seen that solar PV is more profitable than wind energy at 5MW of power capacity. It can also be noted that the more sophisticated the tracking system the higher the NPV value is. This applies in all locations except in Marrakech, where all PV configurations have a very similar NPV value. This is due to the fact that the solar energy resource in this location is large enough that those panel configurations with tracking systems can sell their energy at low prices, which decreases the amount of income. Therefore, for this location, when deciding which configuration to use, the LCOE can be another criteria to narrow down the choices. Having said that, the north-south axis tracking system and the two-axis tracking system have the lowest LCOE with values of 0.025 €/kWh. The slopped surface with vertical axis tracking system also has the lowest LCOE when comparing the same technology in other locations.

When it comes to wind energy, this technology has the lowest LCOE in all locations (excluding Marrakech, as mentioned previously) amongst all technologies, with an average of 0.04 €/kWh. Wind turbines might be the best choice when considering the attractiveness of the price when selling the electricity to the network operator. Essaouira, Safi and Laayoune are the best options when deciding the location of a wind farm, since they have the highest NPV and the lowest LCOE respectively [Figure 6] [Figure 7].

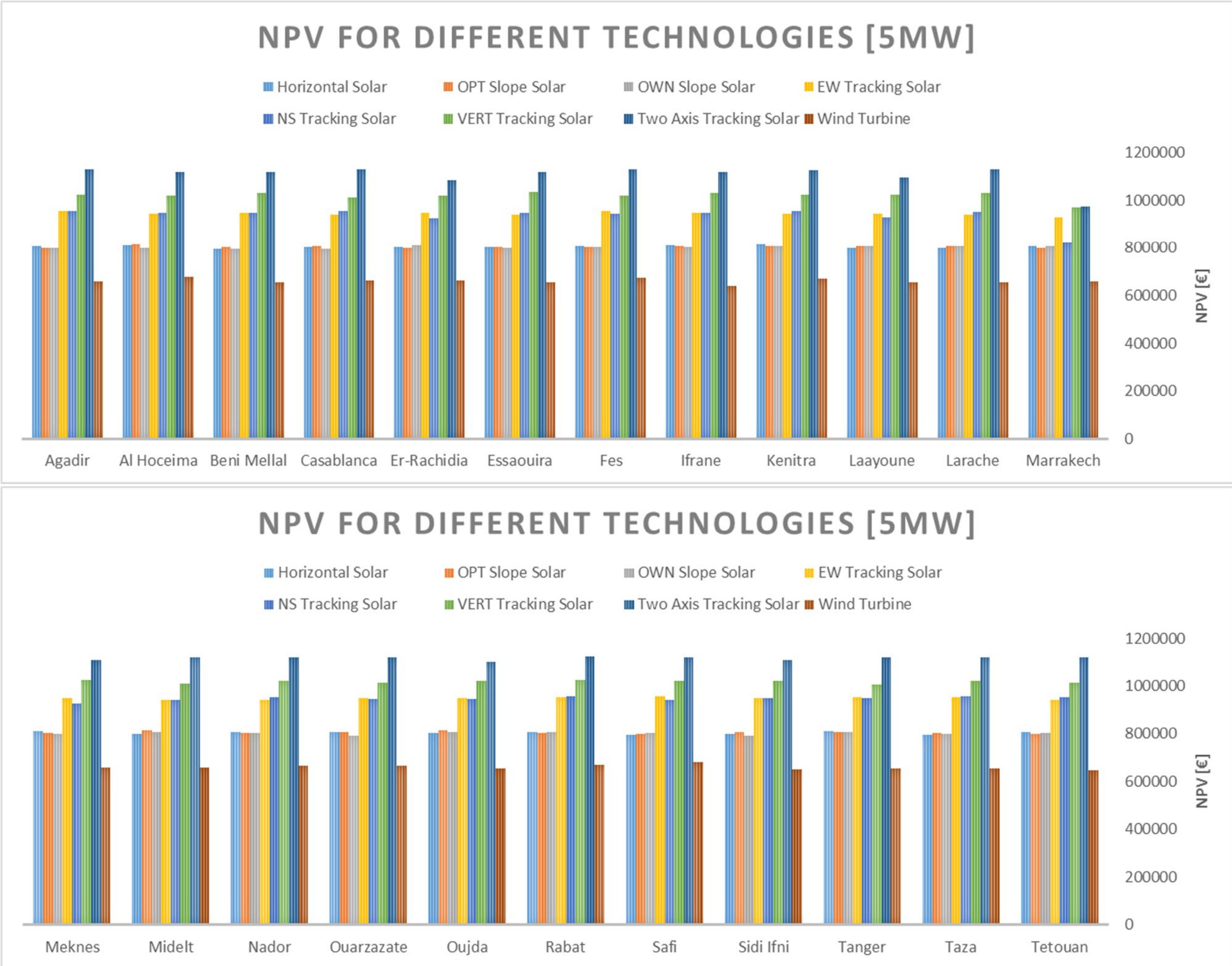

Figure 6. Mean NPV values for all technologies in each studied city for a 5MW power plant. Horizontal solar: 0º tilted surface; OPT Slope Solar: tilted surface at optimum angle; OWN Slope Solar: tilted surface at chosen angle; EW Tracking Solar: horizontal east-west axis tracking system panel; NS Tracking Solar: horizontal north-south axis tracking system panel; VERT Tracking Solar: vertical axis tracking system panel with a tilted surface; Two Axis Tracking Solar: two axis tracking system panel; Wind Turbine: wind turbine. Source [own elaboration]

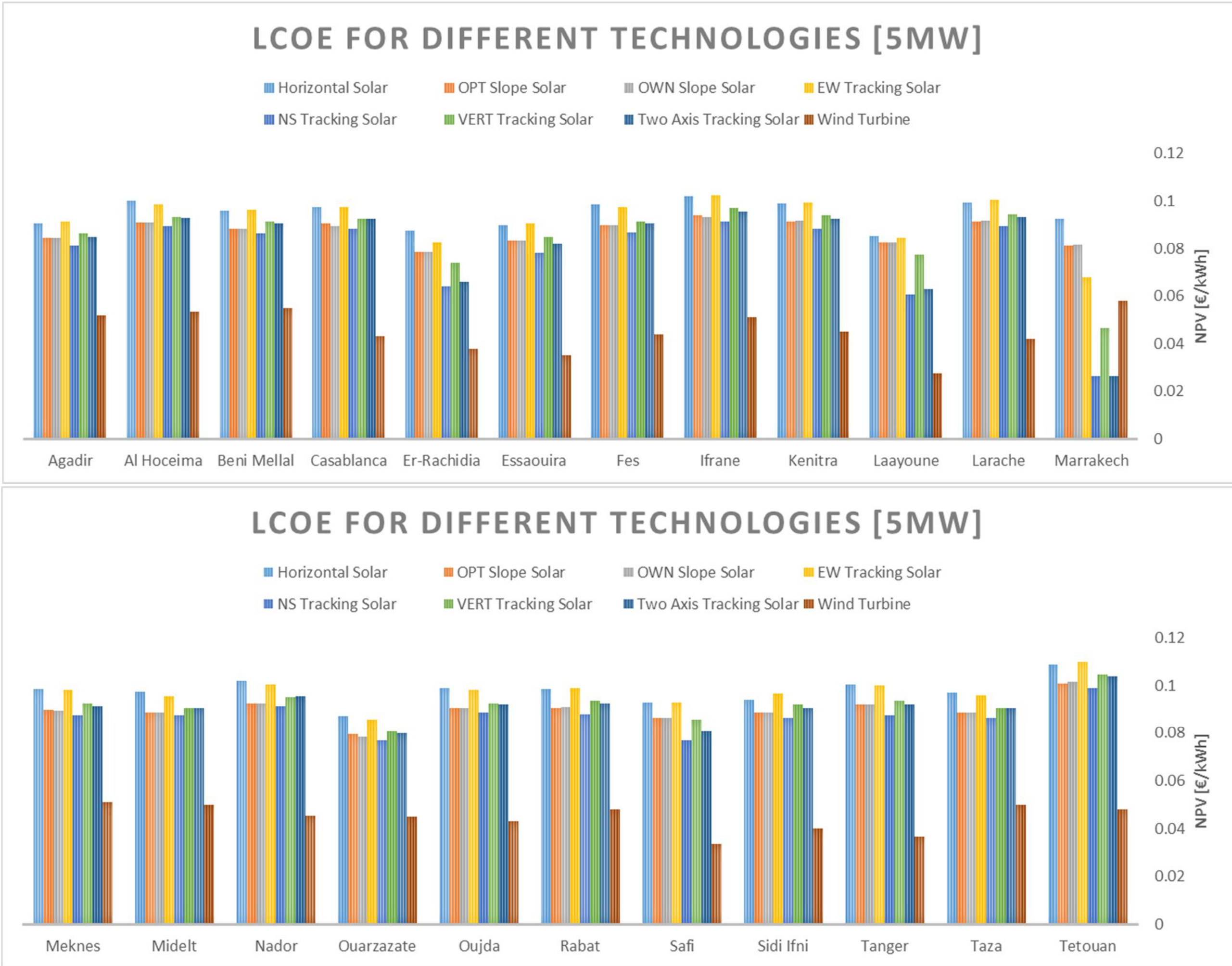

Figure 7. Mean LCOE values for all technologies in each studied city for a 5MW power plant. Horizontal solar: 0º tilted surface; OPT Slope Solar: tilted surface at optimum angle; OWN Slope Solar: tilted surface at chosen angle; EW Tracking Solar: horizontal east-west axis tracking system panel; NS Tracking Solar: horizontal north-south axis tracking system panel; VERT Tracking Solar: vertical axis tracking system panel with a tilted surface; Two Axis Tracking Solar: two axis tracking system panel; Wind Turbine: wind turbine. Source [own elaboration]

- Results for a 3MW power capacity plant:

At first glance on the graph [Figure 8], wind generation does not seem as a suitable choice at this power capacity level. In all 23 locations it has the lowest NPV value and the LCOE seems to be lower than solar PV in cities such as Er-Rachidia, Essaouira, Laayoune and Safi, yet it can surpass the solar PV LCOE of all configurations in Marrakech. In other regions, the wind LCOE has similar values to the solar LCOE. This includes coastal locations and high altitude regions such as Ifrane. Amongst solar NPV's, the two-axis tracking system is the one with the highest value. However, it doesn't have the highest LCOE. The horizontal PV surface has a considerably higher LCOE when looking at the NPV values. Therefore, it is not the desirable solar PV configuration at this power level.

The best choice in this power level is the solar PV, with the most profitable configurations the two-axis tracking, the vertical axis tracking and the north-south horizontal axis tracking systems, as they have the highest NPV values and the lowest LCOE, with the lowest production costs in Marrakech, going as far as 0.042 €/kWh for the vertical axis tracking system and 0.025€/kWh for the other two mentioned tracking systems [Figure 8] [Figure 9].

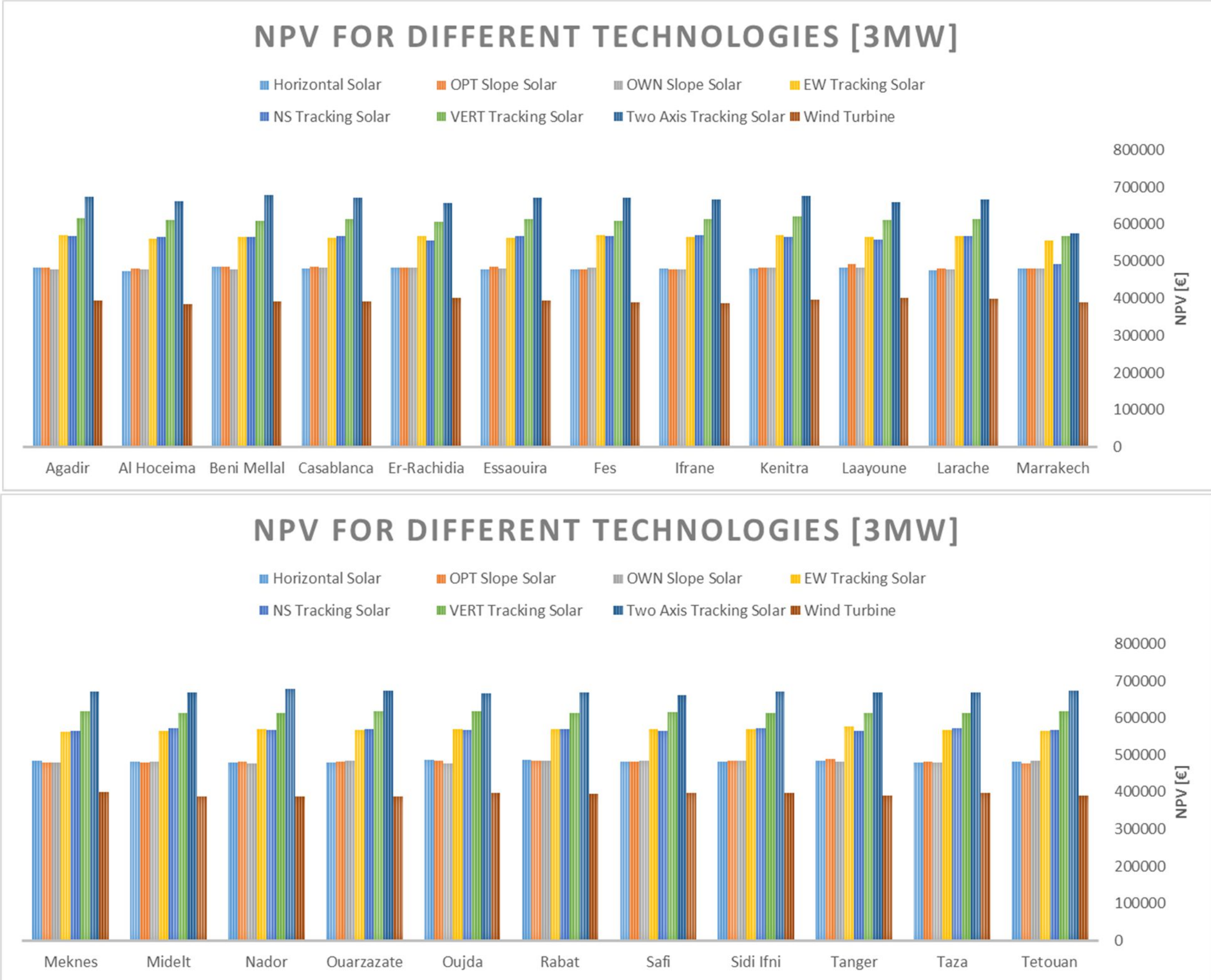

Figure 8. Mean NPV values for all technologies in each studied city for a 3MW power plant. Horizontal solar: 0º tilted surface; OPT Slope Solar: tilted surface at optimum angle; OWN Slope Solar: tilted surface at chosen angle; EW Tracking Solar: horizontal east-west axis tracking system panel; NS Tracking Solar: horizontal north-south axis tracking system panel; VERT Tracking Solar: vertical axis tracking system panel with a tilted surface; Two Axis Tracking Solar: two axis tracking system panel; Wind Turbine: wind turbine. Source [own elaboration]

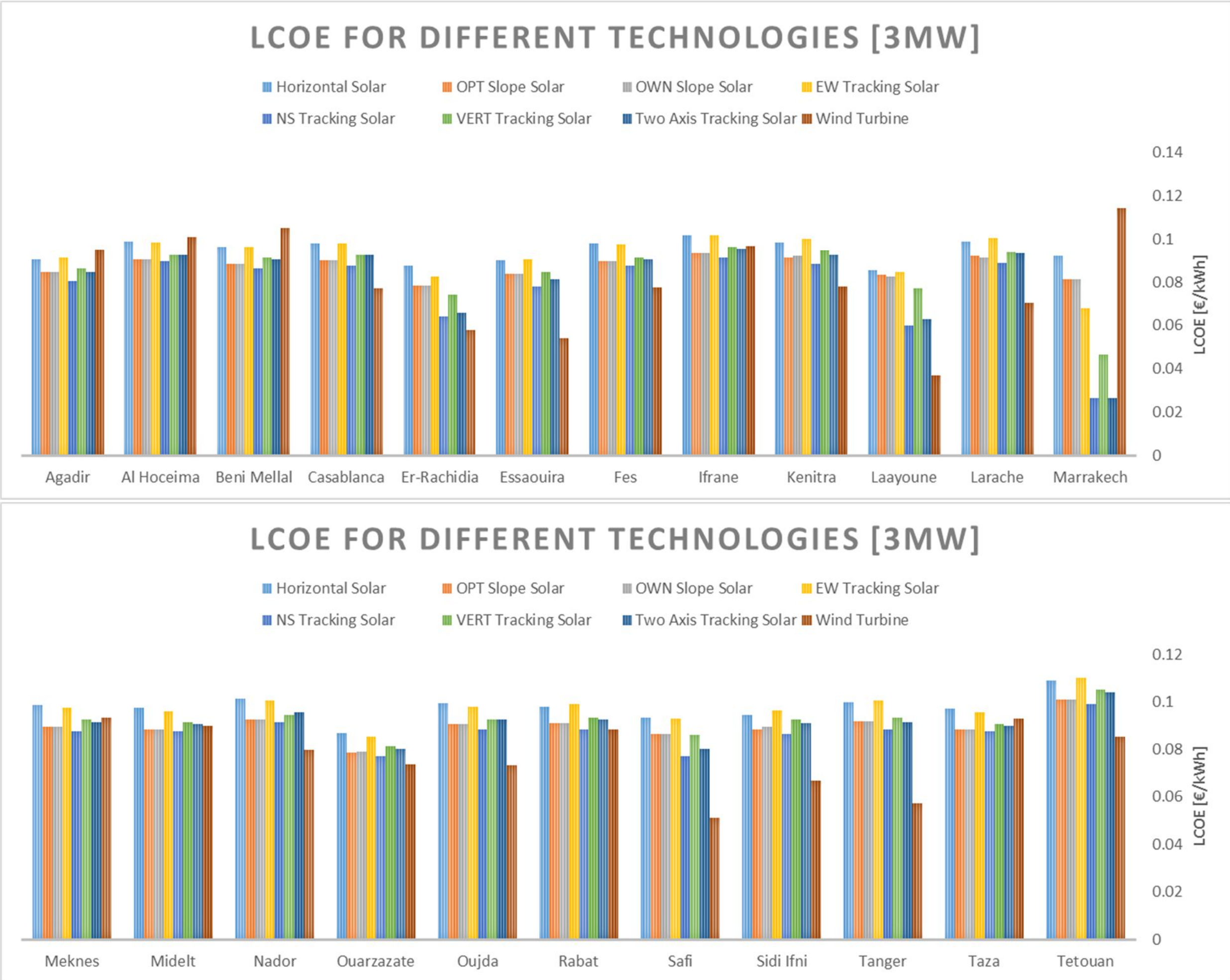

Figure 9. Mean LCOE values for all technologies in each studied city for a 3MW power plant. Horizontal solar: 0º tilted surface; OPT Slope Solar: tilted surface at optimum angle; OWN Slope Solar: tilted surface at chosen angle; EW Tracking Solar: horizontal east-west axis tracking system panel; NS Tracking Solar: horizontal north-south axis tracking system panel; VERT Tracking Solar: vertical axis tracking system panel with a tilted surface; Two Axis Tracking Solar: two axis tracking system panel; Wind Turbine: wind turbine. Source [own elaboration]

- Results for a 100kW power capacity plant:

Wind turbines continue to have lower NPV values compared to solar PV. The LCOE is not the most attractive when comparing to solar PV (excluding Er.Rachidia, Essaouira Laayoune, Safi and Tanger), surpassing the 0.45 €/kWh in Marrakech. For solar PV however, the more perpendicular the beam radiation is to the panel surface the higher the NPV value it is. The LCOE is also more attractive when the tracking system is more sophisticated. Marrakech has the most attractive LCOE for solar PV at this power level when it comes to a north-south axis tracking system and a two axis tracking system. The LCOE can reach up to 0.025 €/kWh. In the northern region, although the NPV are not the lowest in the country, the prices of solar PV are higher than the rest of Morocco, with a maximum of 0.104 €/kWh in Tetouan for the east-west axis tracking system solar PV panel.

In Laayoune however, wind generation is cheaper than solar PV and it is where we can find the higher NPV value amongst the rest of locations, with a levelized cost of 0.048 €/kWh [Figure 10] [Figure 11].

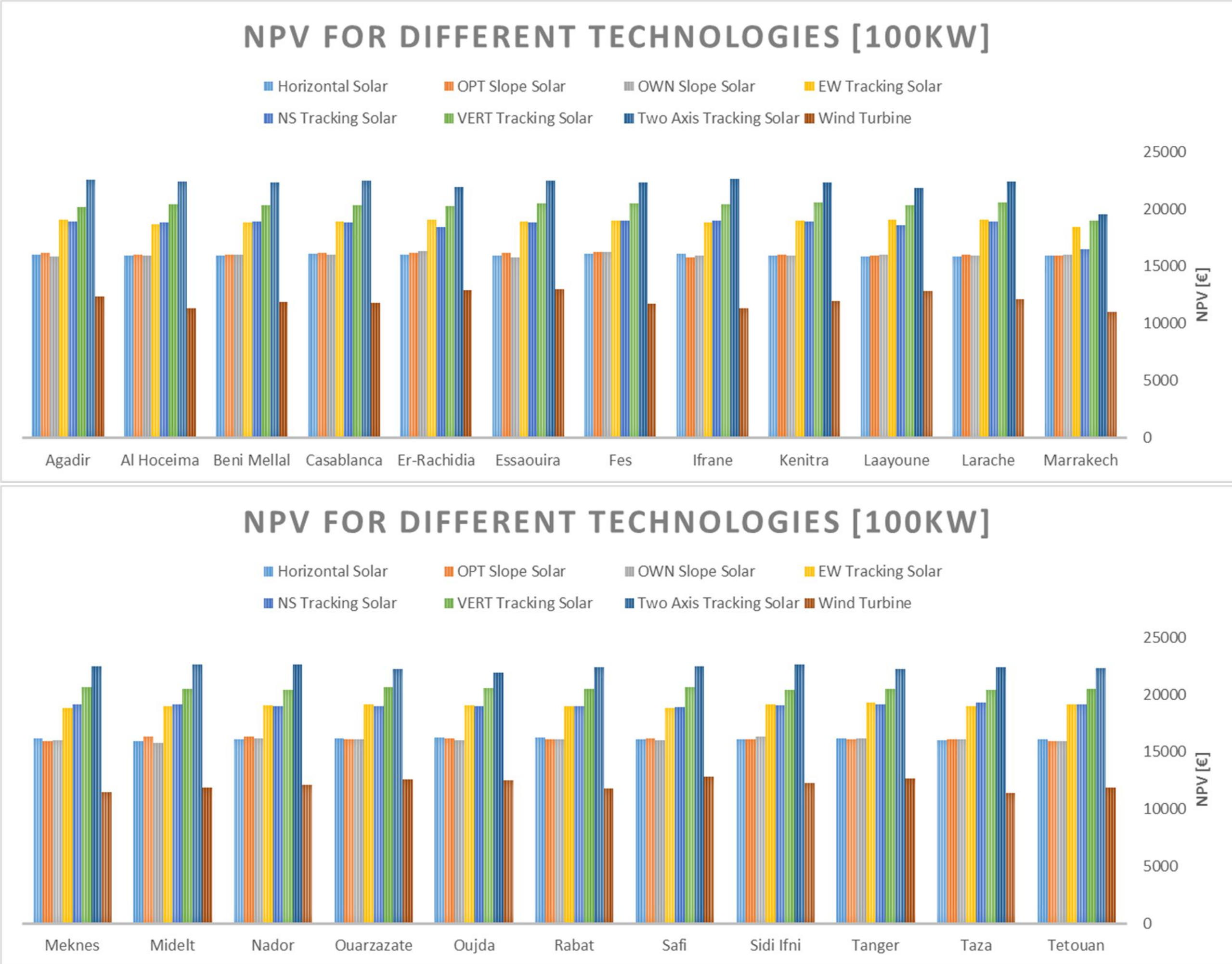

Figure 10. Mean NPV values for all technologies in each studied city for a 100kW power plant. Horizontal solar: 0º tilted surface; OPT Slope Solar: tilted surface at optimum angle; OWN Slope Solar: tilted surface at chosen angle; EW Tracking Solar: horizontal east-west axis tracking system panel; NS Tracking Solar: horizontal north-south axis tracking system panel; VERT Tracking Solar: vertical axis tracking system panel with a tilted surface; Two Axis Tracking Solar: two axis tracking system panel; Wind Turbine: wind turbine. Source [own elaboration]

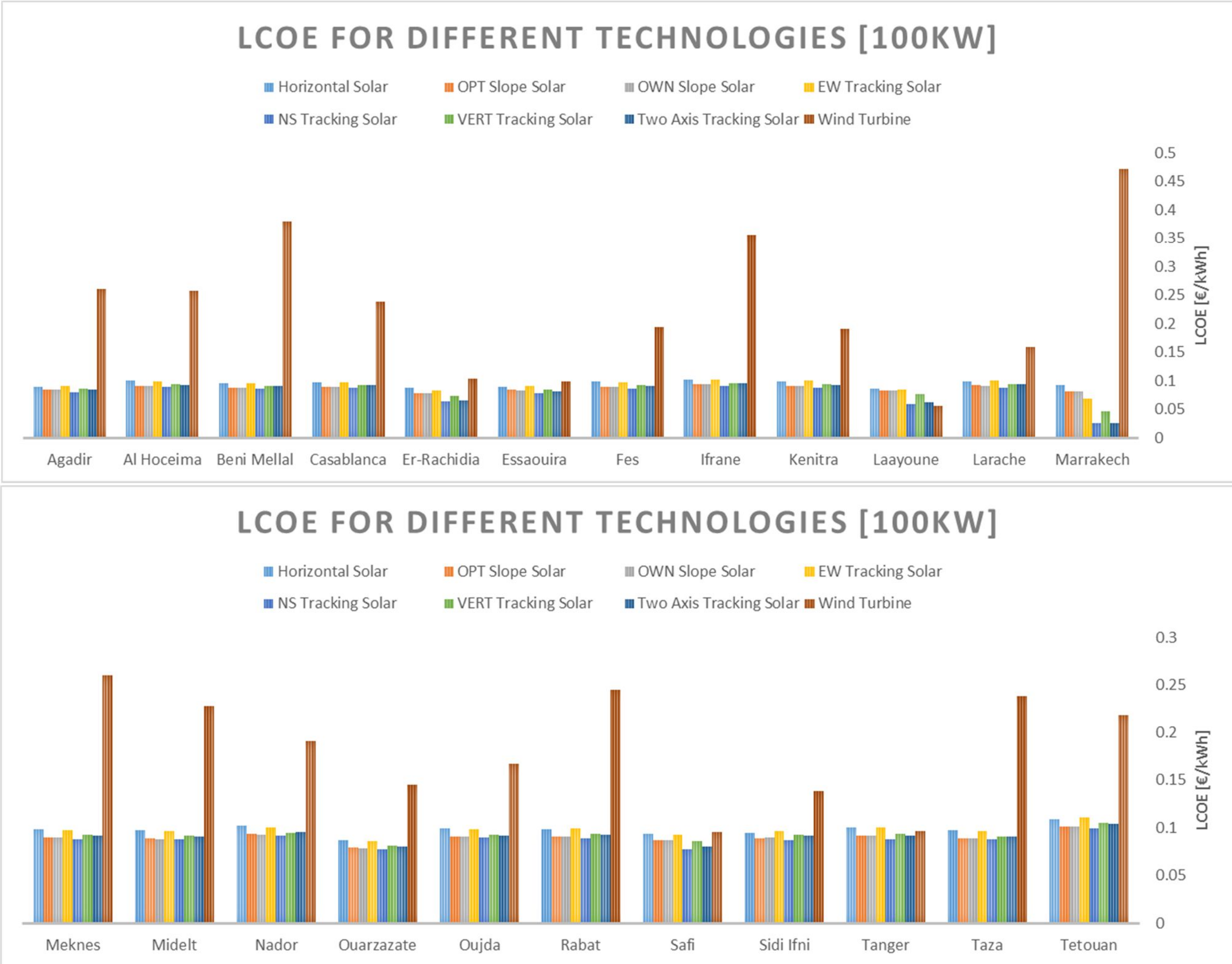

Figure 11. Mean LCOE values for all technologies in each studied city for a 100kW power plant. Horizontal solar: 0º tilted surface; OPT Slope Solar: tilted surface at optimum angle; OWN Slope Solar: tilted surface at chosen angle; EW Tracking Solar: horizontal east-west axis tracking system panel; NS Tracking Solar: horizontal north-south axis tracking system panel; VERT Tracking Solar: vertical axis tracking system panel with a tilted surface; Two Axis Tracking Solar: two axis tracking system panel; Wind Turbine: wind turbine. Source [own elaboration]

5. Environmental impact study

With the Moroccan Solar Plan and the Moroccan Wind Plan, the country will decrease it CO_2 emissions considerably. In 2018 the total electric consumption of the country was 26.83 billion kWh [40]. In the same year the total CO_2 emissions was about 56.85 million tons of CO_2 [41]. Since the renewable mix in that year was 35% of the total production mix and taking into account that the energy consumption increases an average of 3.2% every year, if Morocco manages to increase that number to 42% in 2020, the total CO_2 emissions in that year would be approximately:

$$CO_2\ emissions(2020) = \frac{56.85\ mil\ tons\ CO_2}{(1-0.35)\cdot 26.83\ bn\ kWh}\cdot 26.83\ bn\ kWh\cdot(1+0.032)^{2020-2018}\cdot(1-0.42) \qquad (43)$$

$$CO_2\ emissions(2020) = 54.03\ mil.tons\ CO_2$$

This means that about 10.75% of CO_2 emissions will be avoided in 2020. Applying the same formula as in Eq. (43), in 2030, where the renewable energy mix is of 52%, the kingdom will save up to 26.16% of CO_2 emissions. These numbers are refereeing to the case where 35% of the energy mix is composed from renewable energy for 2020 and 2030. Therefore we can see that as a developing country, this accomplishment will be quite the success in the following years.

Thanks to its efforts, Morocco is currently a big contributor in this climate change fight the world is currently facing. Countries with similar conditions as in Morocco can follow the example and reduce the global CO_2 emissions at a greater scale.

6. Conclusions

It can be noted that in the higher the power capacity for wind turbines, the more attractive is investing in this technology. Very low power capacities have higher LCOE. The locations best suited for this kind of technology are those within the Atlas Mountains and the coastal regions of the kingdom. Although it has the lowest profitability in front of solar PV, the relatively low investment costs and low LCOE does not make it worth discarding the option to invest in this technology, since the low prices means higher chances of a good PPA with the network operator, only when it comes to high power capacity.

When it comes to solar PV, locations with a near deserted climate conditions with low cloud indexes are the best places to install a plant with this technology. Considering that more advanced tracking systems have higher installation costs, one-axis' tracking systems seem the better choice when deciding on this technology. Just like wind energy, the higher the power capacity level, the lower the LCOE, although the difference is not as noticeable as that of wind turbines. Still, lower LCOE means a fine opportunity to establish a PPA with the country's sole network operator.

In this study we have reviewed the economic feasibility of solar PV and wind energy in Morocco. The previous sections have proven that the technology best suited for a location may not be a good choice for another place. It should be reminded that the parameters used in this paper may not correspond with the ones used in practical applications. This is due to the big number of incentives the Moroccan government offer to foreign and local investors wishing to involve in these types of economic activities [42]. Therefore, the study here conducted could be regarded as a conservative or cautious scenario not including tax incentives currently in force. A more specific and detailed study should be conducted for real applications. The effective implementation could have better results than the ones obtained in this work. If this is accomplished, not only the electricity produced will come mostly from renewable sources, but the amount of CO_2 emissions will decrease significantly, contributing positively to the climate change issue.

Economic budget

This chapter aims to estimate the cost of this work using available data on the web. The hours spent in this work will determine the economic budget. In 2019, the average salary an engineer earns is about 11.32 €/hour [43]. The total amount of hours spent in this project is 600 hours. Therefore, the taxable base in this case is:

$$Tax.base = 11.32 \frac{€}{hour} \cdot 600\ hours = 6792€ \quad (44)$$

In Spain, the VAT value is 21% [44]. This means that the amount of taxes derived from this project is:

$$Taxes = 7358€ \cdot 21\% = 1426.32\ € \quad (45)$$

With all the information now calculated, the total economical budget is the following:

Economical Budget	
Engineering work………………………………………………	6792 €
VAT(21%)…………………………………………………	1426.32€
Total………………………………………………………..	8218.32€
This budget is valid until 01/12/2019	
	Today at 04 of June, 2019 in Barcelona

Table 7. Economical budget of the project.

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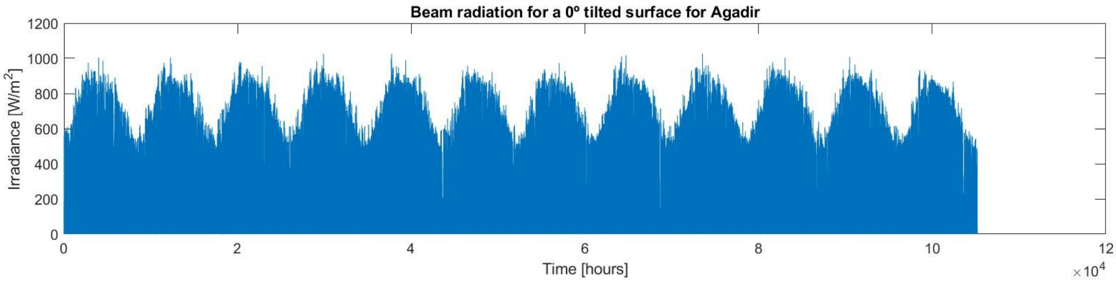
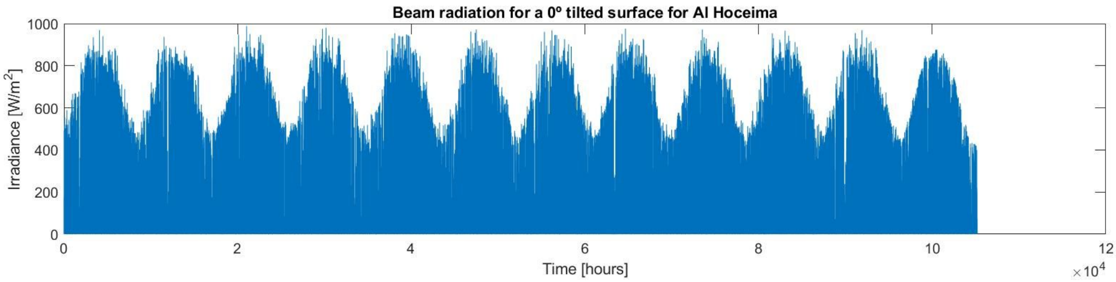
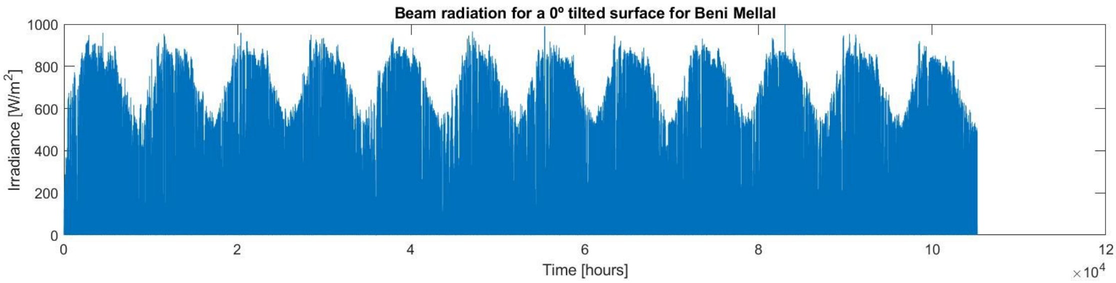
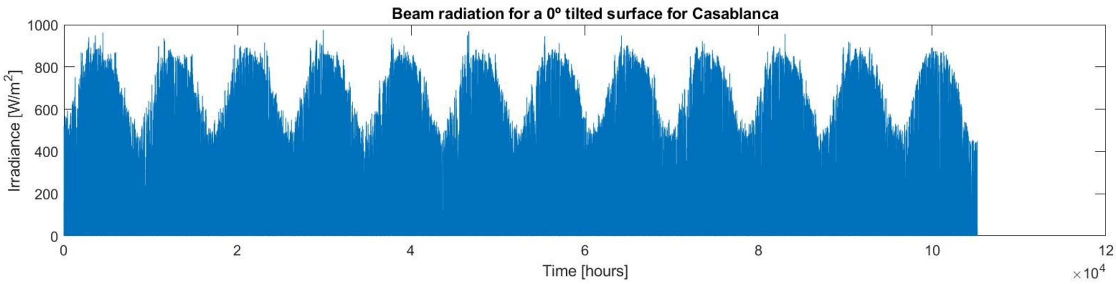
Appendix

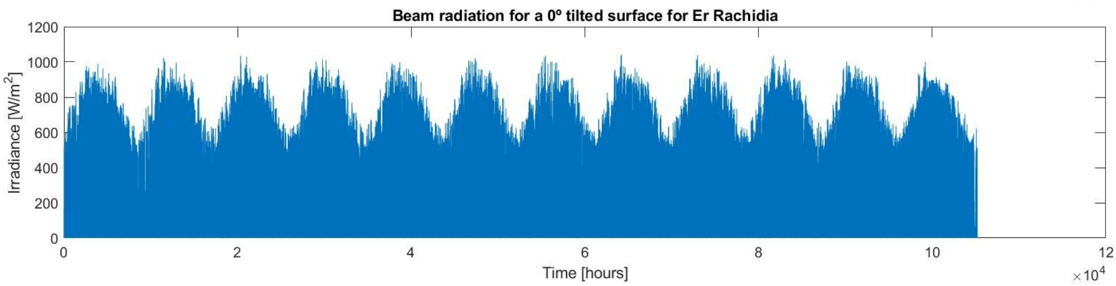
Beam radiation for a 0º tilted surface of all cities

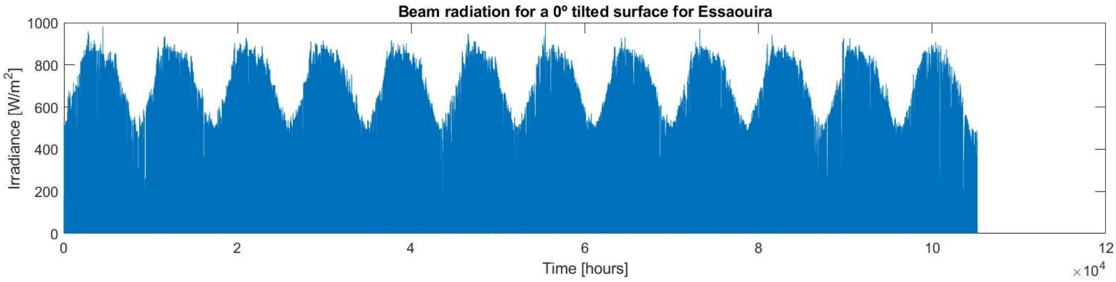


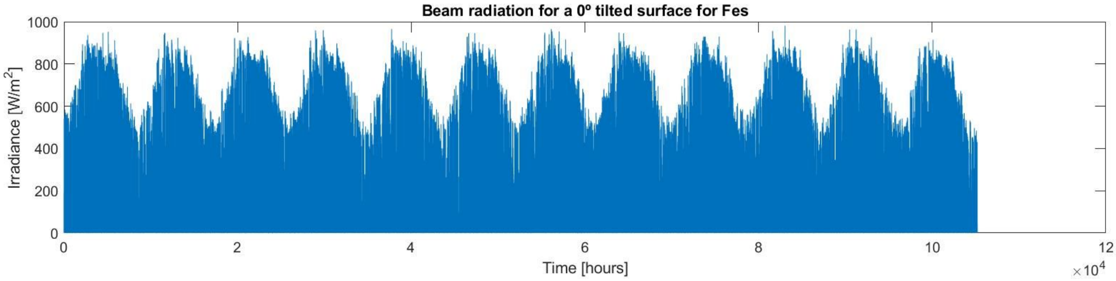


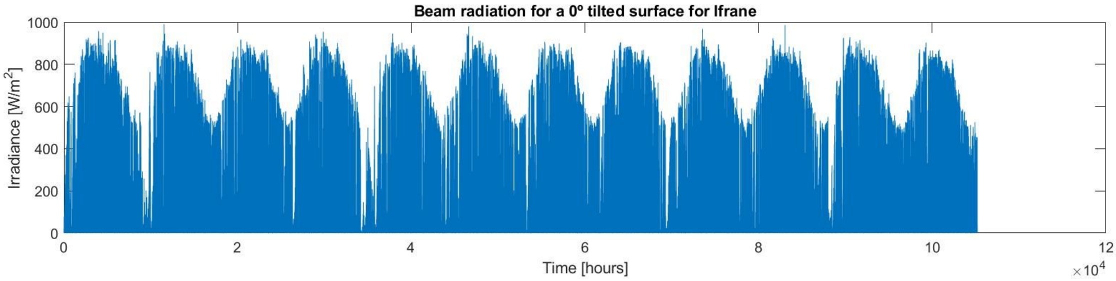


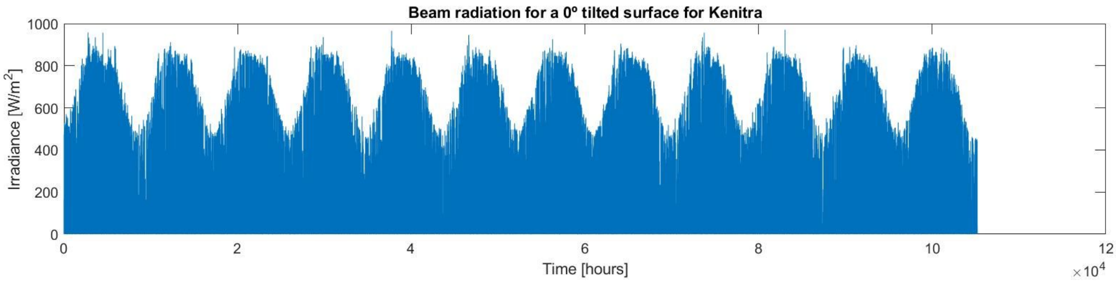


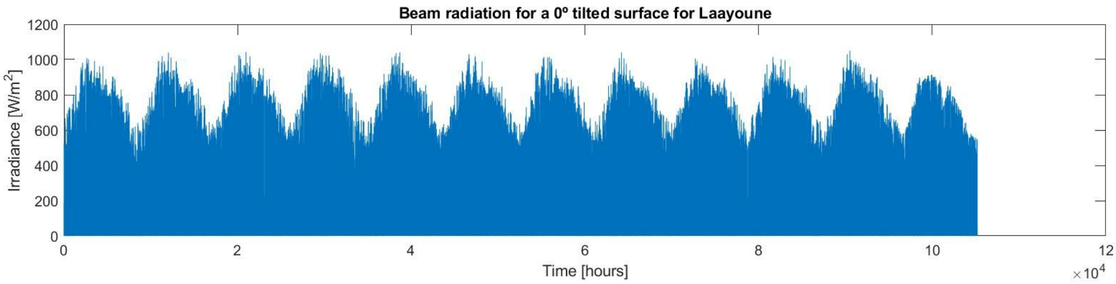


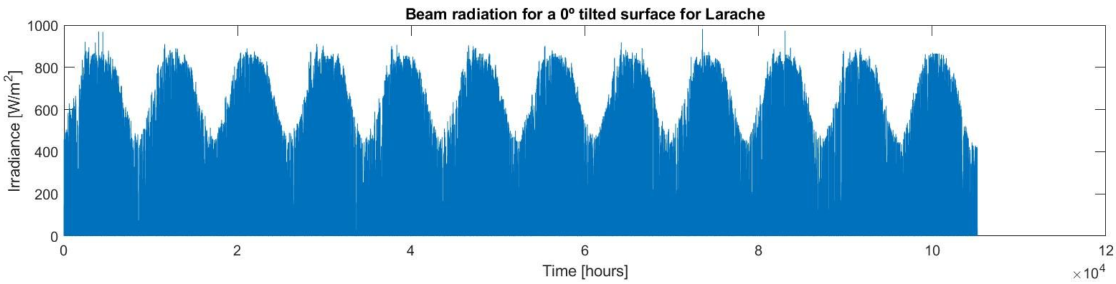

Beam radiation for a 0º tilted surface for Essaouira
Irradiance [W/m2]
Time [hours]
×10^4

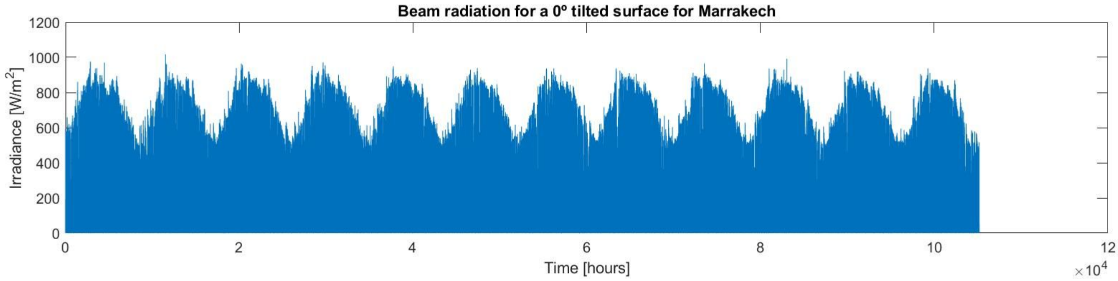

Beam radiation for a 0º tilted surface for Fes
Irradiance [W/m2]
Time [hours]
×10^4

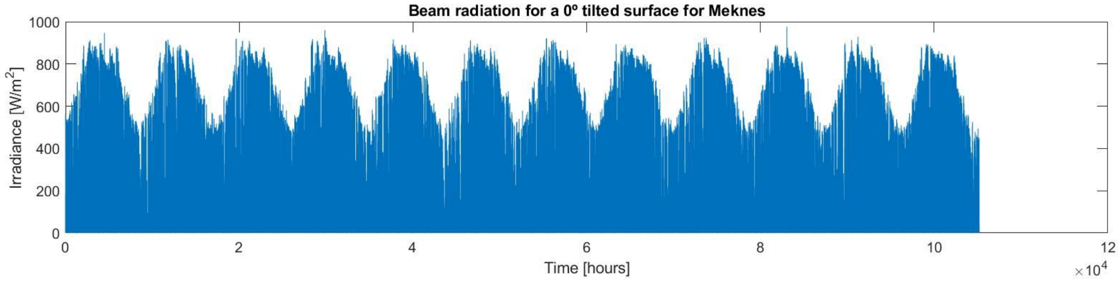

Beam radiation for a 0º tilted surface for Ifrane
Irradiance [W/m2]
Time [hours]
×10^4

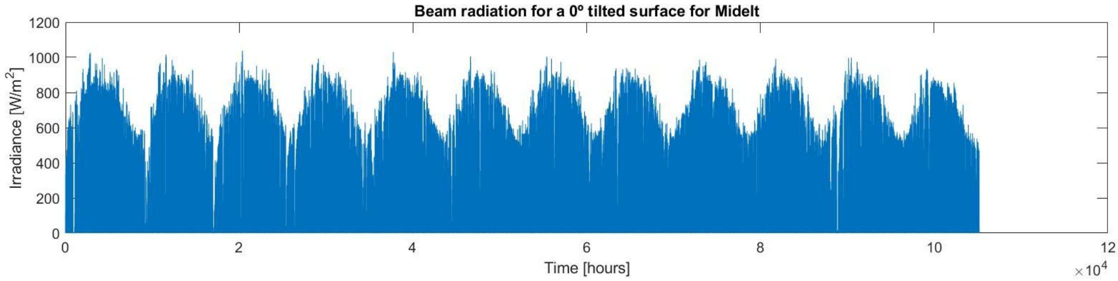

Beam radiation for a 0º tilted surface for Kenitra
Irradiance [W/m2]
Time [hours]
×10^4

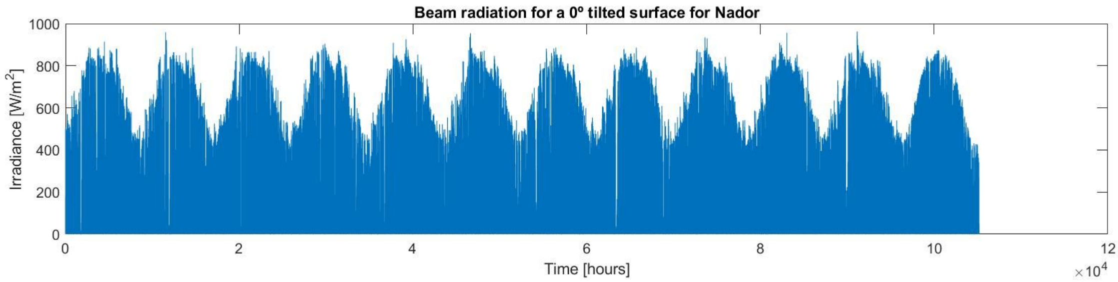

Beam radiation for a 0º tilted surface for Laayoune
Irradiance [W/m2]
Time [hours]
×10^4

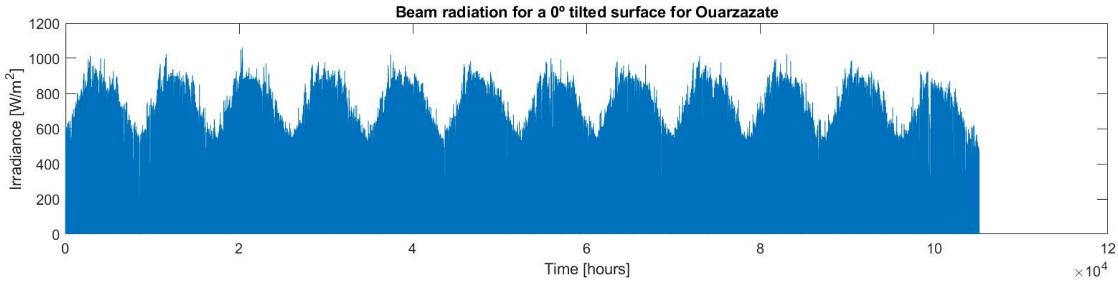

Beam radiation for a 0º tilted surface for Larache
Irradiance [W/m2]
Time [hours]
×10^4

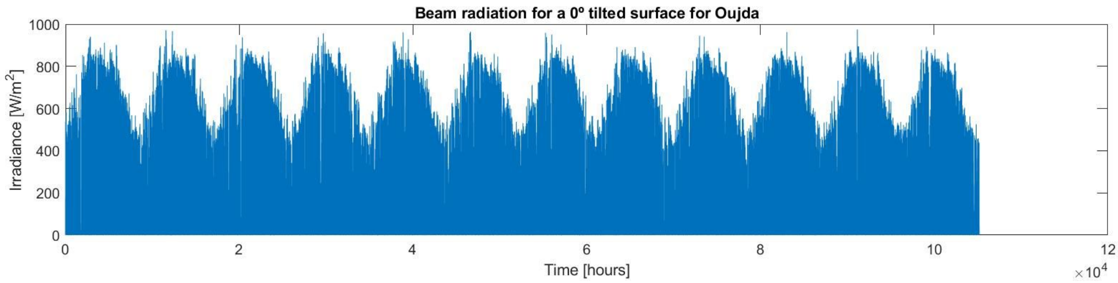

Beam radiation for a 0º tilted surface for Marrakech
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

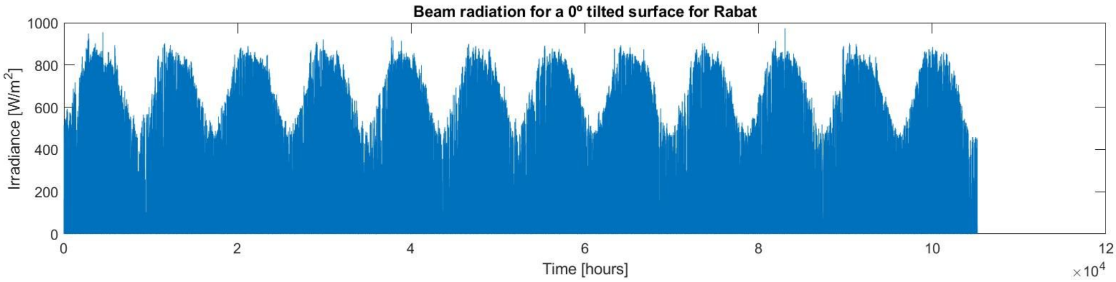

Beam radiation for a 0º tilted surface for Meknes
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

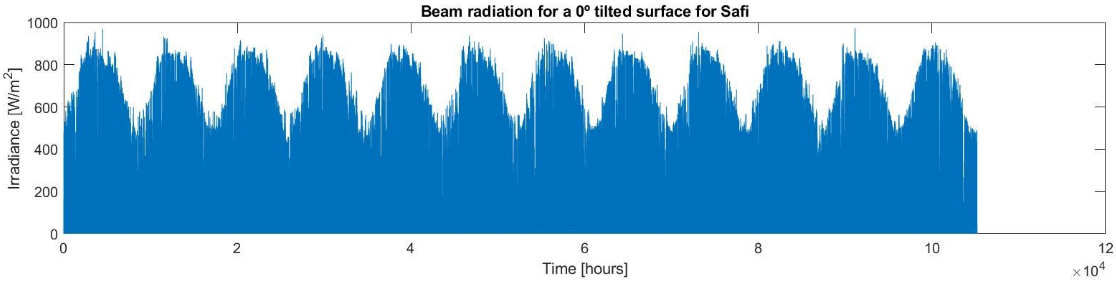

Beam radiation for a 0º tilted surface for Midelt
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

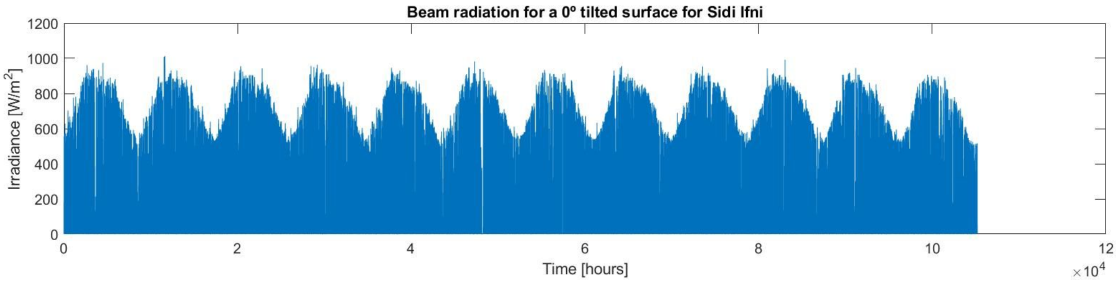

Beam radiation for a 0º tilted surface for Nador
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

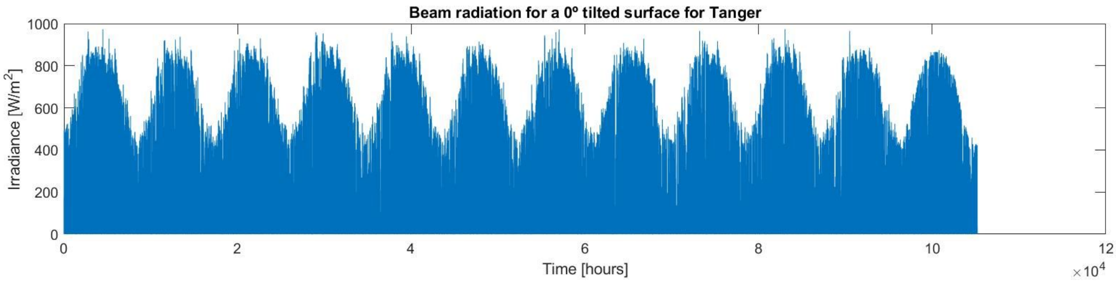

Beam radiation for a 0º tilted surface for Ouarzazate
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

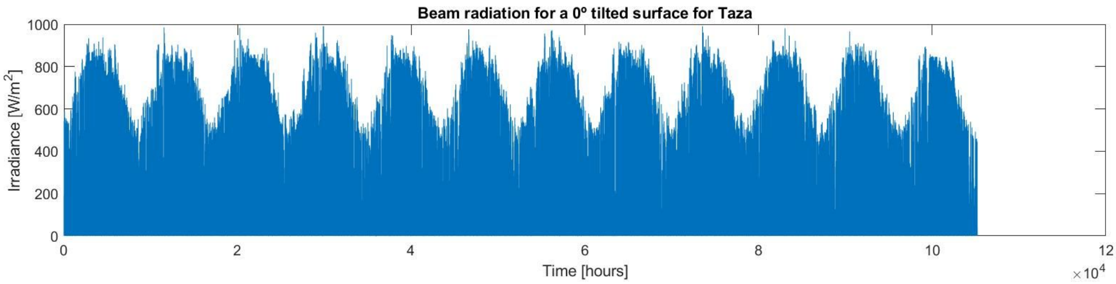

Beam radiation for a 0º tilted surface for Oujda
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

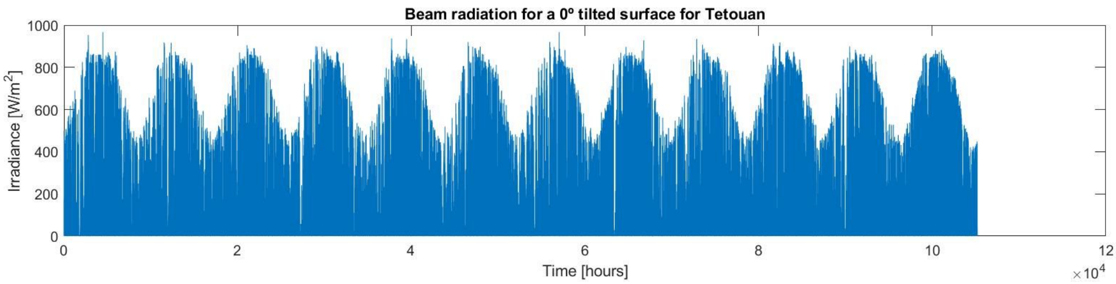

Beam radiation for a 0º tilted surface for Rabat
Irradiance [W/m2]
Time [hours]
×10^4


Beam radiation for a 0º tilted surface for Safi
Irradiance [W/m2]
Time [hours]
×10^4

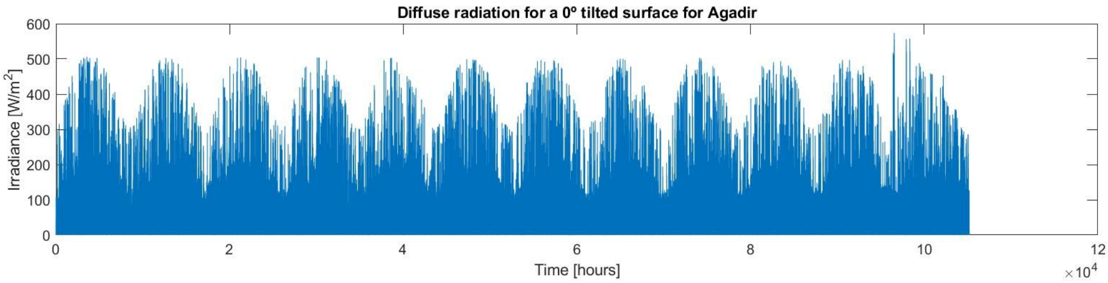

Beam radiation for a 0º tilted surface for Sidi Ifni
Irradiance [W/m2]
Time [hours]
×10^4

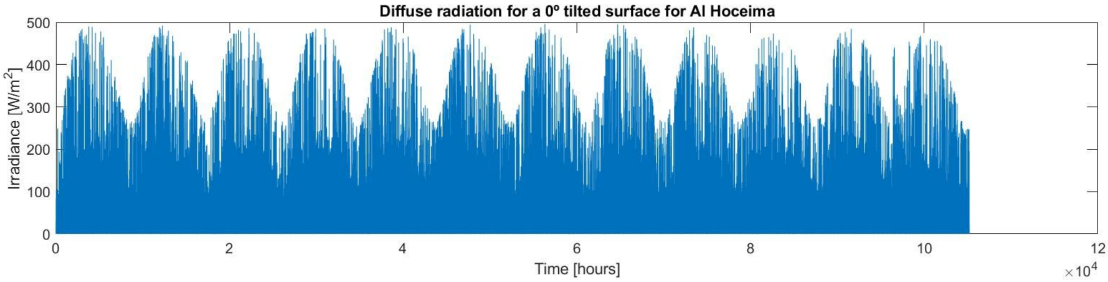

Beam radiation for a 0º tilted surface for Tanger
Irradiance [W/m2]
Time [hours]
×10^4

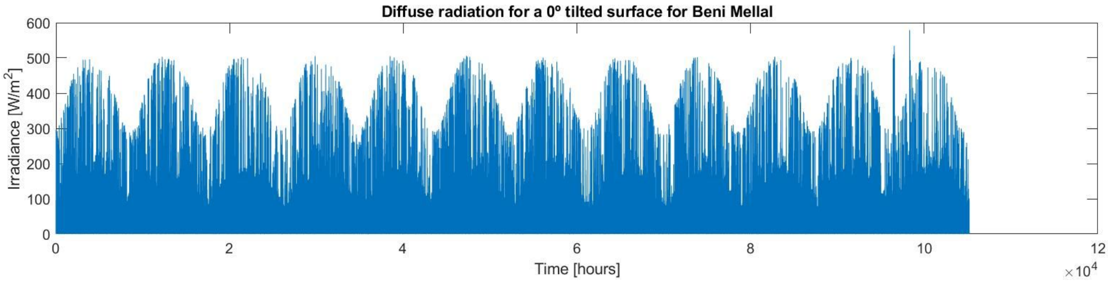

Beam radiation for a 0º tilted surface for Taza
Irradiance [W/m2]
Time [hours]
×10^4

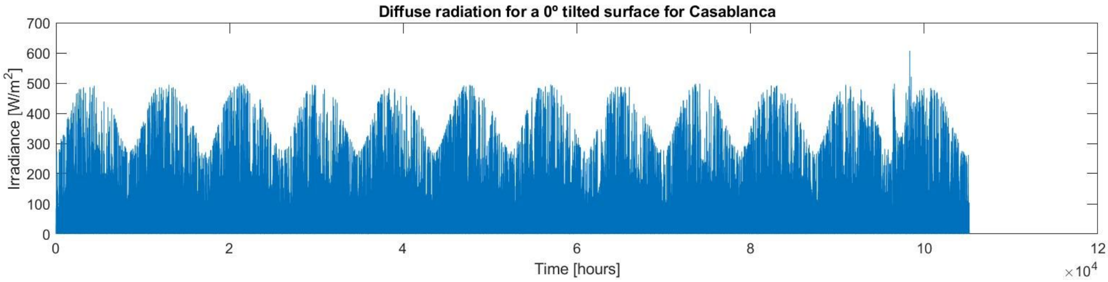

Beam radiation for a 0º tilted surface for Tetouan
Irradiance [W/m2]
Time [hours]
×10^4

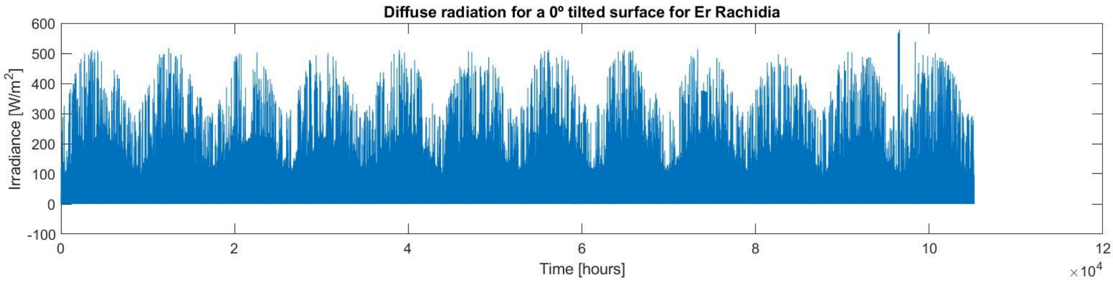
Diffuse radiation for a 0º tilted surface of all cities

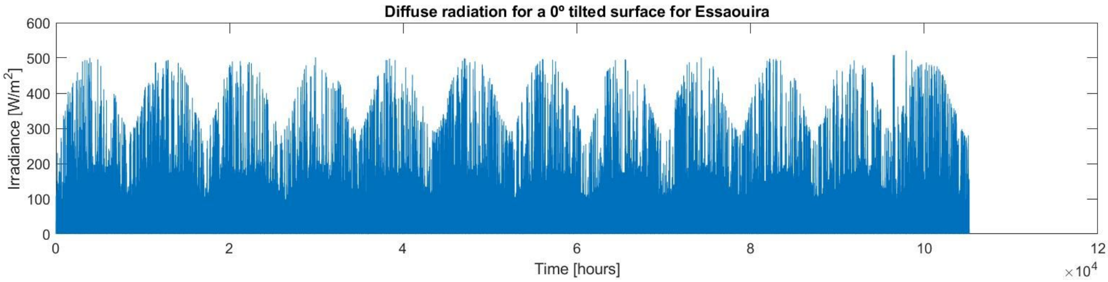


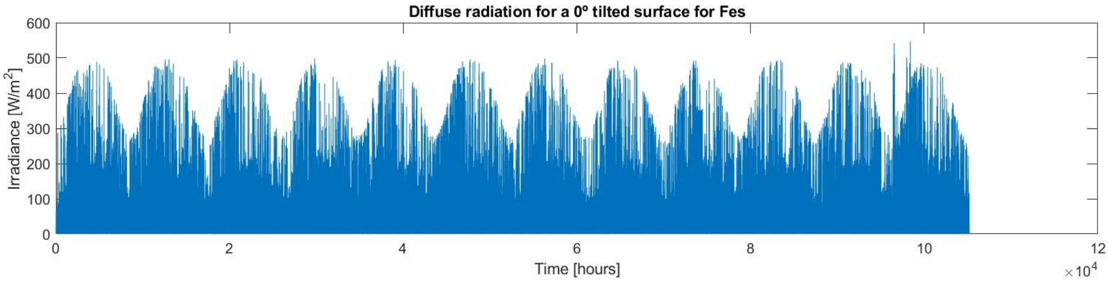


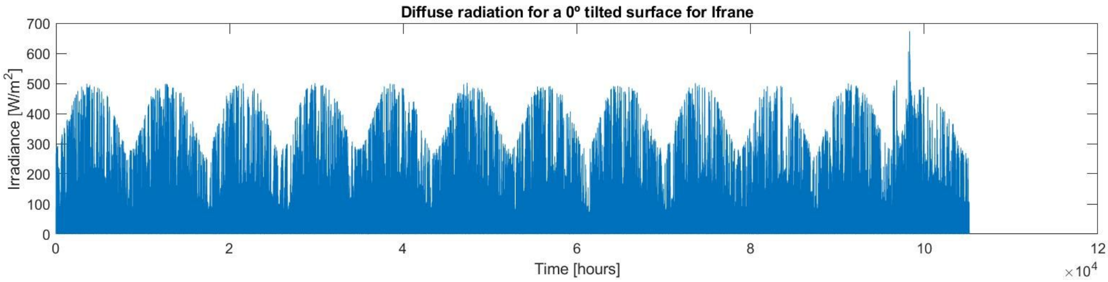


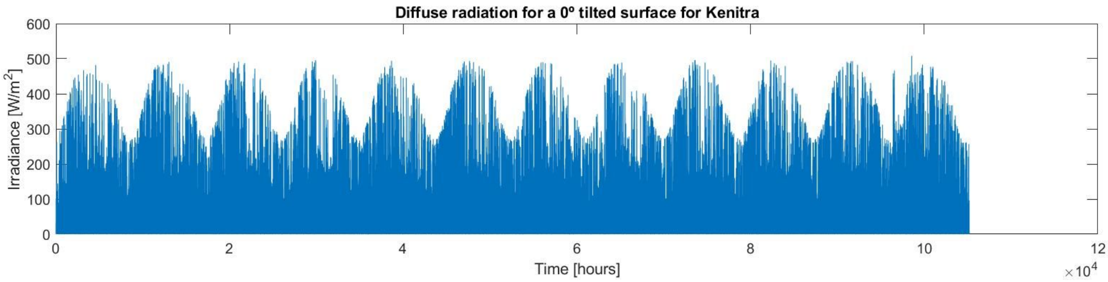


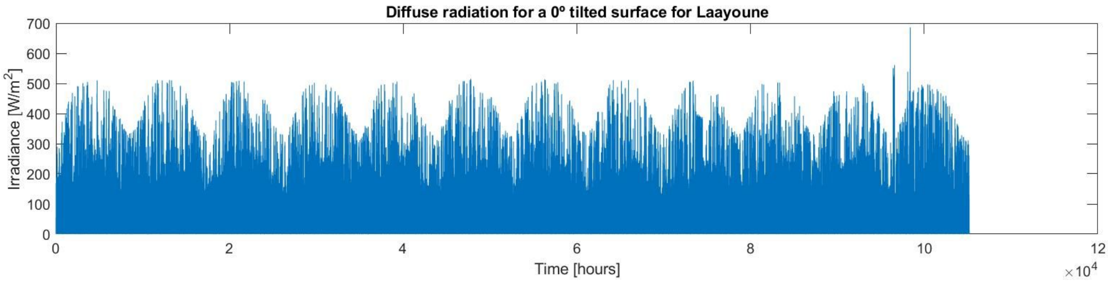


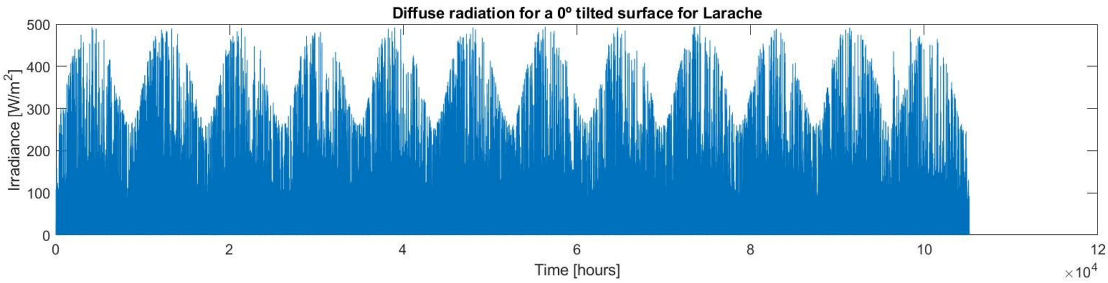

Diffuse radiation for a 0º tilted surface for Essaouira
Irradiance [W/m^2]
Time [hours]
×10^4

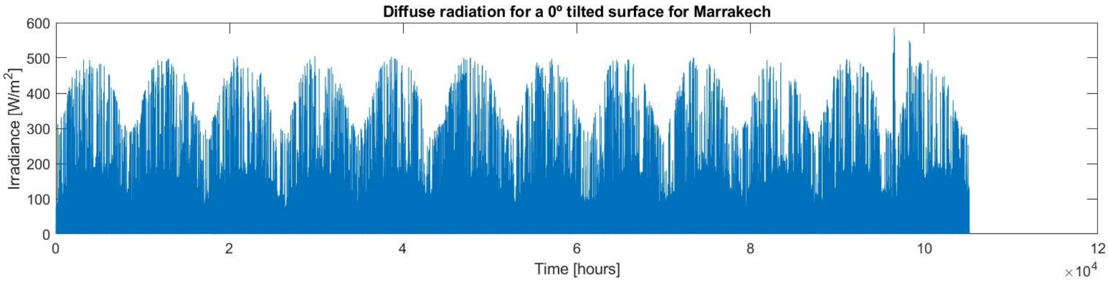

Diffuse radiation for a 0º tilted surface for Fes
Irradiance [W/m^2]
Time [hours]
×10^4

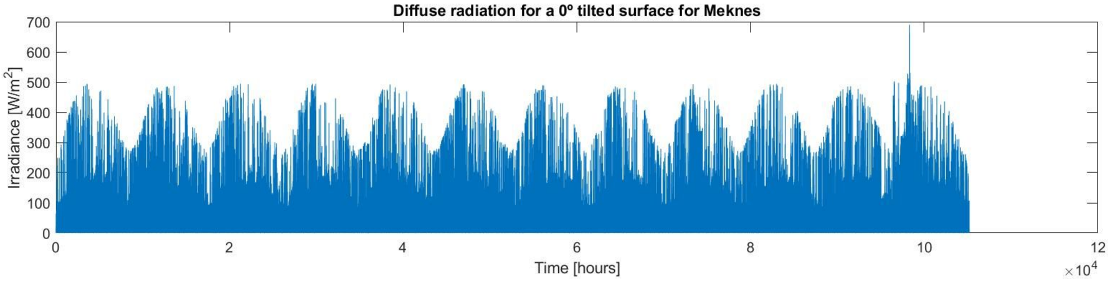

Diffuse radiation for a 0º tilted surface for Ifrane
Irradiance [W/m^2]
Time [hours]
×10^4

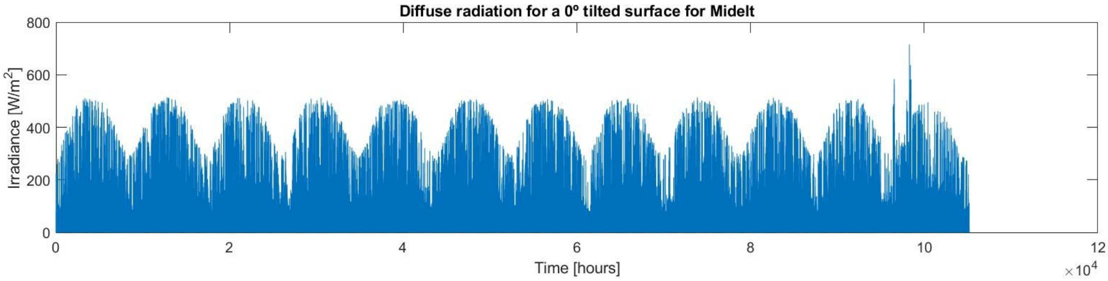

Diffuse radiation for a 0º tilted surface for Kenitra
Irradiance [W/m^2]
Time [hours]
×10^4

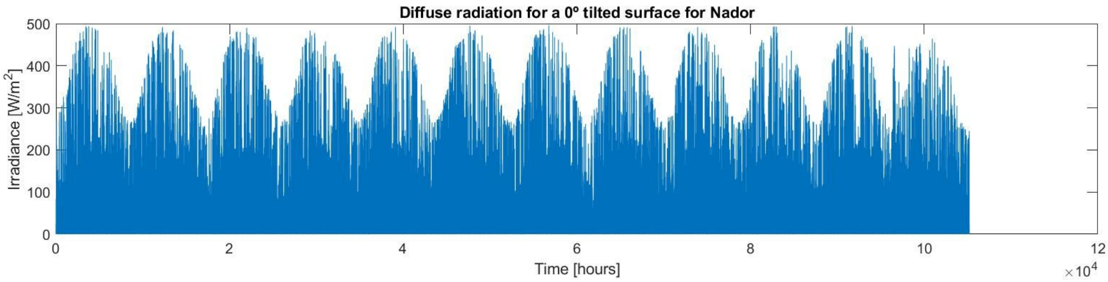

Diffuse radiation for a 0º tilted surface for Laayoune
Irradiance [W/m^2]
Time [hours]
×10^4


Diffuse radiation for a 0º tilted surface for Larache
Irradiance [W/m^2]
Time [hours]
×10^4


Diffuse radiation for a 0º tilted surface for Marrakech
Irradiance [W/m^2]
0
100
200
300
400
500
600
Time [hours]
0
2
4
6
8
10
12
$\times 10^4$


Diffuse radiation for a 0º tilted surface for Meknes
Irradiance [W/m^2]
0
100
200
300
400
500
600
700
Time [hours]
0
2
4
6
8
10
12
$\times 10^4$


Diffuse radiation for a 0º tilted surface for Midelt
Irradiance [W/m^2]
0
200
400
600
800
Time [hours]
0
2
4
6
8
10
12
$\times 10^4$


Diffuse radiation for a 0º tilted surface for Nador
Irradiance [W/m^2]
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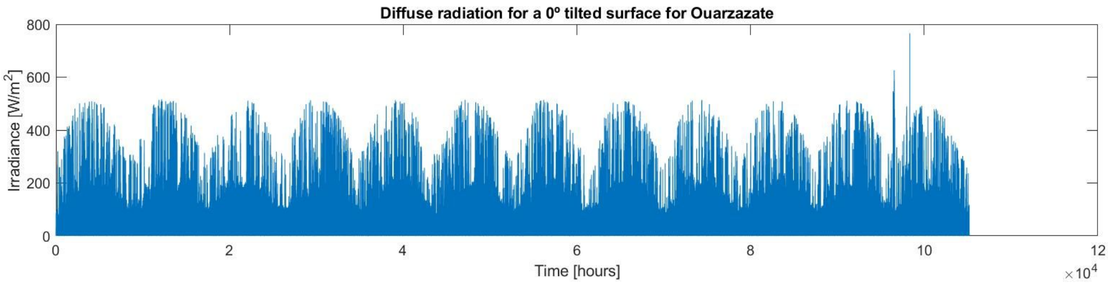
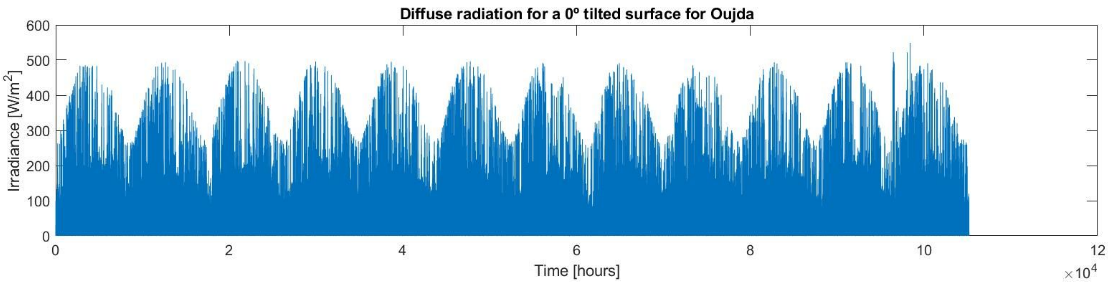
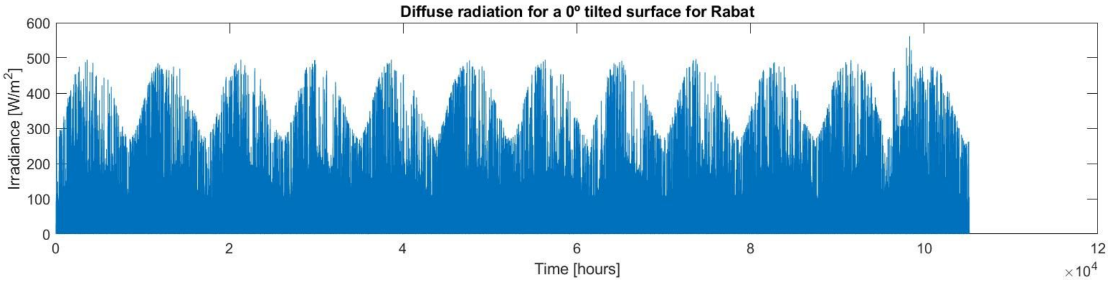
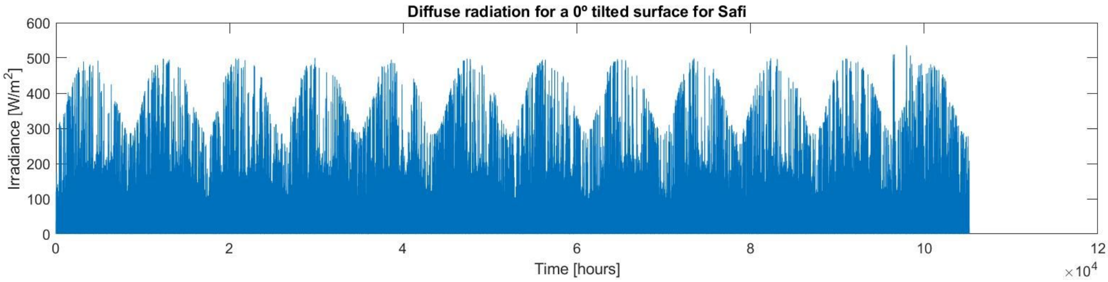
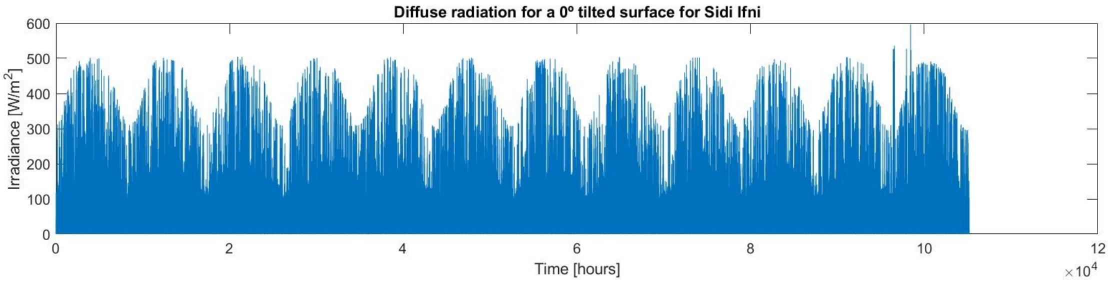
100
200
300
400
500
Time [hours]
0
2
4
6
8
10
12
$\times 10^4$

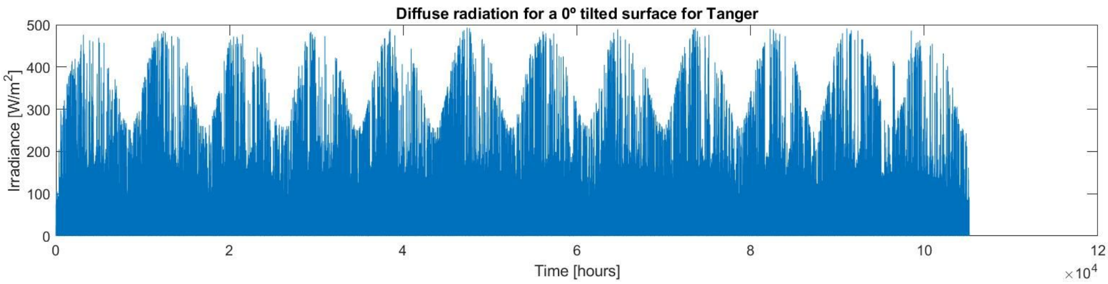

Diffuse radiation for a 0º tilted surface for Ouarzazate
Irradiance [W/m^2]
0
200
400
600
800
Time [hours]
0
2
4
6
8
10
12
$\times 10^4$

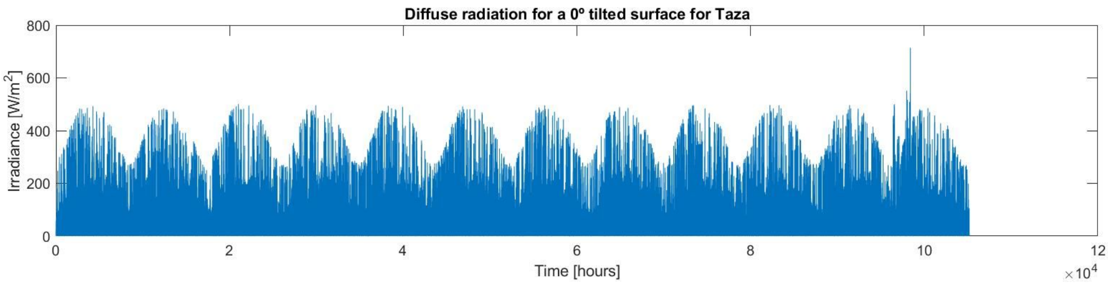

Diffuse radiation for a 0º tilted surface for Oujda
Irradiance [W/m^2]
0
100
200
300
400
500
600
Time [hours]
0
2
4
6
8
10
12
$\times 10^4$

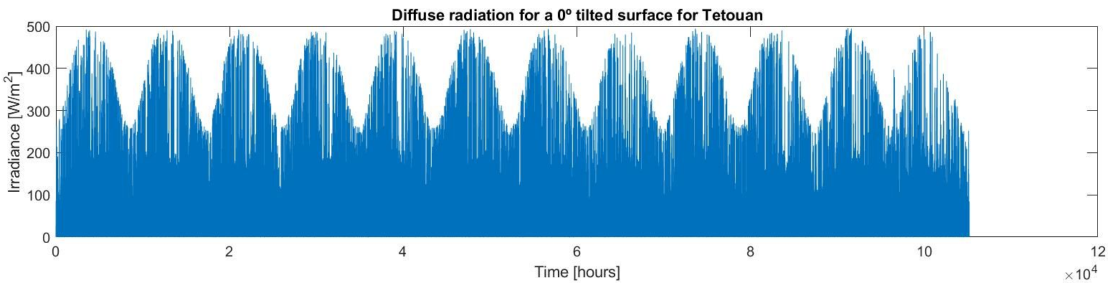

Diffuse radiation for a 0º tilted surface for Rabat
Irradiance [W/m2]
Time [hours]
×10^4


Diffuse radiation for a 0º tilted surface for Safi
Irradiance [W/m2]
Time [hours]
×10^4

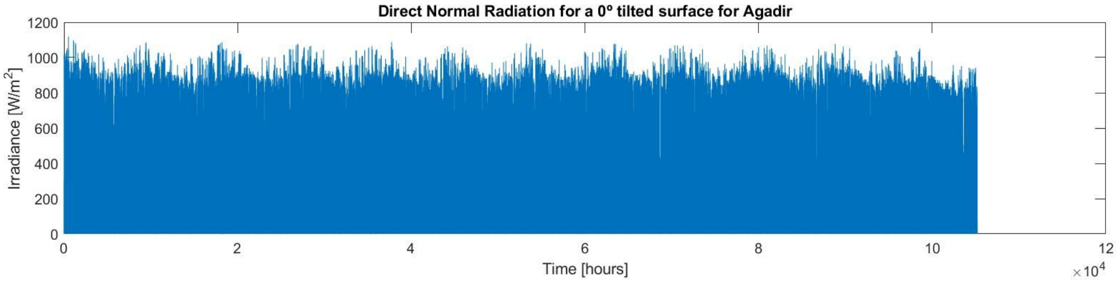

Diffuse radiation for a 0º tilted surface for Sidi Ifni
Irradiance [W/m2]
Time [hours]
×10^4

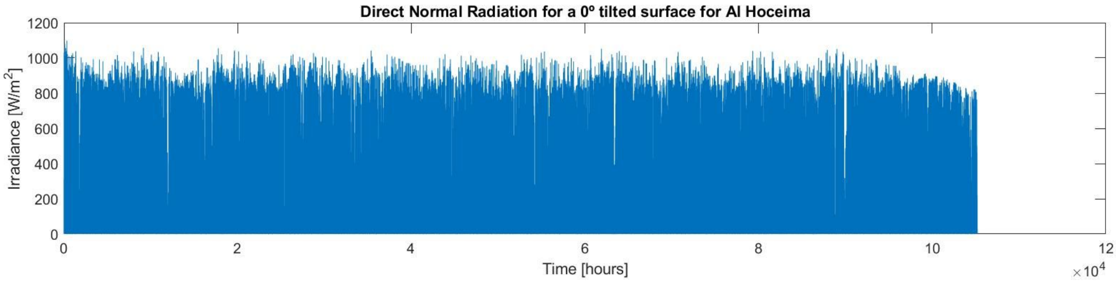

Diffuse radiation for a 0º tilted surface for Tanger
Irradiance [W/m2]
Time [hours]
×10^4

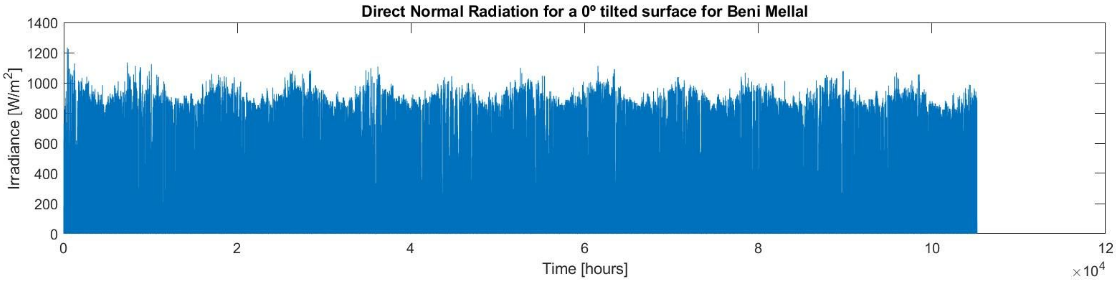

Diffuse radiation for a 0º tilted surface for Taza
Irradiance [W/m2]
Time [hours]
×10^4

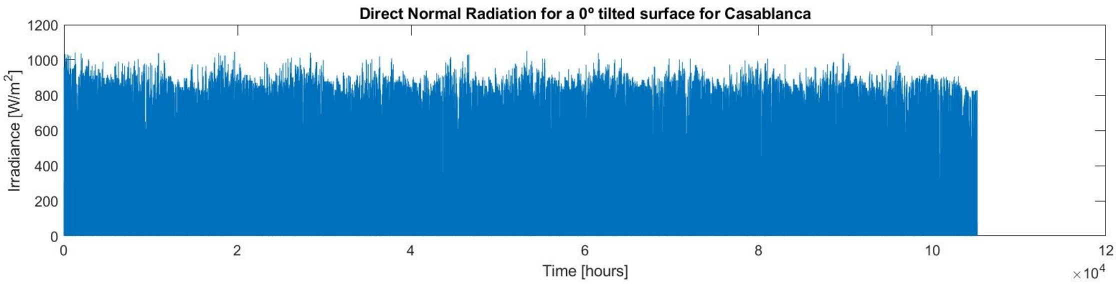

Diffuse radiation for a 0º tilted surface for Tetouan
Irradiance [W/m2]
Time [hours]
×10^4

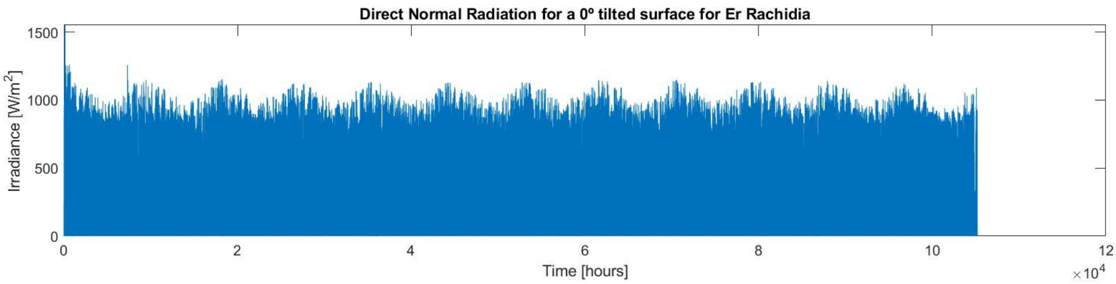
Direct Normal Radiation for a 0º tilted surface of all cities

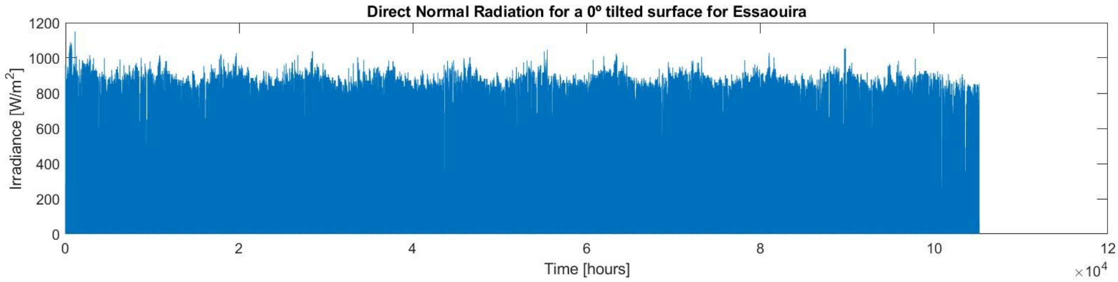


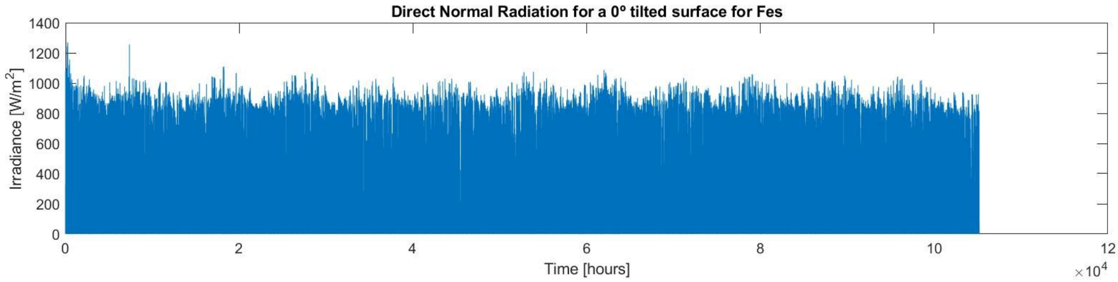


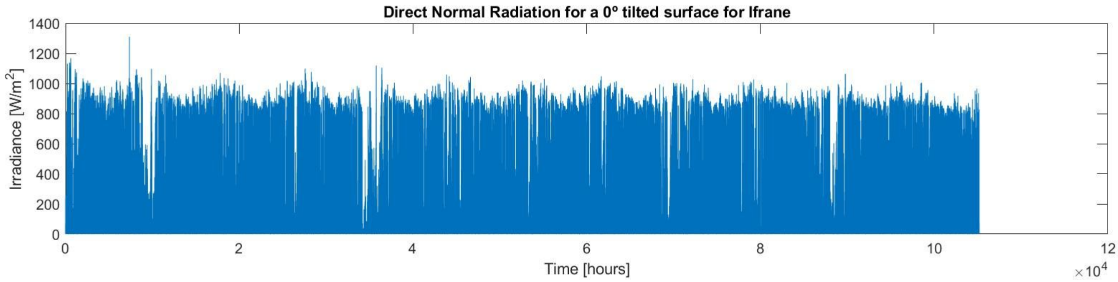


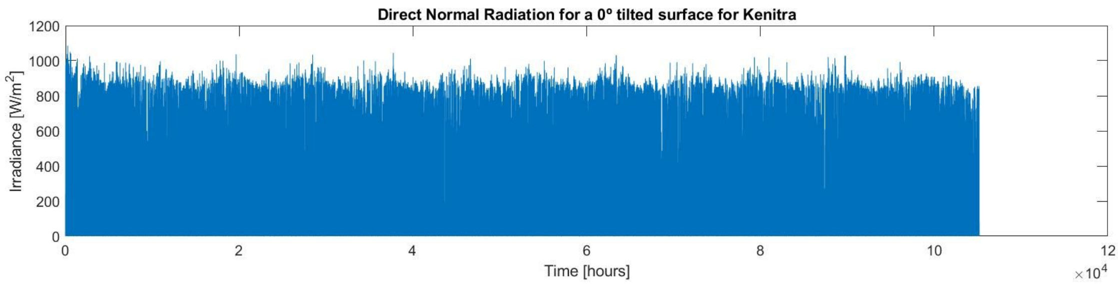


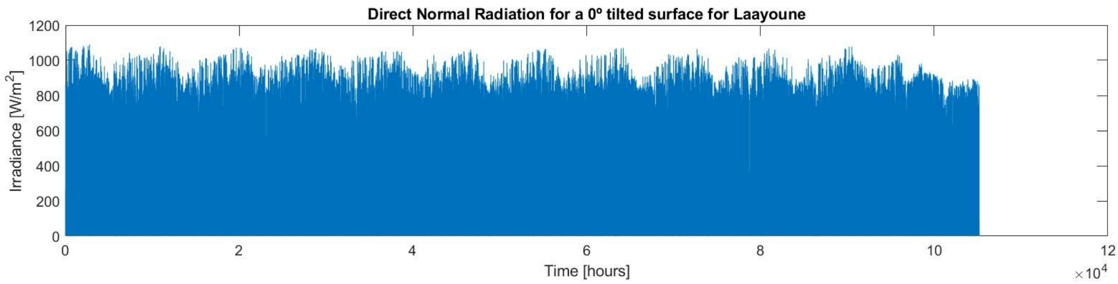


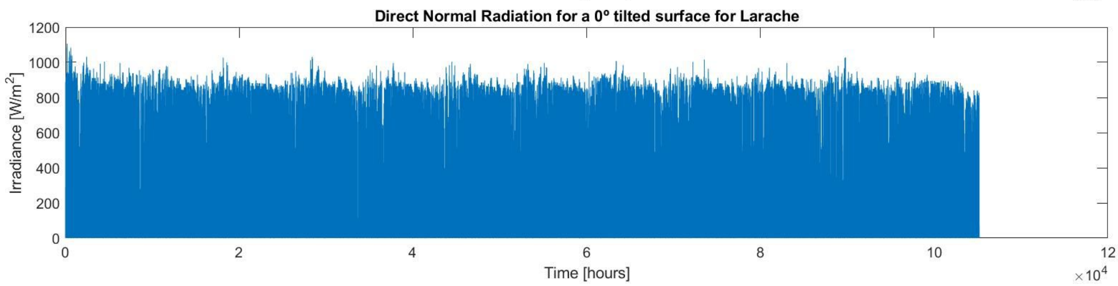

Direct Normal Radiation for a 0º tilted surface for Essaouira
Irradiance [W/m2]
Time [hours]
×10^4

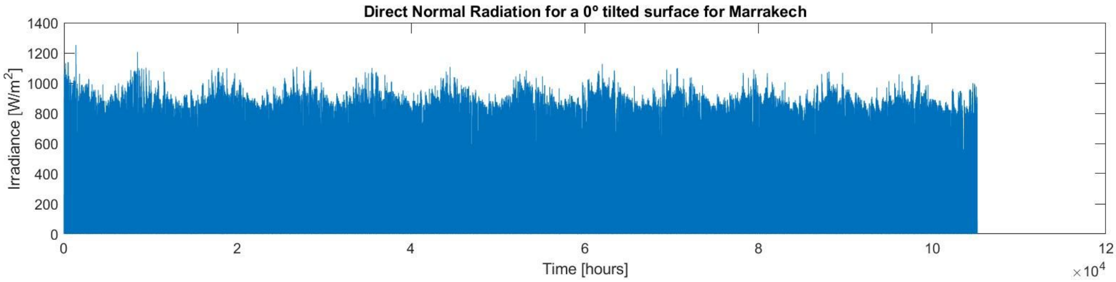

Direct Normal Radiation for a 0º tilted surface for Fes
Irradiance [W/m2]
Time [hours]
×10^4

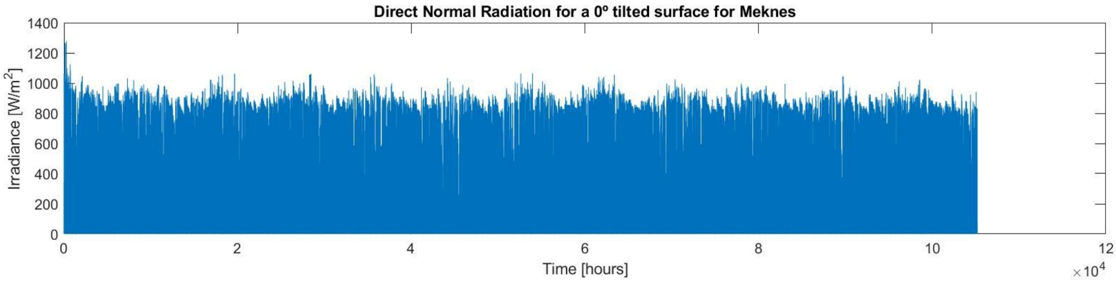

Direct Normal Radiation for a 0º tilted surface for Ifrane
Irradiance [W/m2]
Time [hours]
×10^4

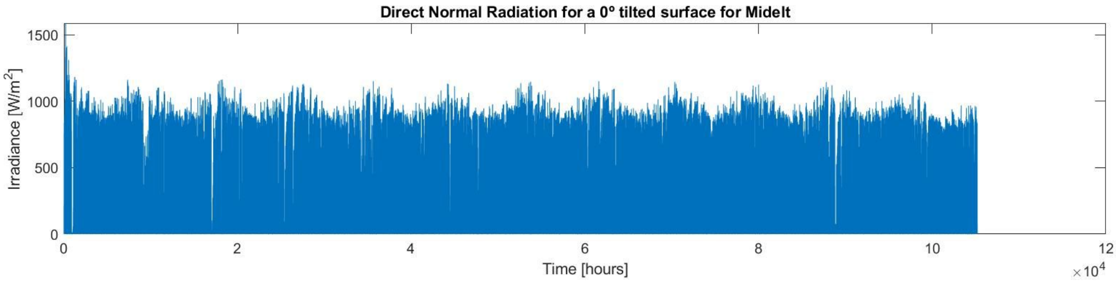

Direct Normal Radiation for a 0º tilted surface for Kenitra
Irradiance [W/m2]
Time [hours]
×10^4

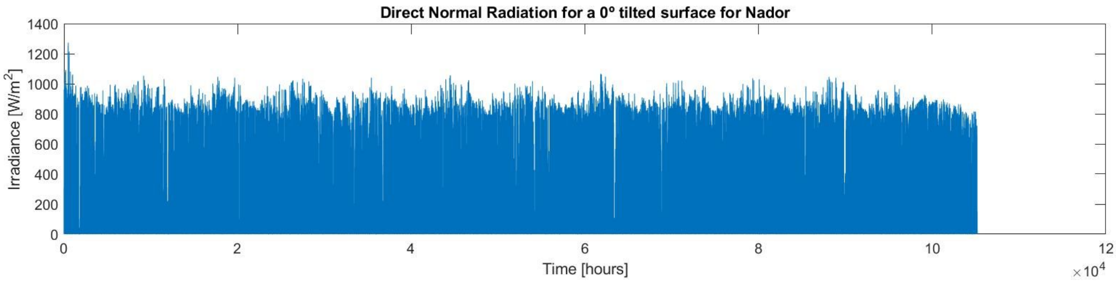

Direct Normal Radiation for a 0º tilted surface for Laayoune
Irradiance [W/m2]
Time [hours]
×10^4

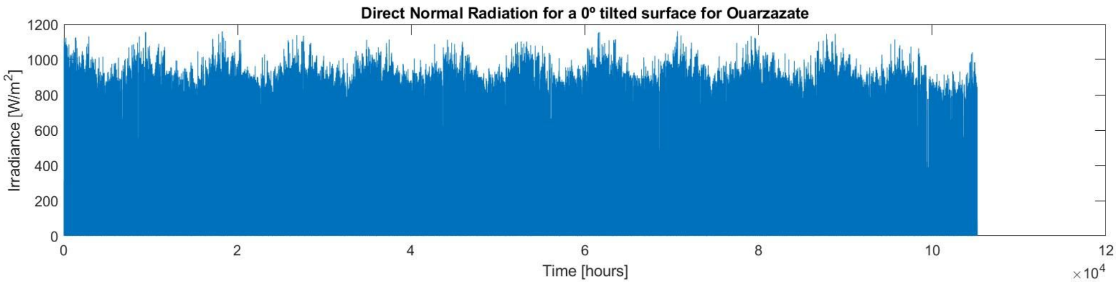

Direct Normal Radiation for a 0º tilted surface for Larache
Irradiance [W/m2]
Time [hours]
×10^4

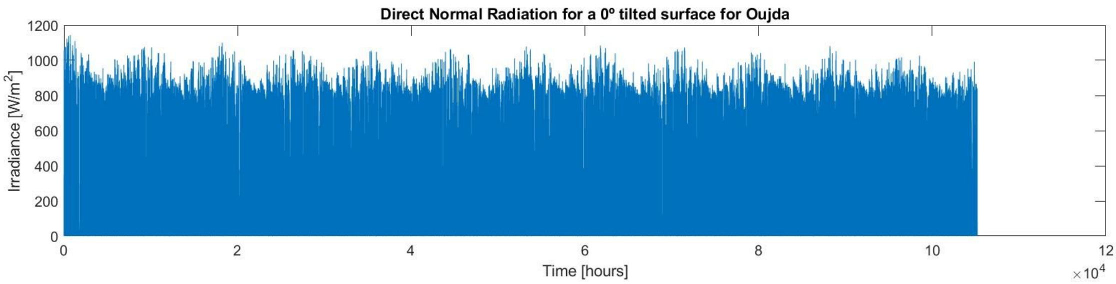

Direct Normal Radiation for a 0º tilted surface for Marrakech
Irradiance [W/m^2]
0
200
400
600
800
1000
1200
1400
Time [hours]
0
2
4
6
8
10
12
$\times 10^4$

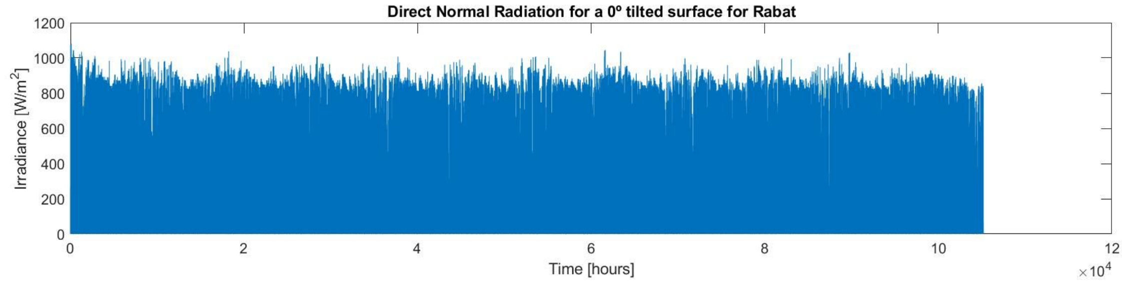

Direct Normal Radiation for a 0º tilted surface for Meknes
Irradiance [W/m^2]
0
200
400
600
800
1000
1200
1400
Time [hours]
0
2
4
6
8
10
12
$\times 10^4$

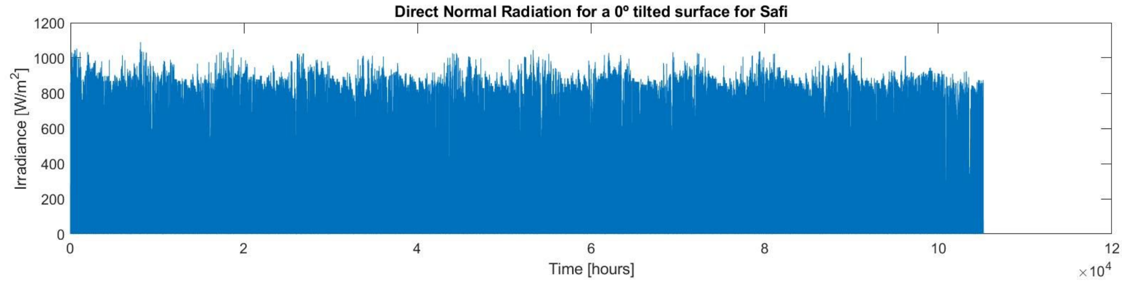

Direct Normal Radiation for a 0º tilted surface for Midelt
Irradiance [W/m^2]
0
500
1000
1500
Time [hours]
0
2
4
6
8
10
12
$\times 10^4$

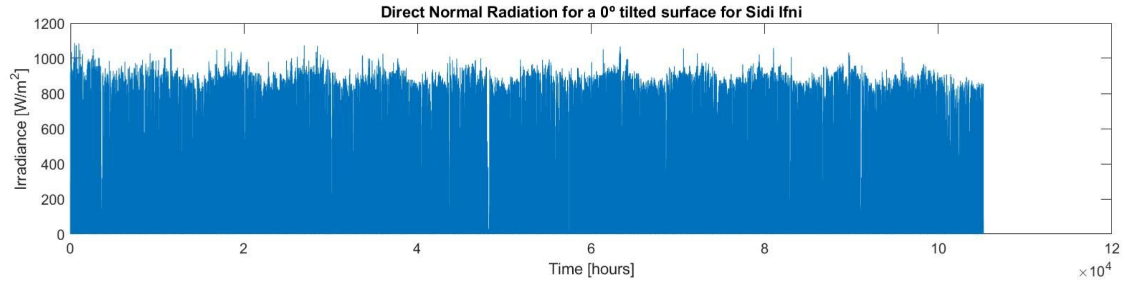

Direct Normal Radiation for a 0º tilted surface for Nador
Irradiance [W/m^2]
0
200
400
600
800
1000
1200
1400
Time [hours]
0
2
4
6
8
10
12
$\times 10^4$

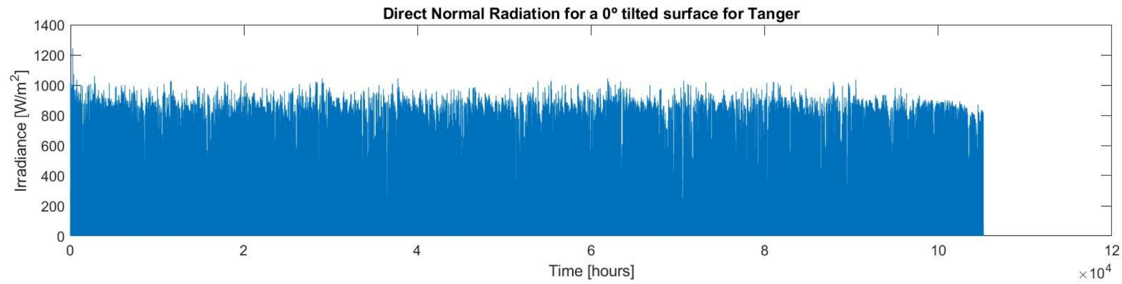

Direct Normal Radiation for a 0º tilted surface for Ouarzazate
Irradiance [W/m^2]
0
200
400
600
800
1000
1200
Time [hours]
0
2
4
6
8
10
12
$\times 10^4$

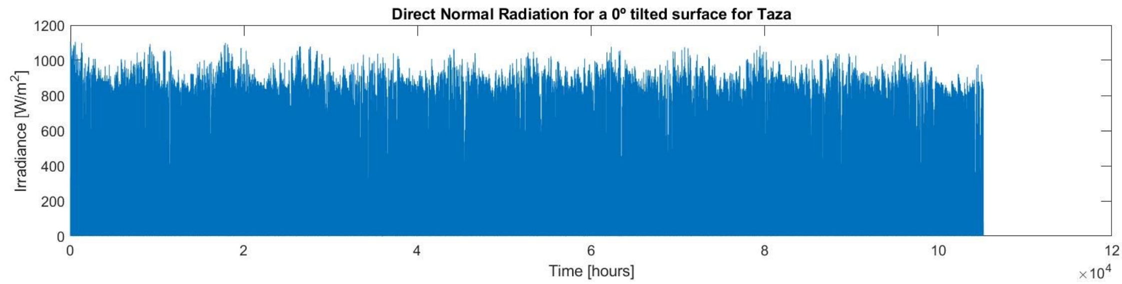

Direct Normal Radiation for a 0º tilted surface for Oujda
Irradiance [W/m^2]
0
200
400
600
800
1000
1200
Time [hours]
0
2
4
6
8
10
12
$\times 10^4$

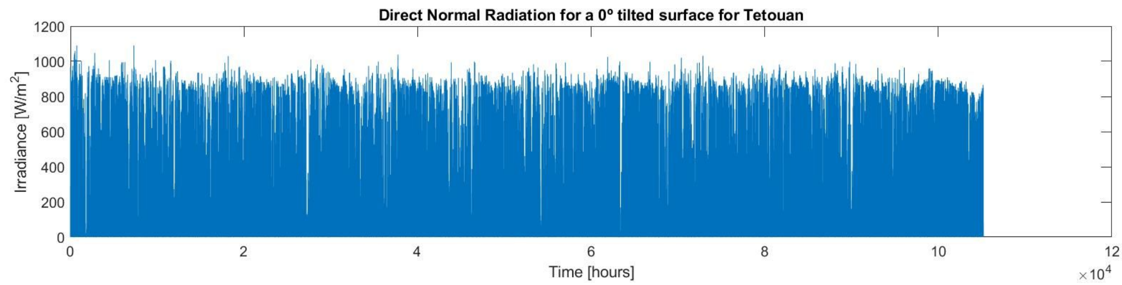

Direct Normal Radiation for a 0º tilted surface for Rabat
Irradiance [W/m^2]
Time [hours]
$\times 10^4$


Direct Normal Radiation for a 0º tilted surface for Safi
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

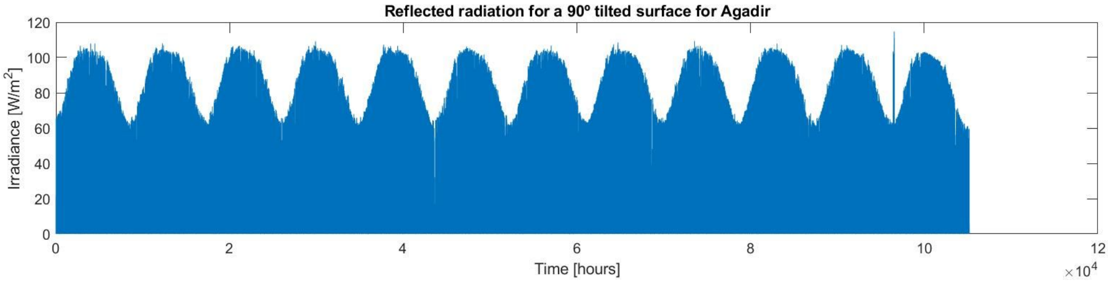

Direct Normal Radiation for a 0º tilted surface for Sidi Ifni
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

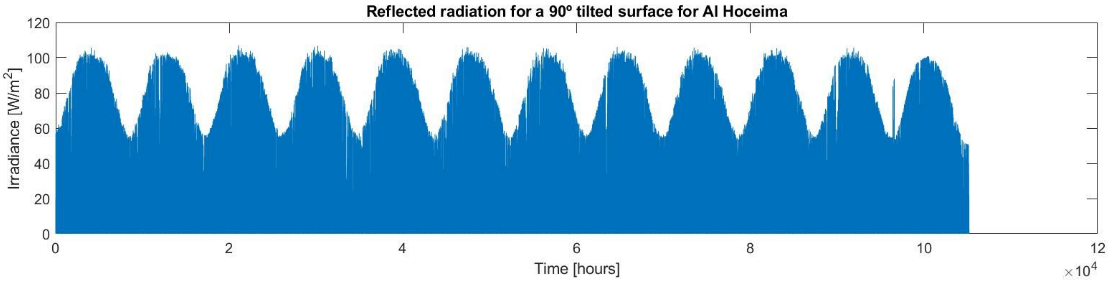

Direct Normal Radiation for a 0º tilted surface for Tanger
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

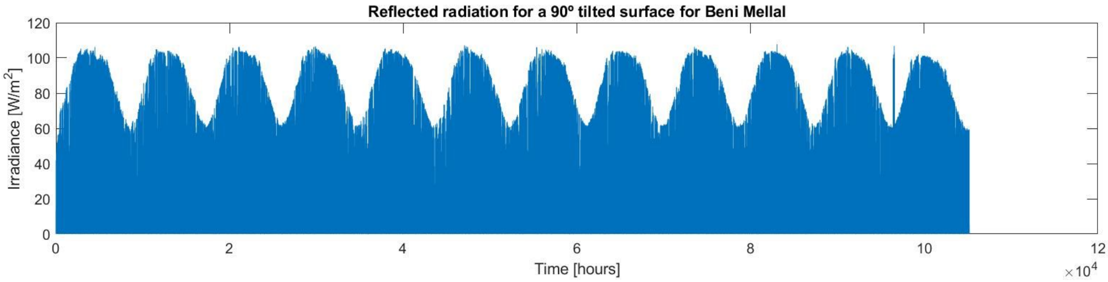

Direct Normal Radiation for a 0º tilted surface for Taza
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

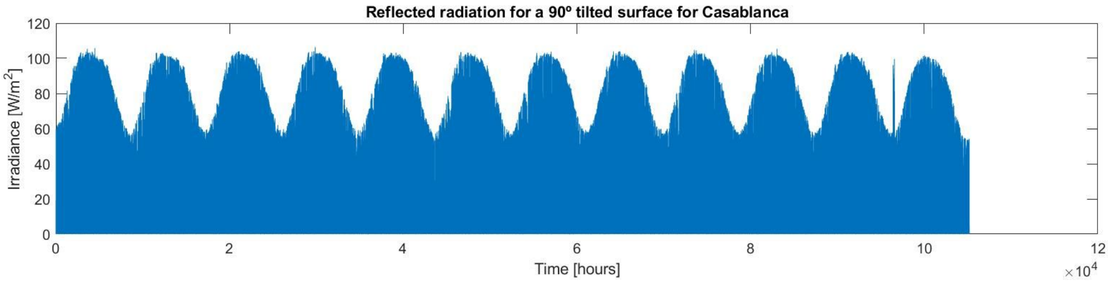

Direct Normal Radiation for a 0º tilted surface for Tetouan
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

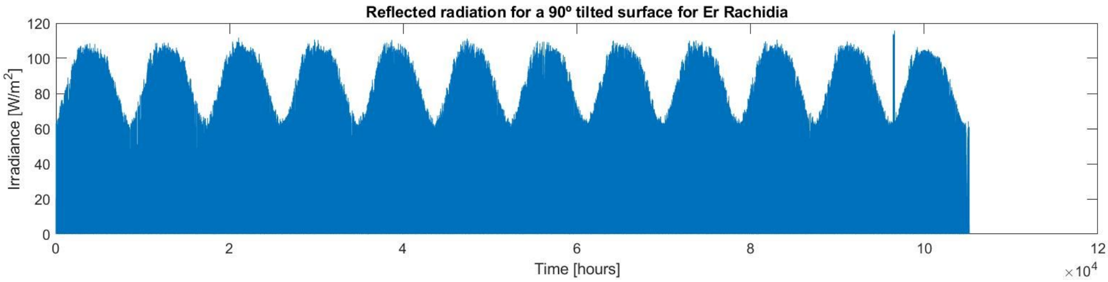
Reflected radiation for a 90º tilted surface for all cities

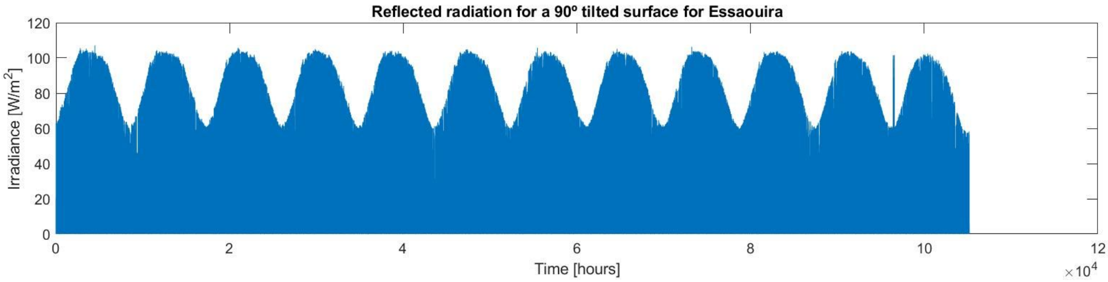


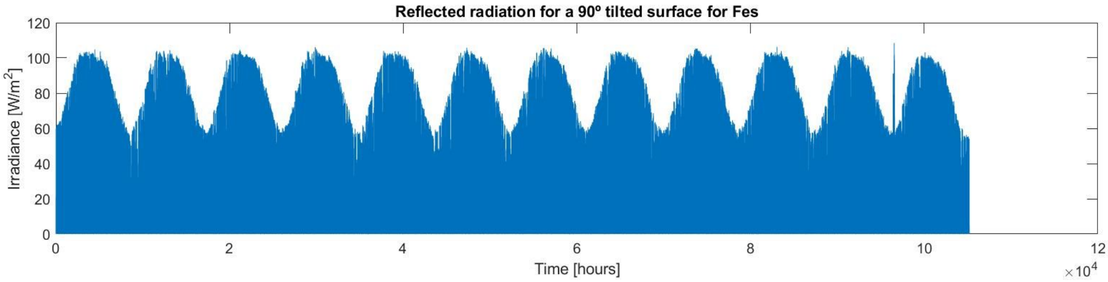


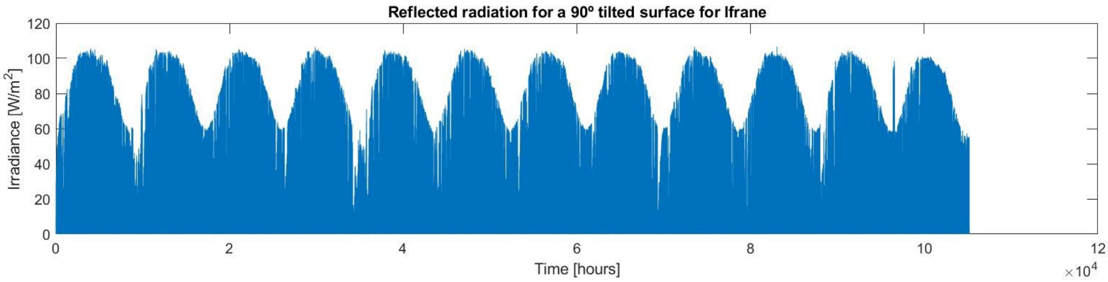


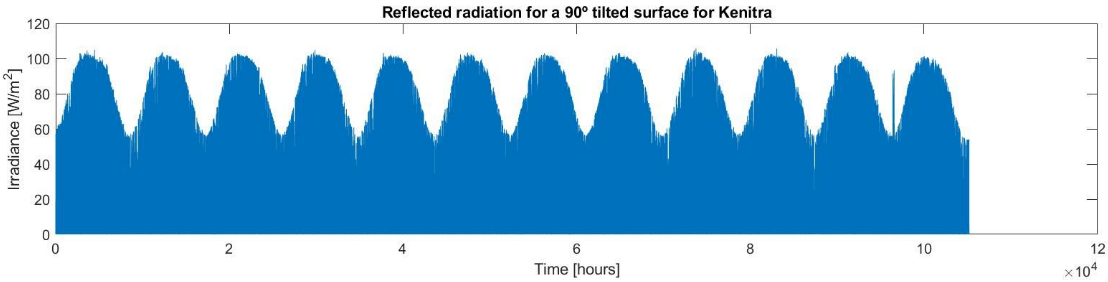


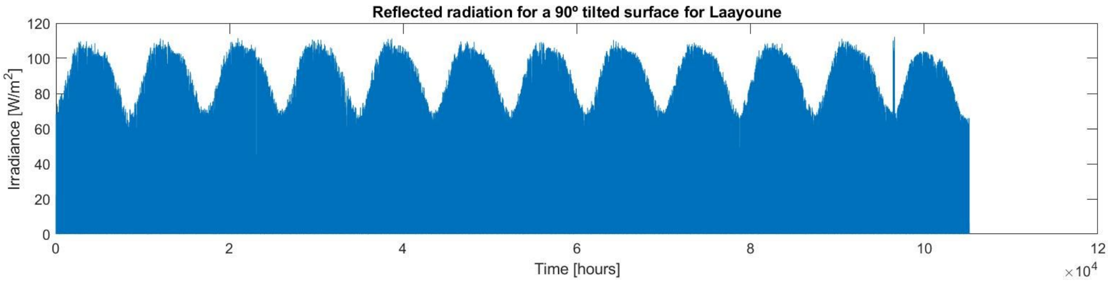


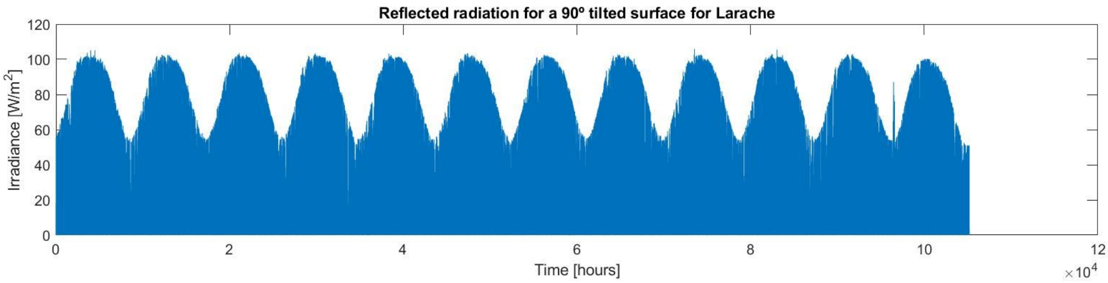

Reflected radiation for a 90º tilted surface for Essaouira
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

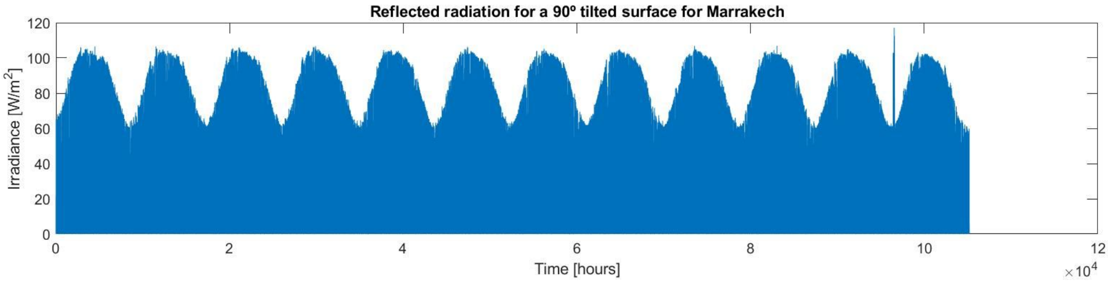

Reflected radiation for a 90º tilted surface for Fes
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

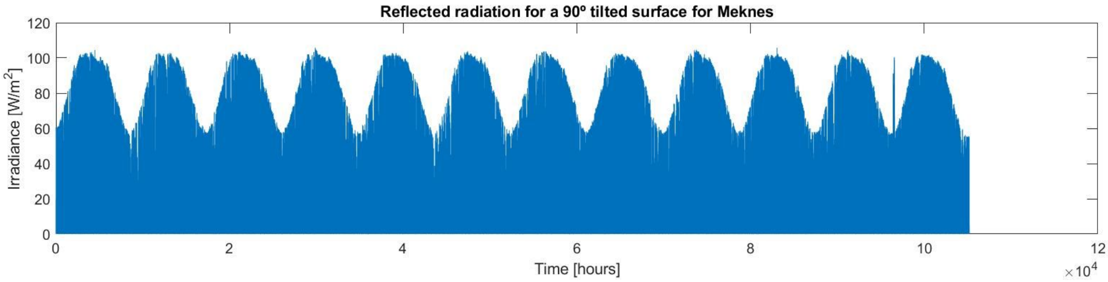

Reflected radiation for a 90º tilted surface for Ifrane
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

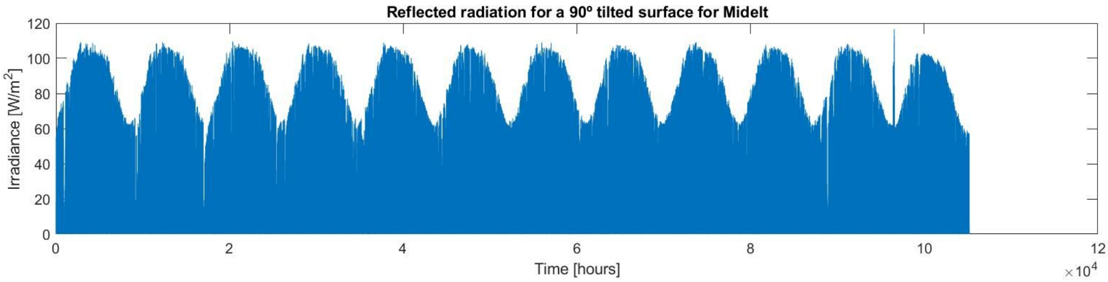

Reflected radiation for a 90º tilted surface for Kenitra
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

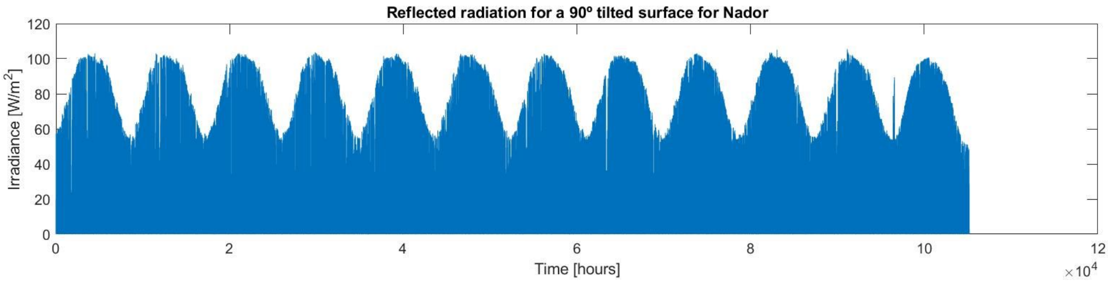

Reflected radiation for a 90º tilted surface for Laayoune
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

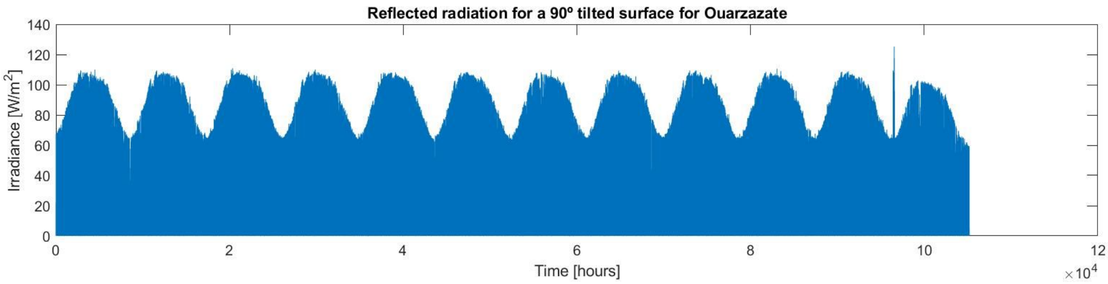

Reflected radiation for a 90º tilted surface for Larache
Irradiance [W/m^2]
Time [hours]
$\times 10^4$

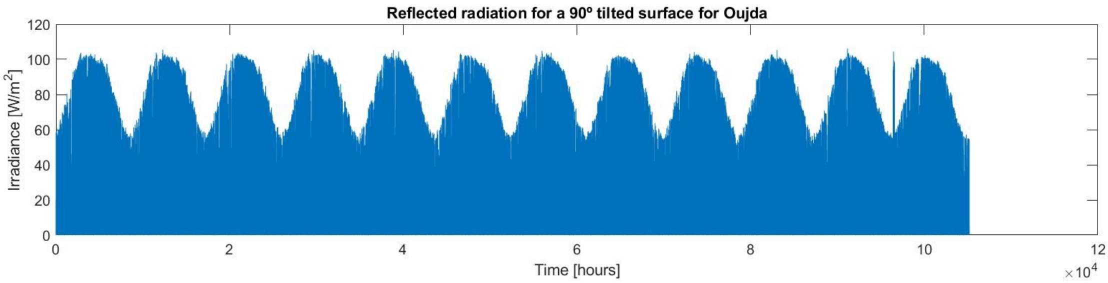

Reflected radiation for a 90º tilted surface for Marrakech
Irradiance [W/m^2]
Time [hours]
×10^4

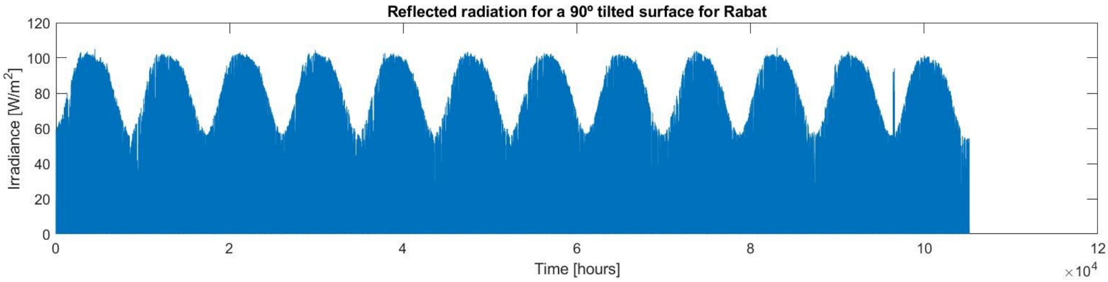

Reflected radiation for a 90º tilted surface for Meknes
Irradiance [W/m^2]
Time [hours]
×10^4

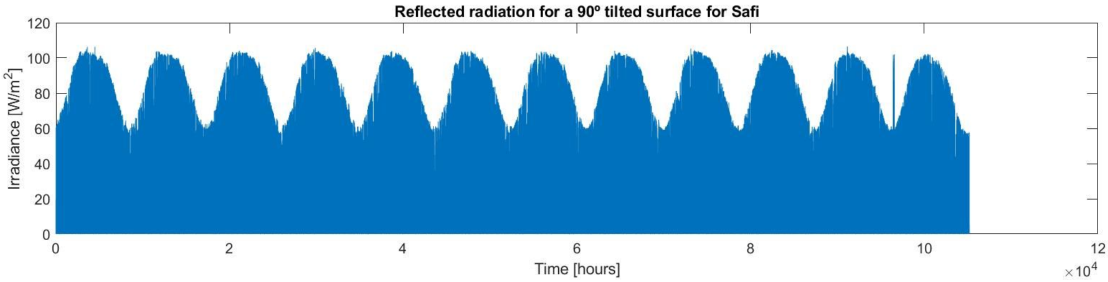

Reflected radiation for a 90º tilted surface for Midelt
Irradiance [W/m^2]
Time [hours]
×10^4

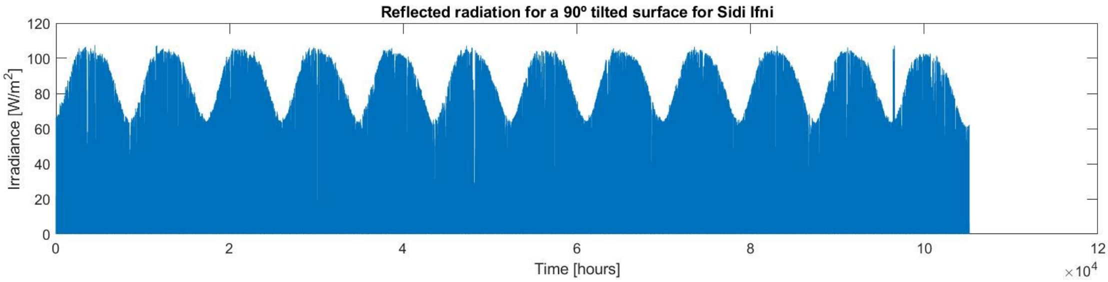

Reflected radiation for a 90º tilted surface for Nador
Irradiance [W/m^2]
Time [hours]
×10^4

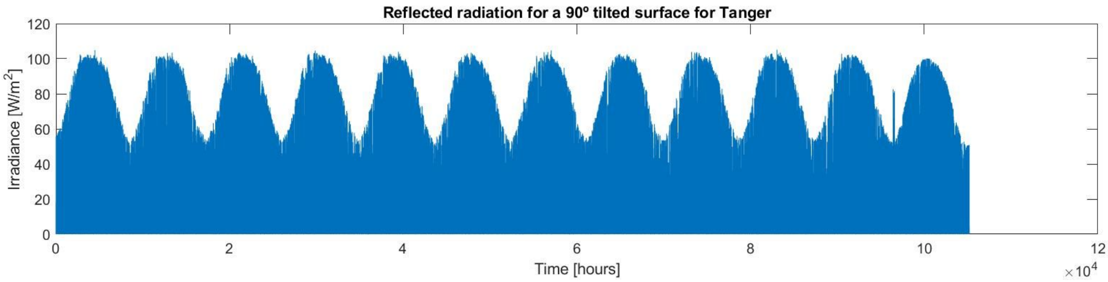

Reflected radiation for a 90º tilted surface for Ouarzazate
Irradiance [W/m^2]
Time [hours]
×10^4

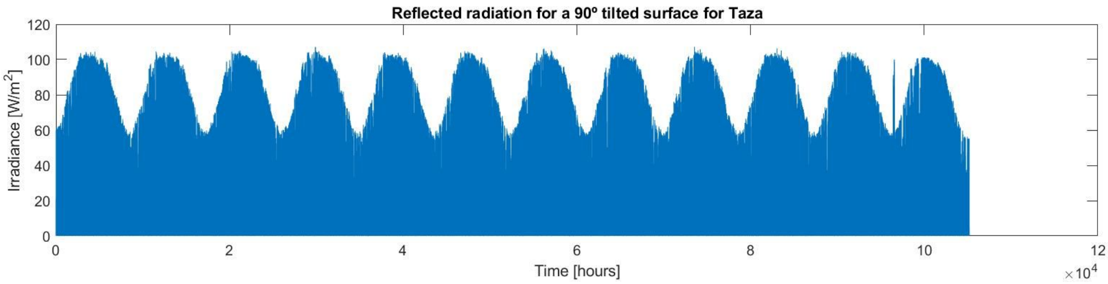

Reflected radiation for a 90º tilted surface for Oujda
Irradiance [W/m^2]
Time [hours]
×10^4

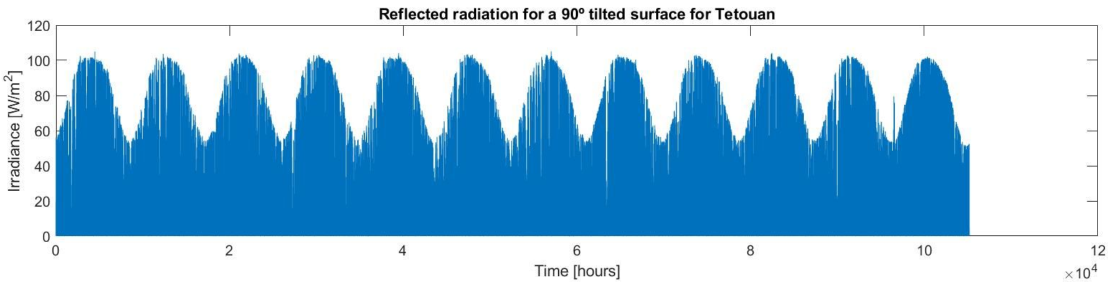

Reflected radiation for a 90º tilted surface for Rabat
Irradiance [W/m2]
Time [hours]
×10^4


Reflected radiation for a 90º tilted surface for Safi
Irradiance [W/m2]
Time [hours]
×10^4

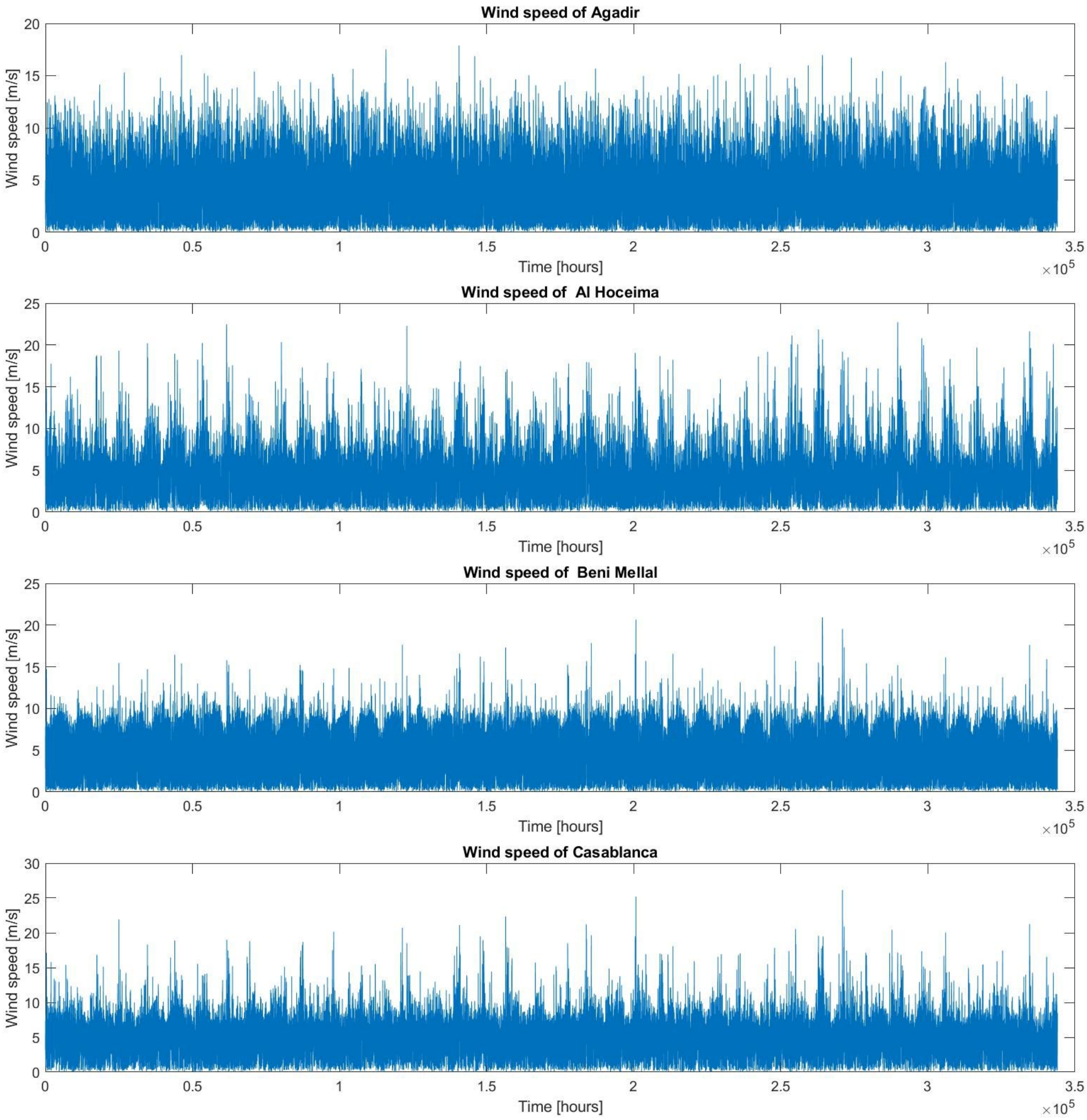

Reflected radiation for a 90º tilted surface for Sidi Ifni
Irradiance [W/m2]
Time [hours]
×10^4

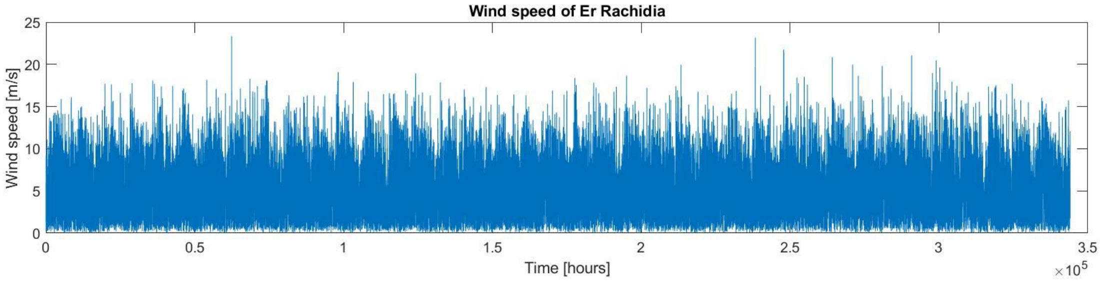

Reflected radiation for a 90º tilted surface for Tanger
Irradiance [W/m2]
Time [hours]
×10^4

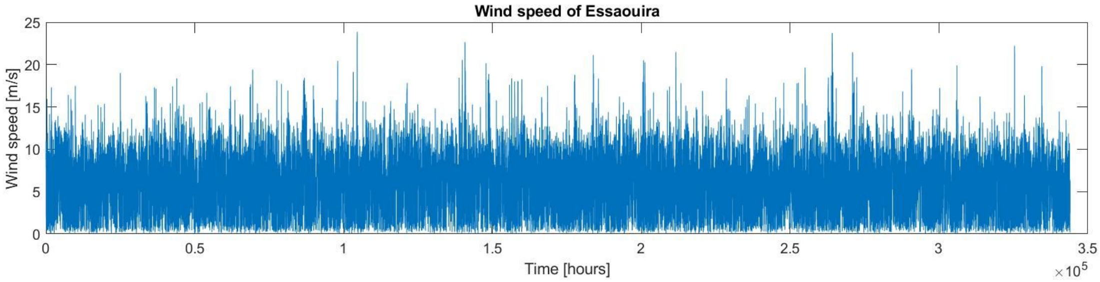

Reflected radiation for a 90º tilted surface for Taza
Irradiance [W/m2]
Time [hours]
×10^4

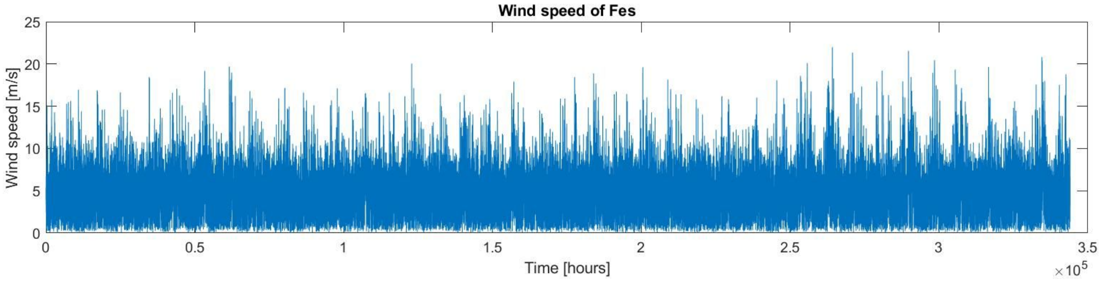

Reflected radiation for a 90º tilted surface for Tetouan
Irradiance [W/m2]
Time [hours]
×10^4

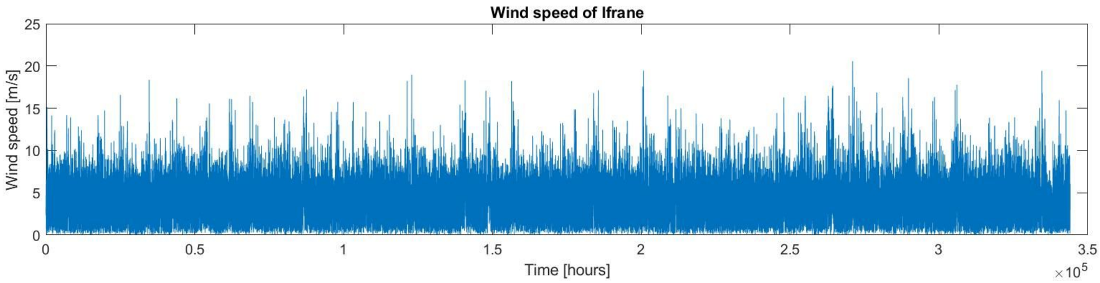
Wind speed for all cities

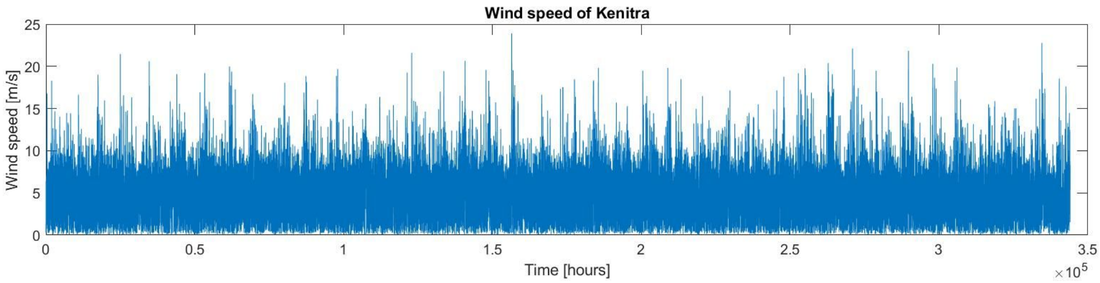


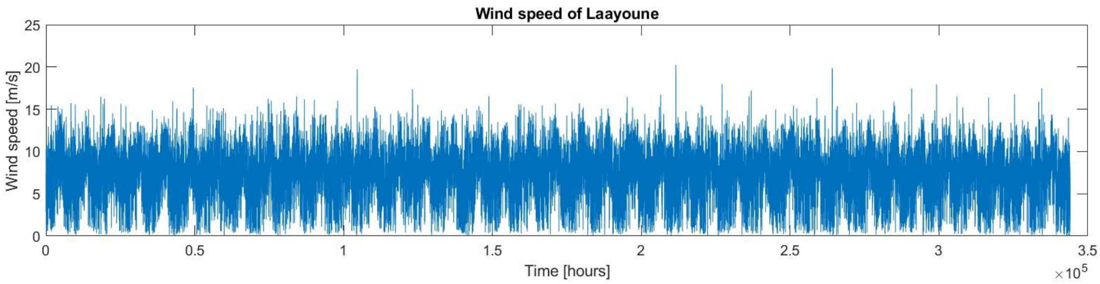

Wind speed of Er Rachidia
Wind speed [m/s]
Time [hours]
×10^5

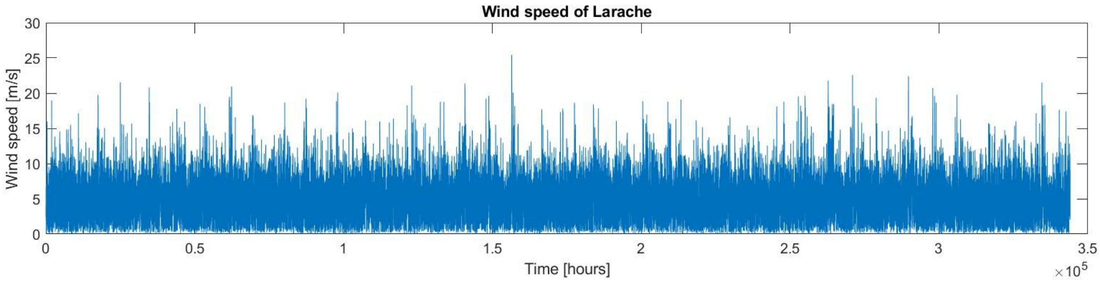

Wind speed of Essaouira
Wind speed [m/s]
Time [hours]
×10^5

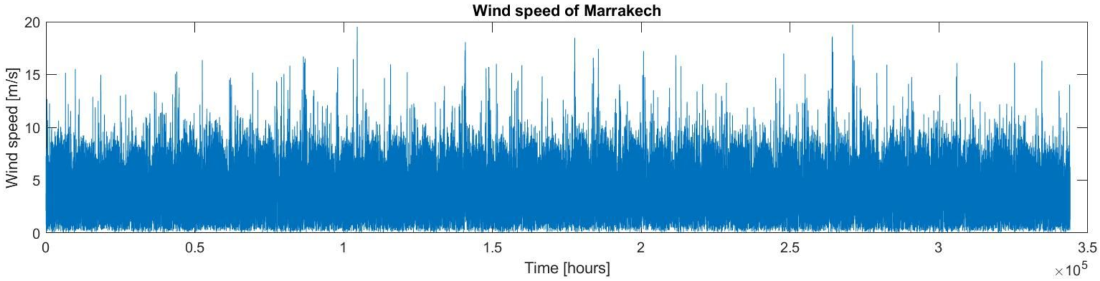

Wind speed of Fes
Wind speed [m/s]
Time [hours]
×10^5

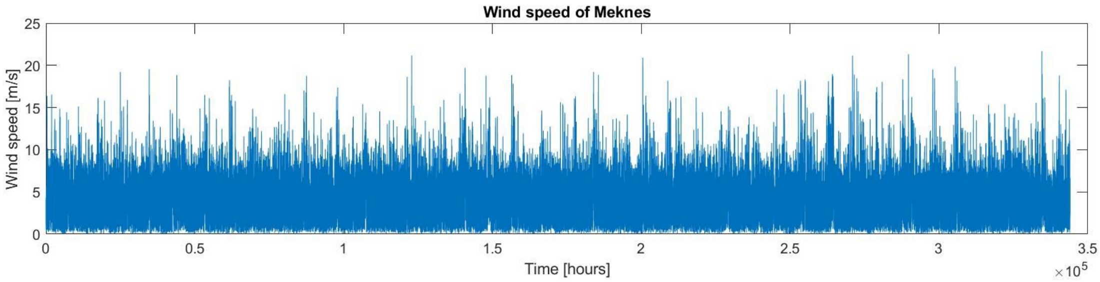

Wind speed of Ifrane
Wind speed [m/s]
Time [hours]
×10^5

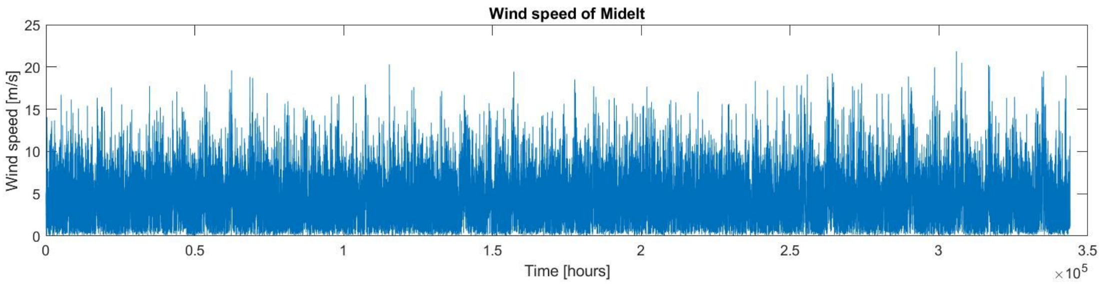

Wind speed of Kenitra
Wind speed [m/s]
Time [hours]
×10^5

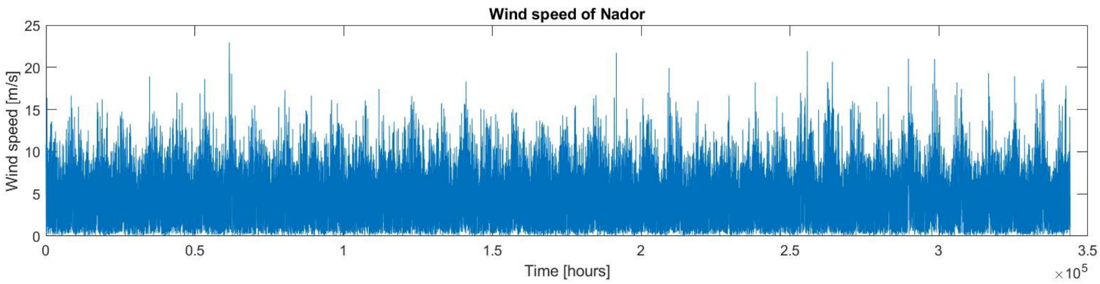

Wind speed of Laayoune
Wind speed [m/s]
Time [hours]
×10^5

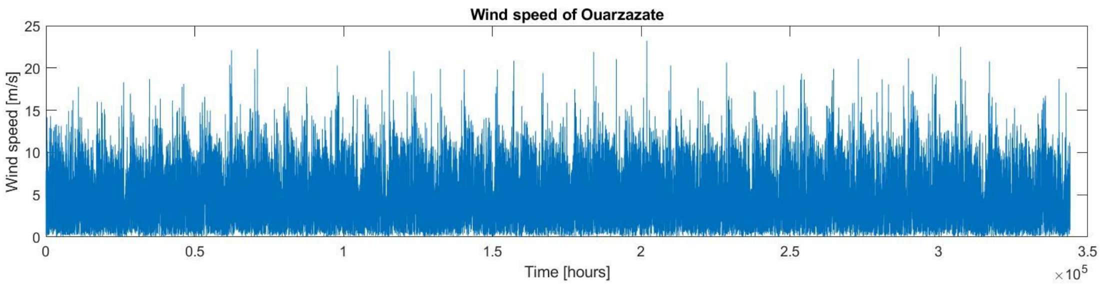

Wind speed of Larache
Wind speed [m/s]
Time [hours]
×10^5

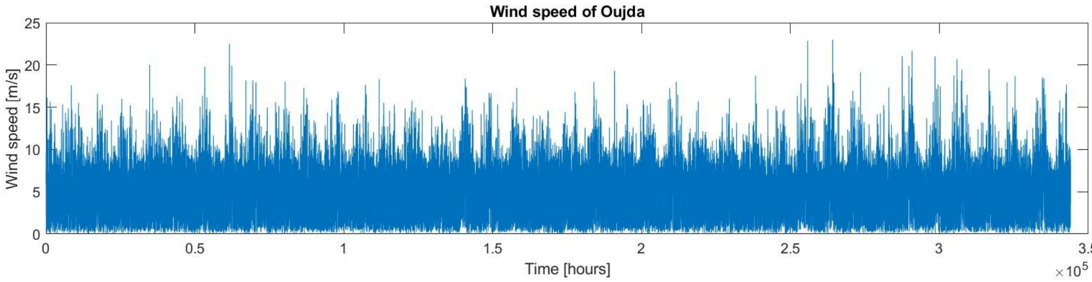

Wind speed of Marrakech
Wind speed [m/s]
Time [hours]
×10^5

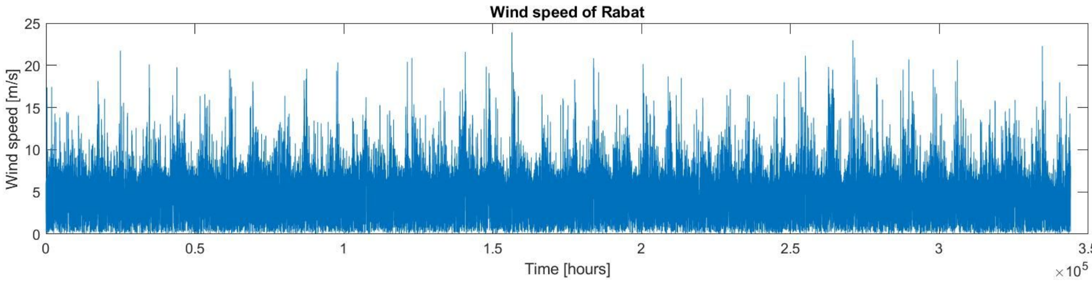

Wind speed of Meknes
Wind speed [m/s]
Time [hours]
×10^5

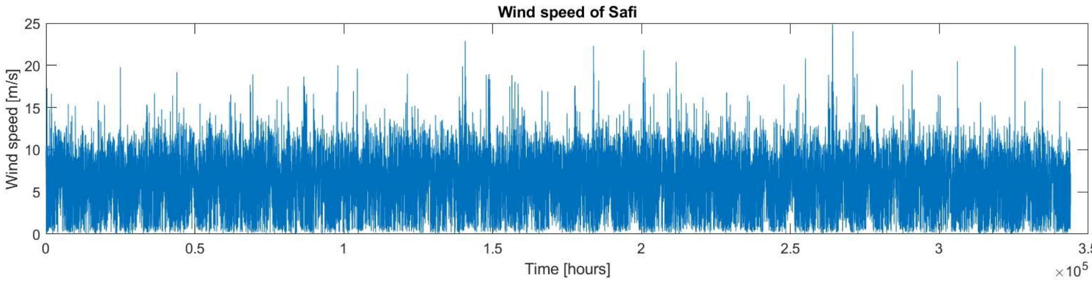

Wind speed of Midelt
Wind speed [m/s]
Time [hours]
×10^5

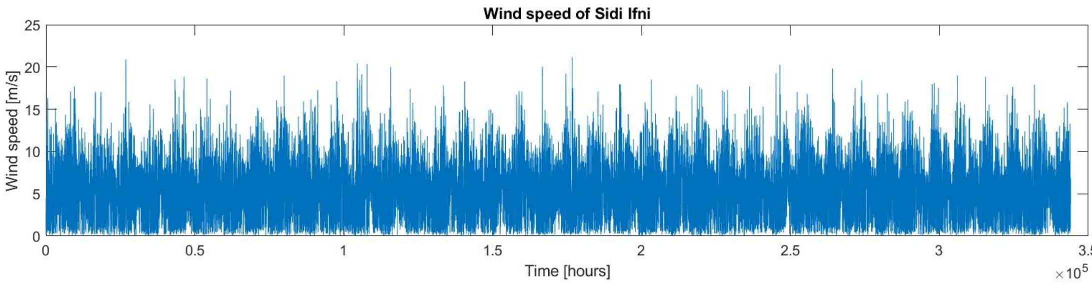

Wind speed of Nador
Wind speed [m/s]
Time [hours]
×10^5

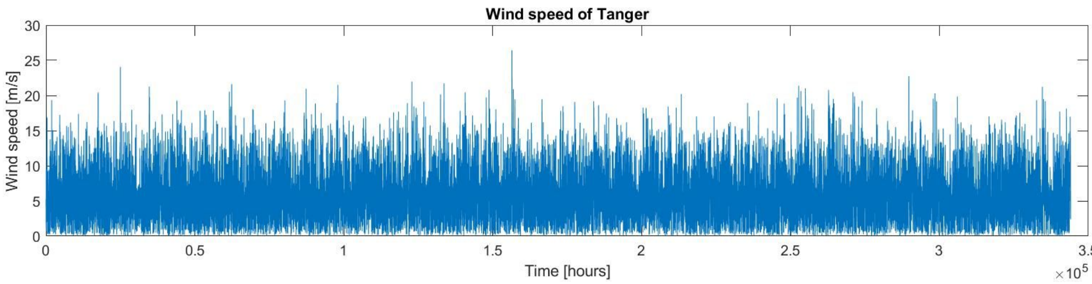

Wind speed of Ouarzazate
Wind speed [m/s]
Time [hours]
×10^5

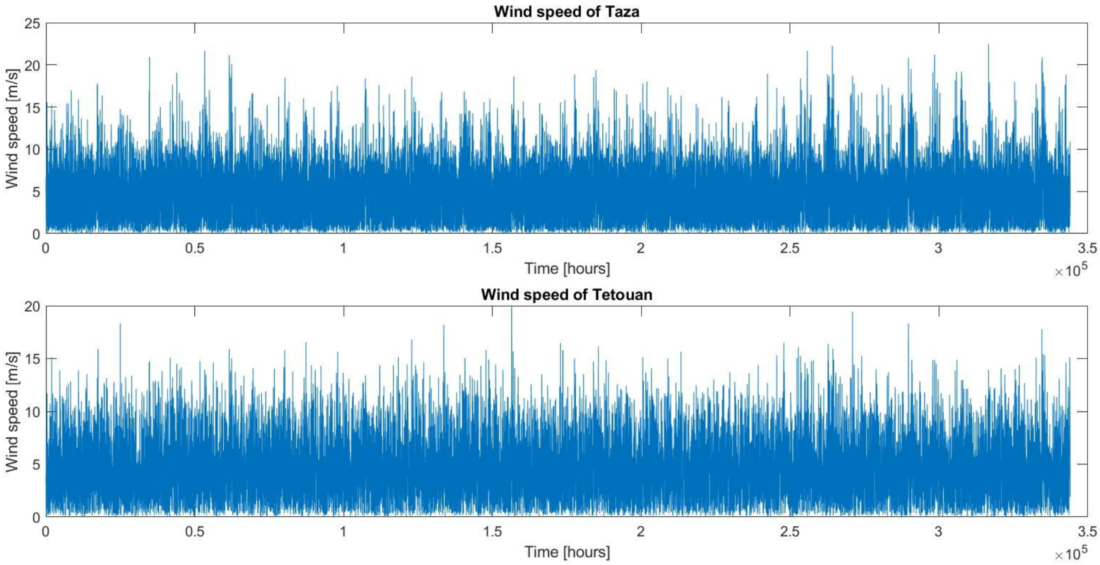

Wind speed of Oujda
Wind speed [m/s]
Time [hours]
×10^5


Wind speed of Rabat
Wind speed [m/s]
Time [hours]
×10^5


Wind speed of Safi
Wind speed [m/s]
Time [hours]
×10^5


Wind speed of Sidi Ifni
Wind speed [m/s]
Time [hours]
×10^5


Wind speed of Tanger
Wind speed [m/s]
Time [hours]
×10^5


Wind speed of Taza
Wind speed [m/s]
Time [hours]
×10^5
Wind speed of Tetouan
Wind speed [m/s]
Time [hours]
×10^5

NPV and LCOE confidence intervals for all power levels

NPV ranges at 95% confidence interval for 100kW Solar PV and Wind turbine[€ x10^3]

City	Horizontal	OPT Slope	OWN Slope	EW Track.	NS Track	VERT Track.	Two Axis Track	Wind Turbine
Agadir	[15.1,17]	[15.2,17.1]	[14.9,16.8]	[18,20.2]	[17.9,20]	[19.1,21.4]	[21.3,23.9]	[11,13.7]
Al Hoceima	[15,16.8]	[15,17]	[15,16.9]	[17.6,19.9]	[17.9,19.9]	[19.3,21.6]	[21.2,23.7]	[9.95,12.7]
Beni Mellal	[15,16.8]	[15,17]	[15.1,17]	[17.8,20]	[17.9,20]	[19.2,21.5]	[21.1,23.6]	[10.6,13.2]
Casablanca	[15.1,17.1]	[14.9,17.5]	[15,17]	[17.9,20]	[17.8,20]	[19.3,21.5]	[21.3,23.7]	[10.5,13.1]
Er-Rachidia	[15.1,17]	[15.2,17.1]	[15.4,17.2]	[18,20.2]	[17.3,19.7]	[19.1,21.5]	[20.7,23.2]	[11.7,14.2]
Essaouira	[15,16.9]	[15.3,17.1]	[14.8,16.7]	[17.9,20]	[17.8,20]	[19.4,21.6]	[21.3,23.8]	[11.7,14.3]
Fes	[15.2,17]	[15.3,17.2]	[15.3,17.2]	[17.9,20.1]	[18,20.1]	[19.4,21.6]	[21.1,23.6]	[10.3,13.2]
Ifrane	[15.2,17]	[14.9,16.7]	[15,16.9]	[17.9,19.9]	[18,20.1]	[19.3,21.6]	[21.5,23.8]	[10,12.7]
Kenitra	[15,16.9]	[15.1,17]	[15,16.8]	[18,20.1]	[17.9,20]	[19.5,21.7]	[21.1,23.6]	[10.7,13.3]
Laayoune	[14.9,16.8]	[15,16.8]	[15.1,16.9]	[18,20.2]	[17.6,19.7]	[19.2,21.6]	[20.6,23.1]	[11.5,14.2]
Larache	[14.9,16.8]	[15.1,16.9]	[15,16.9]	[18,20.2]	[17.9,20]	[19.5,21.7]	[21.2,23.7]	[10.8,13.4]
Marrakech	[15,16.9]	[14.9,16.9]	[15.1,17]	[17.4,19.6]	[15.4,17.6]	[17.8,20.2]	[18.2,20.9]	[9.69,12.3]
Meknes	[15.1,17.1]	[15,16.8]	[15,16.9]	[17.7,19.9]	[18.1,20.2]	[19.5,21.7]	[21.3,23.6]	[10.1,12.8]
Midelt	[15,16.8]	[15.3,17.2]	[14.8,16.7]	[17.9,20.1]	[18.1,20.2]	[19.3,21.6]	[21.4,23.8]	[10.5,13.1]
Nador	[15.1,17]	[15.3,17.3]	[15.1,17.1]	[18,20.1]	[18,20]	[19.3,21.5]	[21.4,23.8]	[10.7,13.4]
Ouarzazate	[15.2,17]	[15.1,16.9]	[15.1,17]	[18.1,20.1]	[17.9,20.1]	[19.5,21.8]	[21.1,23.4]	[11.2,13.9]
Oujda	[15.3,17.1]	[15.2,17.1]	[15,16.9]	[18,20.1]	[17.9,20.1]	[19.4,21.7]	[20.7,23.1]	[11.1,13.8]
Rabat	[15.2,17.2]	[15.1,16.9]	[15,17]	[17.9,20.1]	[17.9,20.1]	[19.4,21.6]	[21.2,23.6]	[10.4,13.1]
Safi	[15.1,17]	[15.1,17.1]	[15,16.9]	[17.8,19.9]	[17.8,20]	[19.5,21.8]	[21.2,23.7]	[11.5,14]
Sidi Ifni	[15.1,17]	[15.1,16.9]	[15.4,17.1]	[18.1,20.2]	[18,20.1]	[19.3,21.5]	[21.4,23.9]	[10.9,13.6]
Tanger	[15.2,17.1]	[15.1,17]	[15.2,17]	[18.3,20.3]	[18,20.2]	[19.3,21.7]	[21,23.5]	[11.4,13.9]
Taza	[15,16.9]	[15.1,16.9]	[15.1,17]	[17.9,20]	[18.2,20.3]	[19.2,21.6]	[21.2,23.6]	[10,12.7]
Tetouan	[15.1,17]	[14.9,16.8]	[14.9,16.9]	[18,20.2]	[18,20.2]	[19.4,21.6]	[21.1,23.5]	[10.5,13.2]

LCOE ranges at 95% confidence interval for 100kW Solar PV and Wind turbine[Ct/kWh]

City	Horizontal	OPT Slope	OWN Slope	EW Track.	NS Track	VERT Track.	Two Axis Track	Wind Turbine
Agadir	[8.8,9.2]	[8.3,8.6]	[8.2,8.6]	[9,9.3]	[7.9,8.2]	[8.5,8.7]	[8.4,8.6]	[25.6,26.7]
Al Hoceima	[9.8,10.2]	[8.9,9.2]	[8.9,9.3]	[9.7,10]	[8.8,9.1]	[9.2,9.5]	[9.1,9.4]	[25.3,26.3]
Beni Mellal	[9.4,9.8]	[8.7,9]	[8.7,9]	[9.5,9.8]	[8.5,8.8]	[9,9.3]	[8.9,9.2]	[37.3,38.7]
Casablanca	[9.6,10]	[8.8,9.2]	[8.8,9.2]	[9.6,10]	[8.7,9]	[9.1,9.4]	[9.1,9.4]	[23.3,24.3]
Er-Rachidia	[8.6,8.9]	[7.7,8]	[7.7,8]	[8.1,8.4]	[6.3,6.5]	[7.3,7.5]	[6.5,6.7]	[10.2,10.6]
Essaouira	[8.8,9.2]	[8.3,8.6]	[8.2,8.5]	[8.9,9.2]	[7.7,7.9]	[8.4,8.6]	[8.1,8.3]	[9.7,10.1]
Fes	[9.7,10]	[8.8,9.1]	[8.8,9.2]	[9.6,9.9]	[8.5,8.8]	[9.1,9.4]	[8.9,9.2]	[19,19.9]
Ifrane	[10,10.4]	[9.2,9.5]	[9.2,9.5]	[10,10.4]	[9,9.3]	[9.5,9.8]	[9.5,9.8]	[34.8,36.3]
Kenitra	[9.7,10]	[9,9.3]	[9,9.3]	[9.8,10.2]	[8.7,9]	[9.3,9.6]	[9.1,9.4]	[18.8,19.5]
Laayoune	[8.4,8.7]	[8.1,8.4]	[8.1,8.4]	[8.3,8.6]	[5.9,6.1]	[7.6,7.8]	[6.2,6.4]	[5.5,5.7]
Larache	[9.7,10.1]	[9,9.4]	[9,9.3]	[9.9,10.2]	[8.7,9]	[9.3,9.6]	[9.2,9.5]	[15.6,16.2]
Marrakech	[9,9.4]	[7.9,8.3]	[8,8.3]	[6.7,6.9]	[2.6,2.7]	[4.6,4.7]	[2.6,2.7]	[46.2,48.1]
Meknes	[9.6,10]	[8.8,9.2]	[8.8,9.1]	[9.6,9.9]	[8.6,8.9]	[9.1,9.4]	[9,9.3]	[25.5,26.5]
Midelt	[9.6,9.9]	[8.7,9]	[8.6,8.9]	[9.4,9.8]	[8.6,8.9]	[9,9.3]	[8.9,9.2]	[22.3,23.2]
Nador	[10,10.4]	[9.1,9.5]	[9.1,9.4]	[9.9,10.2]	[9,9.3]	[9.3,9.6]	[9.4,9.7]	[18.7,19.5]
Ouarzazate	[8.5,8.9]	[7.8,8]	[7.7,8]	[8.4,8.7]	[7.6,7.8]	[8,8.2]	[7.9,8.1]	[14.2,14.8]
Oujda	[9.8,10.1]	[8.9,9.2]	[8.9,9.2]	[9.6,10]	[8.8,9.1]	[9.1,9.4]	[9.1,9.3]	[16.3,17]
Rabat	[9.7,10]	[8.9,9.2]	[8.9,9.3]	[9.7,10.1]	[8.7,9]	[9.2,9.5]	[9.1,9.4]	[24,25]

Safi	[9.2,9.5]	[8.5,8.8]	[8.5,8.8]	[9.1,9.4]	[7.6,7.8]	[8.5,8.7]	[7.9,8.2]	[9.4,9.7]
Sidi Ifni	[9.3,9.6]	[8.7,9]	[8.8,9.1]	[9.5,9.8]	[8.5,8.8]	[9.1,9.4]	[9,9.3]	[13.5,14.1]
Tanger	[9.8,10.2]	[9,9.4]	[9,9.4]	[9.9,10.2]	[8.7,8.9]	[9.2,9.5]	[9,9.3]	[9.5,9.8]
Taza	[9.5,9.9]	[8.7,9]	[8.7,9]	[9.4,9.8]	[8.6,8.9]	[8.9,9.2]	[8.9,9.2]	[23.4,24.3]
Tetouan	[10.7,11.1]	[9.9,10.3]	[9.9,10.3]	[10.9,11.2]	[9.7,10.1]	[10.3,10.7]	[10.2,10.5]	[21.4,22.3]

NPV ranges at 95% confidence interval for 3MW Solar PV and Wind turbine

City	Horizontal [€ x105]	OPT Slope [€ x105]	OWN Slope [€ x105]	EW Track. [€ x105]	NS Track [€ x105]	VERT Track. [€ x105]	Two Axis Track [€ x105]	Wind Turbine [€ x105]
Agadir	[4.55,5.12]	[4.54,5.12]	[4.49,5.05]	[5.38,6.04]	[5.38,6.01]	[5.84,6.49]	[6.36,7.1]	[353,433]
Al Hoceima	[4.46,5.01]	[4.53,5.09]	[4.51,5.06]	[5.27,5.96]	[5.34,5.98]	[5.78,6.47]	[6.26,6.98]	[344,426]
Beni Mellal	[4.55,5.13]	[4.57,5.12]	[4.47,5.06]	[5.35,5.99]	[5.33,6.01]	[5.77,6.44]	[6.43,7.16]	[353,431]
Casablanca	[4.52,5.1]	[4.44,5.24]	[4.54,5.1]	[5.33,5.97]	[5.35,6]	[5.79,6.48]	[6.35,7.09]	[354,429]
Er-Rachidia	[4.54,5.11]	[4.53,5.11]	[4.55,5.12]	[5.37,5.99]	[5.23,5.91]	[5.72,6.41]	[6.21,6.95]	[363,439]
Essaouira	[4.49,5.06]	[4.57,5.13]	[4.51,5.11]	[5.35,5.95]	[5.37,6]	[5.8,6.47]	[6.35,7.09]	[357,430]
Fes	[4.49,5.05]	[4.49,5.08]	[4.54,5.1]	[5.37,6.03]	[5.37,5.99]	[5.74,6.44]	[6.34,7.07]	[352,426]
Ifrane	[4.52,5.08]	[4.49,5.04]	[4.49,5.06]	[5.35,5.98]	[5.41,6.03]	[5.79,6.47]	[6.31,7.03]	[347,427]
Kenitra	[4.51,5.07]	[4.54,5.11]	[4.54,5.09]	[5.39,6.03]	[5.34,6]	[5.88,6.55]	[6.39,7.14]	[359,435]
Laayoune	[4.54,5.11]	[4.64,5.2]	[4.55,5.09]	[5.35,5.98]	[5.25,5.91]	[5.77,6.45]	[6.23,6.98]	[363,440]
Larache	[4.48,5.04]	[4.53,5.09]	[4.5,5.07]	[5.35,6]	[5.35,6]	[5.79,6.47]	[6.31,7.03]	[359,438]
Marrakech	[4.53,5.09]	[4.51,5.1]	[4.53,5.09]	[5.25,5.9]	[4.58,5.24]	[5.32,6.06]	[5.37,6.16]	[352,427]
Meknes	[4.56,5.12]	[4.5,5.07]	[4.51,5.07]	[5.3,5.96]	[5.34,5.97]	[5.85,6.53]	[6.35,7.08]	[362,437]
Midelt	[4.53,5.09]	[4.51,5.07]	[4.54,5.09]	[5.32,5.98]	[5.43,6.05]	[5.79,6.49]	[6.32,7.05]	[350,425]
Nador	[4.5,5.07]	[4.55,5.1]	[4.48,5.06]	[5.4,6.03]	[5.36,6]	[5.82,6.46]	[6.41,7.15]	[351,426]
Ouarzazate	[4.51,5.08]	[4.53,5.08]	[4.55,5.13]	[5.35,5.99]	[5.38,6.01]	[5.82,6.53]	[6.37,7.1]	[349,425]
Oujda	[4.57,5.15]	[4.57,5.12]	[4.49,5.06]	[5.37,6.03]	[5.36,6]	[5.83,6.54]	[6.3,7.02]	[359,434]
Rabat	[4.6,5.14]	[4.56,5.11]	[4.56,5.11]	[5.37,6.05]	[5.39,6.03]	[5.78,6.49]	[6.32,7.05]	[356,432]
Safi	[4.53,5.1]	[4.53,5.1]	[4.55,5.13]	[5.39,6.01]	[5.33,6]	[5.82,6.52]	[6.25,6.97]	[360,437]
Sidi Ifni	[4.53,5.12]	[4.56,5.1]	[4.56,5.1]	[5.38,6.03]	[5.42,6.05]	[5.81,6.48]	[6.37,7.08]	[357,436]
Tanger	[4.54,5.13]	[4.61,5.16]	[4.53,5.1]	[5.47,6.09]	[5.35,5.98]	[5.8,6.46]	[6.34,7.06]	[350,429]
Taza	[4.49,5.08]	[4.53,5.09]	[4.51,5.08]	[5.36,5.99]	[5.41,6.06]	[5.82,6.47]	[6.32,7.04]	[359,438]
Tetouan	[4.53,5.1]	[4.48,5.04]	[4.55,5.11]	[5.34,5.98]	[5.36,6]	[5.84,6.53]	[6.37,7.12]	[351,430]

LCOE ranges at 95% confidence interval for 3MW Solar PV and Wind turbine[Ct/kWh]

City	Horizontal	OPT Slope	OWN Slope	EW Track.	NS Track	VERT Track.	Two Axis Track	Wind Turbine
Agadir	[8.9,9.2]	[8.3,8.6]	[8.3,8.6]	[9,9.3]	[7.9,8.2]	[8.5,8.8]	[8.3,8.6]	[9.3,9.7]
Al Hoceima	[9.7,10.1]	[8.9,9.2]	[8.9,9.2]	[9.7,10]	[8.8,9.1]	[9.1,9.4]	[9.1,9.4]	[9.9,10.3]
Beni Mellal	[9.5,9.8]	[8.7,9]	[8.7,9]	[9.5,9.8]	[8.5,8.8]	[9,9.3]	[8.9,9.2]	[10.3,10.7]
Casablanca	[9.6,10]	[8.8,9.2]	[8.8,9.2]	[9.6,10]	[8.6,8.9]	[9.1,9.4]	[9.1,9.4]	[7.5,7.9]
Er-Rachidia	[8.6,8.9]	[7.7,8]	[7.7,8]	[8.1,8.4]	[6.3,6.5]	[7.3,7.5]	[6.5,6.7]	[5.7,5.9]
Essaouira	[8.8,9.2]	[8.2,8.6]	[8.2,8.6]	[8.9,9.2]	[7.7,7.9]	[8.3,8.6]	[8,8.3]	[5.3,5.5]
Fes	[9.6,10]	[8.8,9.1]	[8.8,9.1]	[9.6,9.9]	[8.6,8.9]	[9,9.3]	[8.9,9.2]	[7.6,7.9]
Ifrane	[10,10.4]	[9.2,9.5]	[9.2,9.5]	[10,10.4]	[9,9.3]	[9.5,9.8]	[9.4,9.7]	[9.5,9.9]
Kenitra	[9.7,10]	[9,9.3]	[9,9.4]	[9.8,10.2]	[8.7,9]	[9.3,9.6]	[9.1,9.4]	[7.6,8]
Laayoune	[8.4,8.7]	[8.2,8.5]	[8.1,8.4]	[8.3,8.6]	[5.9,6.1]	[7.6,7.8]	[6.2,6.4]	[3.6,3.8]
Larache	[9.7,10.1]	[9,9.4]	[9,9.3]	[9.9,10.2]	[8.7,9.1]	[9.2,9.6]	[9.2,9.5]	[6.9,7.2]
Marrakech	[9,9.4]	[8,8.3]	[8,8.3]	[6.7,6.9]	[2.6,2.7]	[4.6,4.7]	[2.6,2.7]	[11.2,11.7]

Meknes	[9.7,10]	[8.8,9.1]	[8.8,9.1]	[9.6,9.9]	[8.6,8.9]	[9.1,9.4]	[9,9.3]	[9.2,9.5]
Midelt	[9.6,9.9]	[8.7,9]	[8.7,9]	[9.4,9.8]	[8.6,8.9]	[9,9.3]	[8.9,9.2]	[8.8,9.2]
Nador	[10,10.3]	[9.1,9.4]	[9.1,9.4]	[9.9,10.2]	[9,9.3]	[9.3,9.6]	[9.4,9.7]	[7.8,8.1]
Ouarzazate	[8.5,8.9]	[7.7,8]	[7.7,8.1]	[8.4,8.7]	[7.6,7.8]	[8,8.2]	[7.9,8.1]	[7.2,7.5]
Oujda	[9.8,10.1]	[8.9,9.2]	[8.9,9.2]	[9.6,10]	[8.7,9]	[9.1,9.4]	[9.1,9.4]	[7.2,7.4]
Rabat	[9.6,10]	[8.9,9.3]	[8.9,9.3]	[9.7,10.1]	[8.7,9]	[9.2,9.5]	[9.1,9.4]	[8.7,9]
Safi	[9.2,9.5]	[8.5,8.8]	[8.5,8.8]	[9.1,9.5]	[7.6,7.8]	[8.5,8.7]	[7.9,8.1]	[5,5.2]
Sidi Ifni	[9.3,9.6]	[8.7,9]	[8.8,9.1]	[9.5,9.8]	[8.5,8.8]	[9.1,9.4]	[9,9.2]	[6.5,6.8]
Tanger	[9.8,10.2]	[9,9.4]	[9,9.4]	[9.9,10.2]	[8.7,9]	[9.2,9.5]	[9,9.3]	[5.6,5.8]
Taza	[9.5,9.9]	[8.7,9]	[8.7,9]	[9.4,9.7]	[8.6,8.9]	[8.9,9.2]	[8.9,9.1]	[9.1,9.5]
Tetouan	[10.7,11.1]	[9.9,10.3]	[9.9,10.3]	[10.8,11.2]	[9.7,10.1]	[10.3,10.7]	[10.2,10.6]	[8.4,8.7]

NPV ranges at 95% confidence interval for 5MW Solar PV and Wind turbine[€ x10^5]

City	Horizontal	OPT Slope	OWN Slope	EW Track.	NS Track	VERT Track.	Two Axis Track	Wind Turbine
Agadir	[7.61,8.55]	[7.52,8.5]	[7.51,8.48]	[9.02,10.1]	[9,10.1]	[9.67,10.8]	[10.7,11.9]	[5.97,7.23]
Al Hoceima	[7.64,8.57]	[7.69,8.64]	[7.54,8.48]	[8.91,9.96]	[8.93,10]	[9.63,10.8]	[10.6,11.8]	[6.14,7.44]
Beni Mellal	[7.49,8.42]	[7.56,8.48]	[7.47,8.43]	[8.93,10]	[8.96,10]	[9.71,10.9]	[10.6,11.8]	[5.9,7.21]
Casablanca	[7.55,8.5]	[7.59,8.52]	[7.48,8.44]	[8.88,9.93]	[8.99,10.1]	[9.57,10.7]	[10.7,11.9]	[5.97,7.27]
Er-Rachidia	[7.56,8.5]	[7.49,8.49]	[7.62,8.57]	[8.95,10]	[8.72,9.78]	[9.63,10.8]	[10.2,11.5]	[6.01,7.23]
Essaouira	[7.58,8.51]	[7.58,8.52]	[7.54,8.48]	[8.86,9.92]	[8.99,10]	[9.79,10.9]	[10.6,11.8]	[5.94,7.19]
Fes	[7.58,8.55]	[7.55,8.52]	[7.59,8.51]	[9,10.1]	[8.9,9.97]	[9.61,10.8]	[10.7,11.9]	[6.1,7.4]
Ifrane	[7.67,8.57]	[7.61,8.56]	[7.57,8.52]	[8.94,10]	[8.96,10]	[9.77,10.9]	[10.6,11.8]	[5.76,7.05]
Kenitra	[7.66,8.6]	[7.63,8.55]	[7.61,8.56]	[8.92,9.99]	[9.01,10.1]	[9.66,10.8]	[10.6,11.9]	[6.06,7.34]
Laayoune	[7.53,8.49]	[7.59,8.56]	[7.58,8.54]	[8.88,9.98]	[8.75,9.85]	[9.67,10.8]	[10.3,11.6]	[5.96,7.17]
Larache	[7.54,8.46]	[7.6,8.53]	[7.6,8.55]	[8.87,9.92]	[9,10]	[9.76,10.9]	[10.7,11.9]	[5.91,7.18]
Marrakech	[7.61,8.54]	[7.52,8.47]	[7.6,8.53]	[8.72,9.83]	[7.65,8.82]	[9.08,10.3]	[9.06,10.4]	[5.95,7.25]
Meknes	[7.62,8.54]	[7.56,8.48]	[7.48,8.44]	[8.96,10]	[8.74,9.8]	[9.7,10.8]	[10.5,11.7]	[5.96,7.17]
Midelt	[7.5,8.47]	[7.65,8.57]	[7.59,8.54]	[8.9,9.97]	[8.88,9.96]	[9.55,10.7]	[10.6,11.8]	[5.92,7.21]
Nador	[7.57,8.51]	[7.53,8.48]	[7.56,8.47]	[8.9,9.97]	[8.98,10.1]	[9.63,10.8]	[10.6,11.8]	[5.99,7.28]
Ouarzazate	[7.58,8.56]	[7.57,8.5]	[7.4,8.37]	[8.98,10]	[8.92,9.99]	[9.58,10.7]	[10.6,11.8]	[6.02,7.29]
Oujda	[7.54,8.52]	[7.66,8.6]	[7.58,8.53]	[8.97,10]	[8.93,9.99]	[9.65,10.8]	[10.4,11.6]	[5.87,7.16]
Rabat	[7.59,8.54]	[7.55,8.49]	[7.56,8.52]	[8.99,10.1]	[9.04,10.1]	[9.69,10.8]	[10.6,11.9]	[6.02,7.32]
Safi	[7.47,8.4]	[7.51,8.47]	[7.52,8.5]	[9.02,10.1]	[8.88,9.98]	[9.64,10.8]	[10.6,11.8]	[6.13,7.43]
Sidi Ifni	[7.49,8.44]	[7.56,8.52]	[7.44,8.39]	[8.98,10]	[8.97,10]	[9.67,10.8]	[10.5,11.7]	[5.86,7.12]
Tanger	[7.66,8.55]	[7.57,8.51]	[7.54,8.54]	[8.97,10.1]	[8.98,10]	[9.5,10.6]	[10.6,11.8]	[5.91,7.17]
Taza	[7.48,8.43]	[7.53,8.53]	[7.49,8.43]	[8.99,10.1]	[9.05,10.1]	[9.64,10.8]	[10.6,11.8]	[5.9,7.14]
Tetouan	[7.6,8.5]	[7.49,8.46]	[7.55,8.51]	[8.9,9.95]	[8.96,10.1]	[9.57,10.7]	[10.6,11.8]	[5.82,7.11]

LCOE ranges at 95% confidence interval for 5MW Solar PV and Wind turbine[Ct/kWh]

City	Horizontal	OPT Slope	OWN Slope	EW Track.	NS Track	VERT Track.	Two Axis Track	Wind Turbine
Agadir	[8.9,9.2]	[8.3,8.6]	[8.3,8.6]	[9,9.3]	[8,8.2]	[8.5,8.8]	[8.4,8.6]	[5.1,5.3]
Al Hoceima	[9.8,10.2]	[8.9,9.3]	[8.9,9.3]	[9.7,10]	[8.8,9.1]	[9.2,9.5]	[9.2,9.4]	[5.2,5.5]
Beni Mellal	[9.4,9.8]	[8.7,9]	[8.7,9]	[9.5,9.8]	[8.5,8.8]	[9,9.3]	[8.9,9.2]	[5.4,5.6]
Casablanca	[9.6,9.9]	[8.9,9.2]	[8.8,9.1]	[9.6,9.9]	[8.7,9]	[9.1,9.4]	[9.1,9.4]	[4.2,4.4]
Er-Rachidia	[8.6,8.9]	[7.7,8]	[7.7,8]	[8.1,8.4]	[6.3,6.5]	[7.3,7.5]	[6.5,6.7]	[3.7,3.9]
Essaouira	[8.8,9.2]	[8.2,8.5]	[8.2,8.5]	[8.9,9.2]	[7.7,7.9]	[8.4,8.6]	[8.1,8.3]	[3.4,3.6]
Fes	[9.7,10]	[8.8,9.2]	[8.8,9.2]	[9.6,9.9]	[8.6,8.8]	[9,9.3]	[8.9,9.2]	[4.3,4.5]

Ifrane	[10,10.4]	[9.2,9.6]	[9.2,9.5]	[10.1,10.4]	[9,9.3]	[9.5,9.9]	[9.4,9.7]	[5,5.2]
Kenitra	[9.7,10.1]	[9,9.3]	[9,9.4]	[9.8,10.1]	[8.7,9]	[9.2,9.6]	[9.1,9.4]	[4.4,4.6]
Laayoune	[8.4,8.7]	[8.1,8.4]	[8.1,8.4]	[8.3,8.6]	[5.9,6.2]	[7.6,7.9]	[6.2,6.4]	[2.7,2.8]
Larache	[9.8,10.1]	[9,9.3]	[9,9.4]	[9.9,10.2]	[8.8,9.1]	[9.3,9.6]	[9.2,9.5]	[4.1,4.3]
Marrakech	[9.1,9.4]	[7.9,8.3]	[8,8.3]	[6.7,6.9]	[2.6,2.7]	[4.6,4.7]	[2.6,2.7]	[5.7,5.9]
Meknes	[9.7,10]	[8.8,9.2]	[8.8,9.1]	[9.6,10]	[8.6,8.9]	[9.1,9.4]	[9,9.3]	[5,5.2]
Midelt	[9.6,9.9]	[8.7,9]	[8.7,9]	[9.4,9.7]	[8.6,8.9]	[8.9,9.2]	[8.9,9.2]	[4.9,5.1]
Nador	[10,10.4]	[9.1,9.4]	[9.1,9.4]	[9.9,10.2]	[9,9.3]	[9.3,9.7]	[9.4,9.7]	[4.5,4.6]
Ouarzazate	[8.5,8.9]	[7.8,8.1]	[7.7,8]	[8.4,8.7]	[7.6,7.8]	[7.9,8.2]	[7.9,8.1]	[4.4,4.6]
Oujda	[9.7,10.1]	[8.9,9.2]	[8.9,9.2]	[9.6,10]	[8.7,9]	[9.1,9.4]	[9.1,9.3]	[4.2,4.4]
Rabat	[9.7,10]	[8.9,9.2]	[8.9,9.3]	[9.7,10.1]	[8.7,8.9]	[9.2,9.5]	[9.1,9.4]	[4.7,4.9]
Safi	[9.1,9.5]	[8.5,8.8]	[8.5,8.8]	[9.1,9.5]	[7.6,7.8]	[8.4,8.7]	[7.9,8.2]	[3.3,3.4]
Sidi Ifni	[9.2,9.6]	[8.7,9]	[8.7,9]	[9.5,9.8]	[8.5,8.8]	[9.1,9.3]	[8.9,9.2]	[3.9,4.1]
Tanger	[9.9,10.2]	[9,9.4]	[9,9.4]	[9.8,10.2]	[8.6,8.9]	[9.2,9.5]	[9.1,9.3]	[3.6,3.7]
Taza	[9.5,9.9]	[8.7,9]	[8.7,9]	[9.4,9.8]	[8.5,8.8]	[8.9,9.2]	[8.9,9.2]	[4.9,5.1]
Tetouan	[10.7,11.1]	[9.9,10.3]	[10,10.3]	[10.8,11.2]	[9.7,10.1]	[10.3,10.6]	[10.2,10.6]	[4.7,4.9]