RESIREA – Work Package 3

Assessment of the renewable energy potential in Oudomxay (Lao PDR), Dak Nong (Vietnam) and Kampong Thom (Cambodia)

Evaluation of the solar photovoltaic potential in the 3 provinces

INTRODUCTION

RESIREA programme aims at defining Decentralized Rural Electrification projects for improving access to electricity in rural areas in three provinces in Southeast Asia: Oudomxay in Lao PDR, Kampong Thom in Cambodia and Dak Nong in Vietnam.

The objective of RESIREA is to propose sustainable DRE projects, using local renewable energies potentials: hydraulic, biomass and solar photovoltaic.
In the targeted zones, RESIREA will compare for each village the different technical options, using the various renewable energy potentials, to select the most adapted and cost efficient option.

As a result, the Work Package 3 of RESIREA work programme consists in evaluating the renewable energy potential in the three provinces. In particular, the results of the investigations considering solar photovoltaic potential are presented in the present report.

Solar irradiation in Southeast Asia is abundant. In remote and isolated areas, grid extension is not economically viable and diesel power generation is costly because of overland transportation of oil through mountainous roads and sometimes impossible, in particular, during rainy seasons. In these cases, stand alone systems, based on renewable energies are required.
In particular, the solar photovoltaic options considered in RESIREA programme can be Solar Home Systems of photovoltaic or centralized photovoltaic system supplying a mini grid.
In both cases, the knowledge of the solar potential is important.

One can assess the solar photovoltaic potential by evaluating locally the following indicators:

- Climate and rain
- Longitude: The higher the value of the longitude the lower the solar radiation in this position. However the longitude is not the only indicator for solar irradiation. The longitude is used here to identify the monthly global radiation in the NASA radiation database.
- Number of sunshine hours: Used to get an overview of critical months in terms of solar radiation.
- Global radiation: Used as input in PV simulation tools as monthly averages to calculate the electricity produced by a PV panel. For PV simulations the distinction of direct and indirect irradiation is not significant as all radiation is used.
- Hourly solar radiation data: Instead of monthly data one can also use hourly data. The simulation tool HOMER developed by NREL synthesizes hourly solar radiation data from monthly averages.

Explanation of terms:

The radiation intensity outside the earth's atmosphere is between 1300 and 1400 W/m^2; this is called the extra-terrestrial radiation. Reflection, scattering and absorption by the atmosphere reduce this value by about 30 %, so that 1000

W/m^2 is incident on the earth's surface at midday when the sky is cloudless. The so-called global radiation consists of two components, the direct and the diffuse radiation. Direct radiation comes directly from the sun, whereas diffuse radiation is incident from all directions; the sky thus appears to be equally bright in all directions. The diffuse component can be seen on sunny days as the blue sky. When the sky is completely overcast, only diffuse radiation reaches the earth's surface.
Even when the sky is clear the maximum usable radiation intensity changes during the course of a day. Less radiation is available early in the morning or in the late afternoon. Then the radiation has a longer path through the atmosphere and is more strongly attenuated than at midday.

weather	clear blue sky	cloudy	overcast sky dull day
global radiation	600 – 1000 W/m^2	200 – 400 W/m^2	50 – 150 W/m^2
diffuse radiation	10 – 20 %	20 – 80 %	80 – 100 %

Tab. 1: Radiation intensity for various weather conditions

Global radiation can be divided into diffuse and direct radiation by statistical correlations. But it is not relevant to calculate PV-Systems.

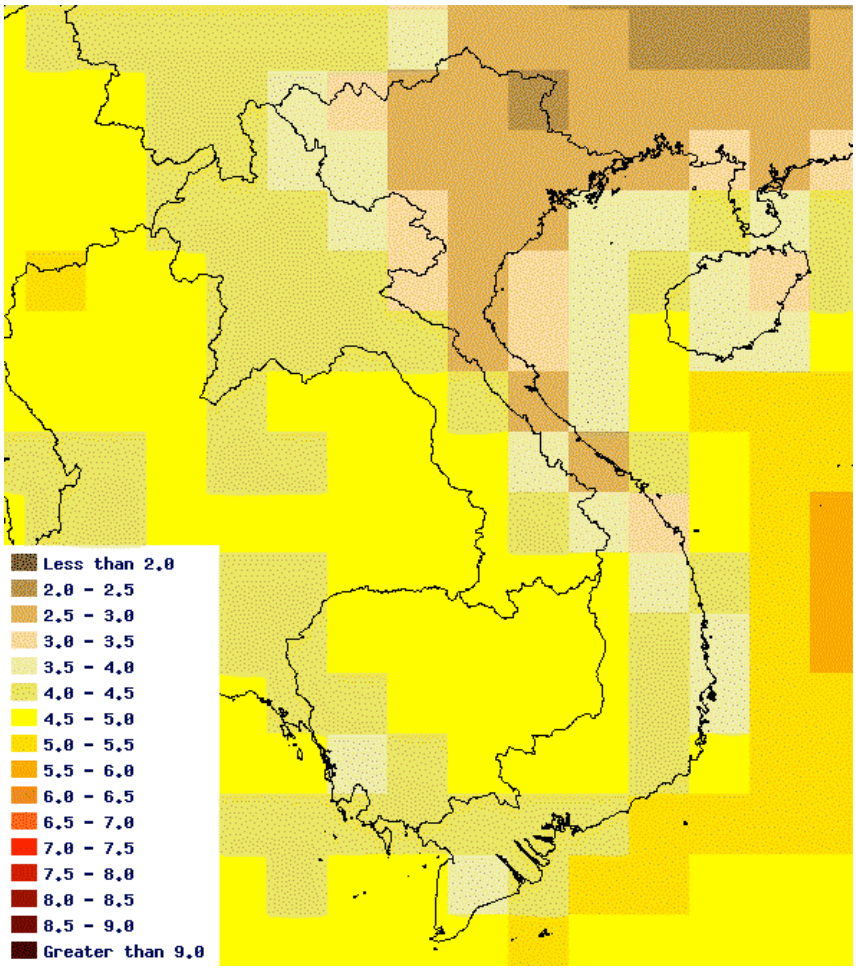

Fig. 1: Solar Irradiance in the three target countries in kWh/ m^2/ day[1]

[1] Source: NREL

The three countries are under hot tropical climate, dominated by the monsoons. The monsoonal airflows are caused by annual alternating high pressure and low pressure over the Central Asian landmass. In summer, moisture-laden air--the southwest monsoon--is drawn landward from the Indian Ocean. The flow is reversed during the winter, and the northeast monsoon sends back dry air. The southwest monsoon brings the rainy season from mid-May to mid-September or to early October, and the northeast monsoon flow of drier and cooler air lasts from early November to March.

Solar photovoltaic potential in Oudomxay province, Lao PDR

1.) Location

The coordinates of Oudomxay province are Latitude 20 and Longitude 101 (see figure below). The province is located at an elevation of 939 meters.

Fig. 2: Location of Oudomxay province

2.) Climate in Lao PDR

Most of the year, the weather in Laos is hot and humid. Lao PDR has three distinct seasons – the dry or cool season starts end of October and continues until February, with cooler weather and reduced humidity. Average temperature might drop to 12°C or 14°C. Summer is from March to June, with temperatures up to 41°C. It is very rainy from June to October with cloudy days. The average annual temperature 29°C ranging in Vientiane and 35°C in April to 20°C in December or January.[2]

[2] http://203.110.64.73:8080/viewContentItem.do?View=viewItem&itemid=2029&ptltid=311

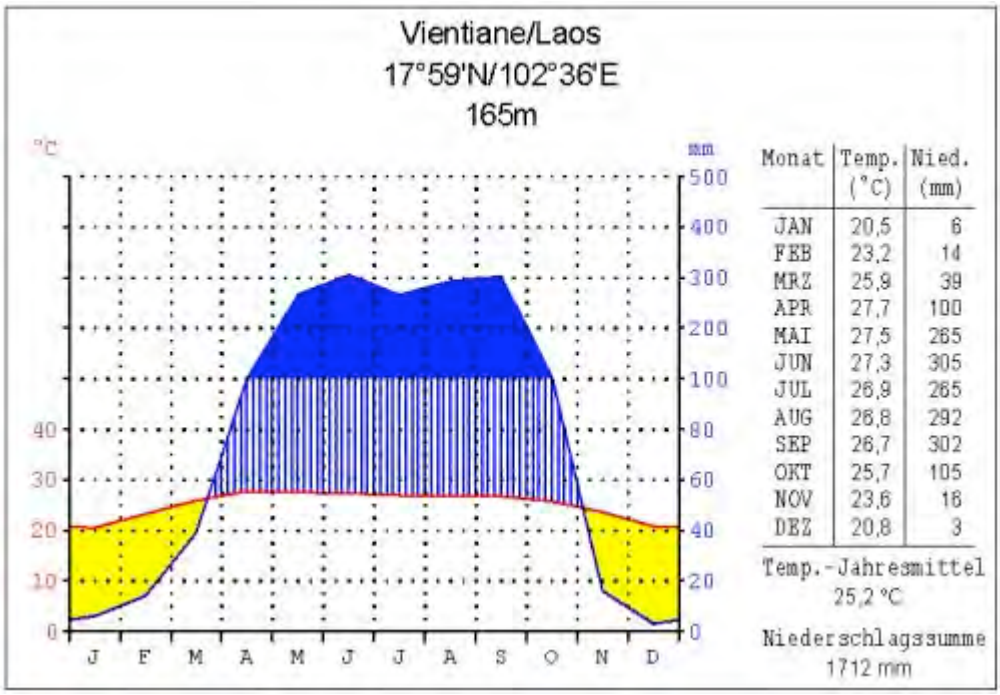

Fig. 3: Climate in Vientiane, Laos[3]

3.) Solar Radiation

Daylight hours in Oudomxay are quite constant and high throughout the year compared to central Europe (figure 4). The highest value is 13,33 in June and the lowest is 10,95 in December.

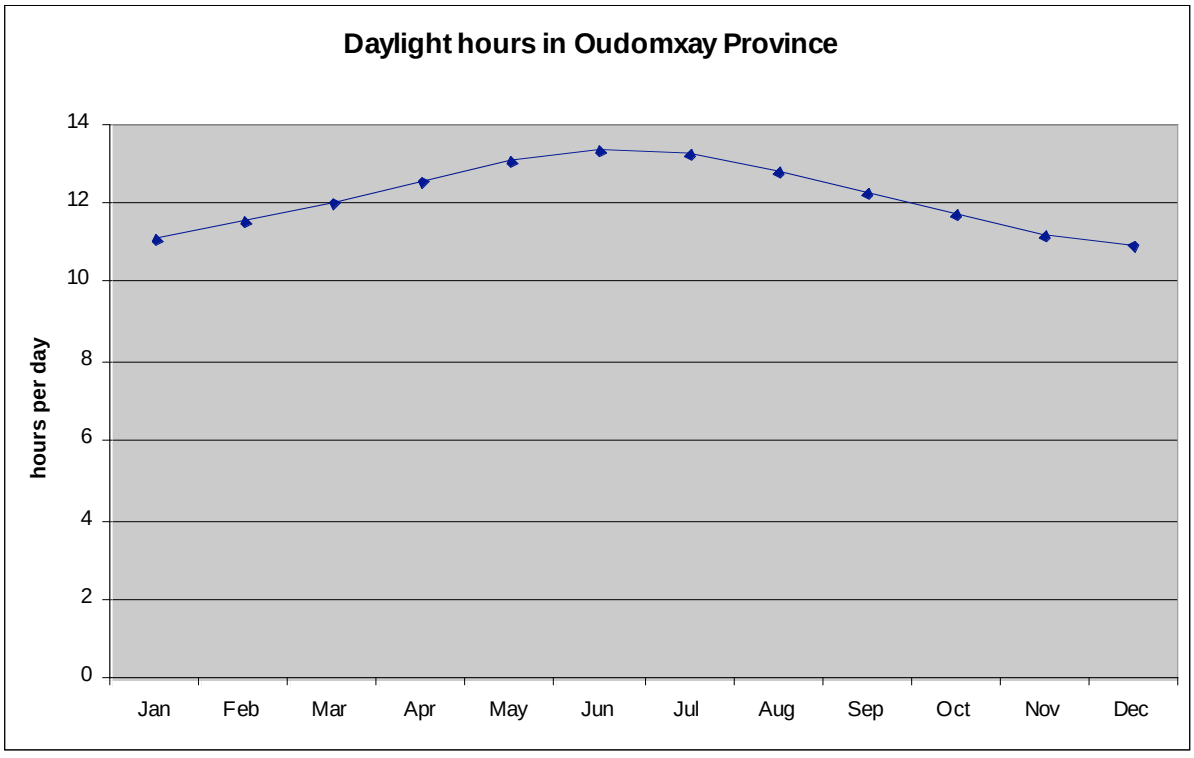

Fig. 4: Monthly average daylight hours in Oudomxay Province

[3] http://upload.wikimedia.org/wikipedia/commons/c/c3/Klima_vientiane.jpg

Sunshine hours decrease during rainy season, especially in the Northern provinces.
For Oudomxay province daily sunshine hours vary between 7 and 4 hours during the year, according to the data of Oudomxay airport in figure 4.[4]

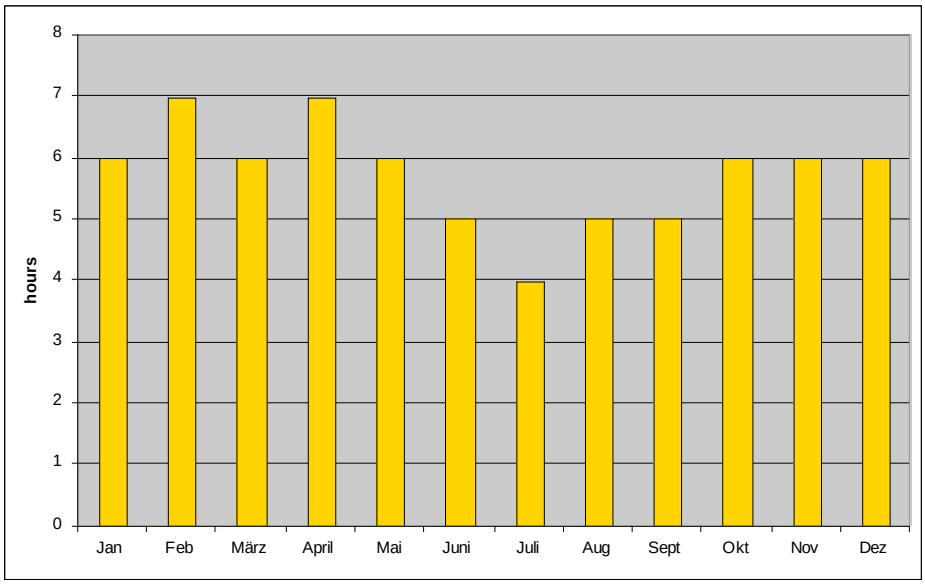

Fig. 5: Monthly average sunshine hours at the airport of Oudomxay province

For the identification of the following solar data of NREL and NASA the coordinates of the provincial capital Xay or close available coordinates were taken: 20°42 N 101°49 E.
For the NREL data only certain parcels of land were available and the coordinates of the closest ones were 20,363 Latitude and 102,146 Longitude. For the NASA data a Latitude of 20 and a Longitude of 101 were chosen.
In figure 5 the global irradiance data of NREL and NASA are quite close and follow the same trend.
The annual average according to NASA is 4,71 kWh/ m2/ day.
Maximum irradiance of the NASA data is 6,07 kWh/ m2/ day in April. The lowest irradiance is 3,94 kWh/ m2/ day in July.

[4] http://www.weather2flights.com/airports/index.php?airport=ODY

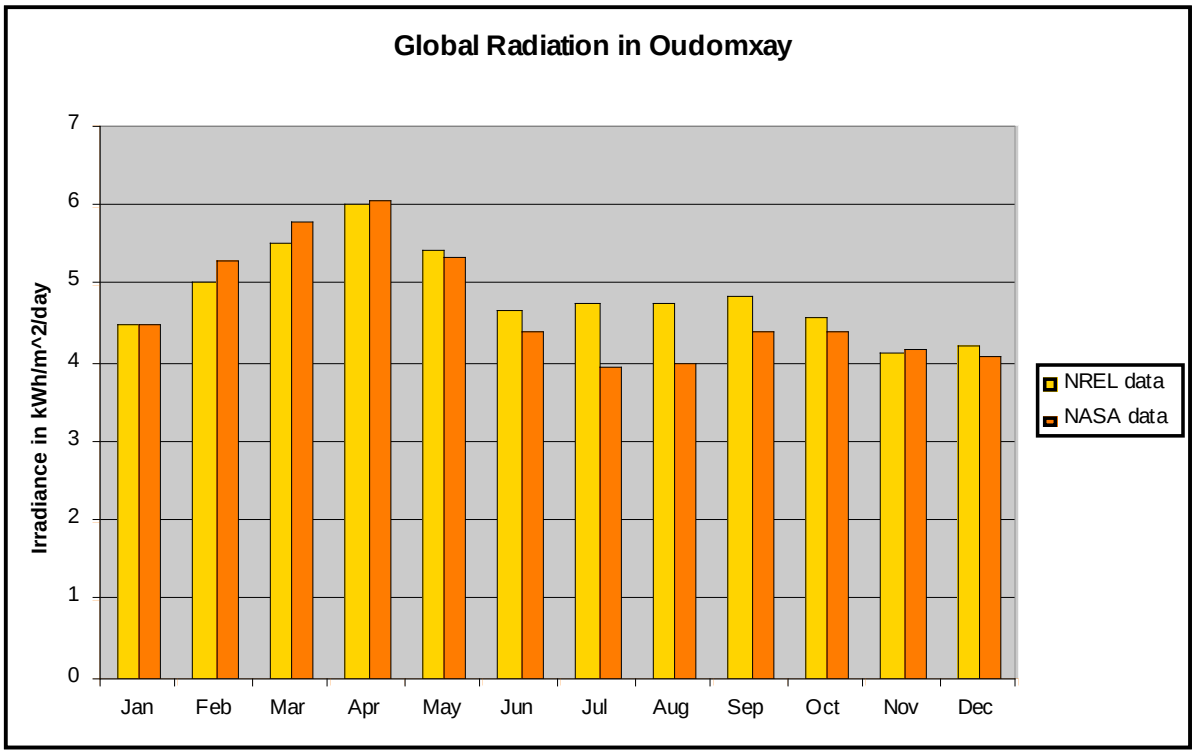

Fig. 6: Monthly average global radiation in Xay provincial city, Odomxay. Data by NREL and NASA

Besides the solar data the mountainous topology of the province has to be taken into account for the positioning of a PV system, to avoid shadow on the photovoltaic panels.

Solar photovoltaic potential in Dak Nong province, Vietnam

1.) Location

The coordinates of Dak Nong province are Latitude 11 and Longitude 107 (see figure below). The province is located at an elevation of 451 meters.

Fig. 7: Location of Dak Nong province

2.) Climate in Vietnam

Vietnam is located between 9 and 23 degrees north. Most of the country has a sub tropical climate and is hot, at least in the summer, and wet most of the year. But the climate of Vietnam varies greatly from one region of the country to another.

Vietnam has a single rainy season during the south monsoon (May-September). Rainfall is infrequent and light during the rest of the year. Rainfall is abundant, with annual rainfall exceeding 1000mm almost everywhere. Annual rainfall is even higher in the hills, especially those facing the sea, in the range of 2000-2500mm.

During the North monsoon, Southern Vietnam tends to be dry and sunny. Temperatures are high all year round for southern and central Vietnam; but northern Vietnam has a definite cooler season. In the southern Vietnam, the lowlands are sheltered from outbreaks of colder northerly air and the dry season is warm to hot with much sunshine.[5][6]
The province of Dak Nong is located in the central highlands, which means in a mountainous area, cooler during winter.

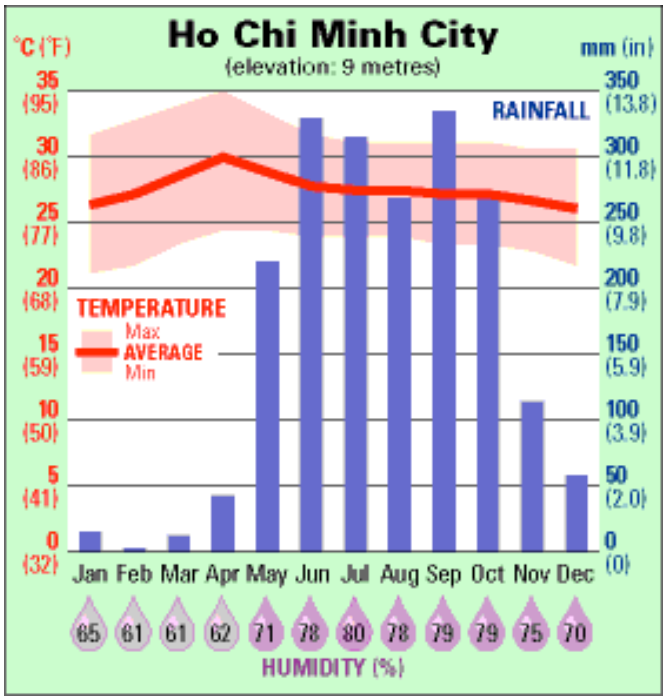

Fig. 8: Climate in Ho Chi Minh City, Vietnam[7]

3.) Solar Radiation

Vietnam possesses good constant solar irradiation conditions in the south and in the centre of the country with values of 4,0 to 5,9 kWh/m^2 per day, while the north has high seasonal variations (2,4 bis 5,6 kWh/ m^2 per day). The amount of sunshine hours is between 1.800 and 2.700 per year.[8]

Daylight hours in Gia Nghia (capital of Dak Nong province) vary between 11,5 in December and 12,77 in June according to NASA data.[9]
Like for Oudomxay province the mountainous area has to be considered also in Dak Nong. The position of mountains and the shadowing will be checked for every PV system.

[5] http://www.vietnamembassy.org.uk/climate.html

[6] http://library.thinkquest.org/25734/data/climate/climate.html

[7] http://www.worldtravelguide.net/country/303/climate/South-East-Asia/Vietnam.html

[8] http://www.gtz.de/de/dokumente/de-windenergie-laenderstudie-2007.pdf

[9] The coordinates of Gia Nghia are 11° 59' 0'' N, 107° 42' 0'' E

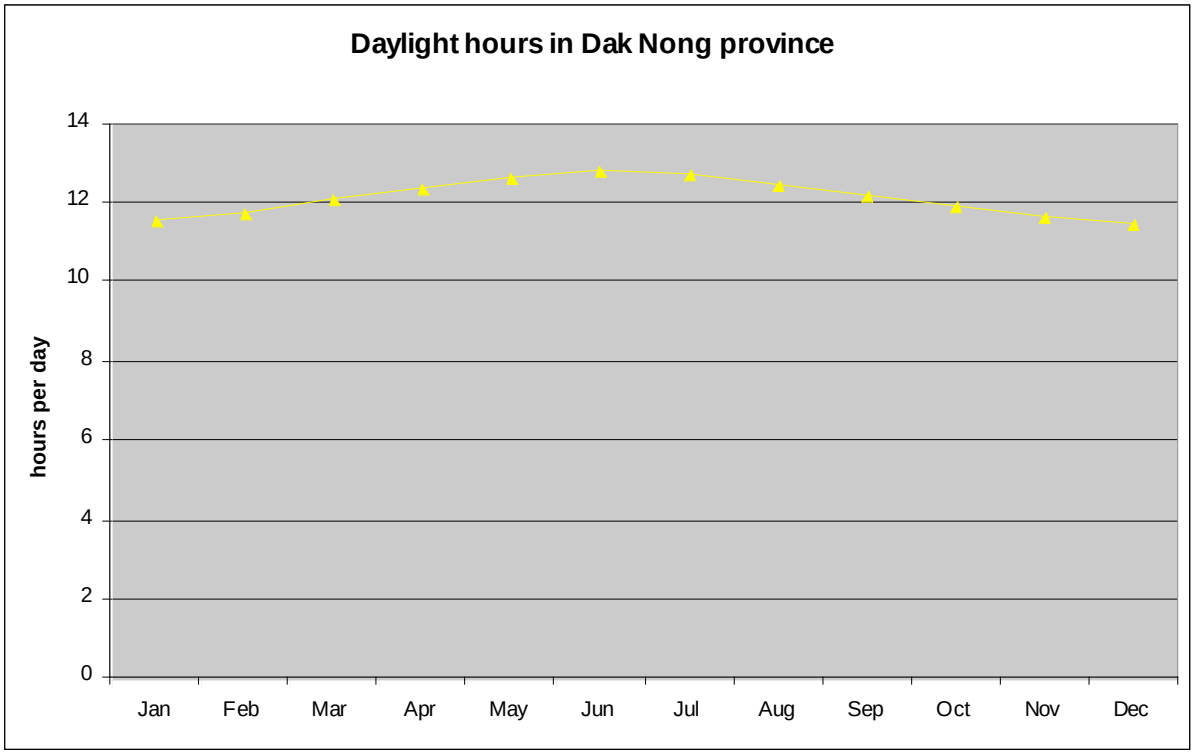

Fig. 9: Monthly average daylight hours in Gia Nghia, Dak Nong Province

Global Radiation in the capital of Dak Nong has a peak in March with 6,23 kWh/m^2/day and a minimum in August with 4,31 kWh/m2/day. The average annual global radiation is 5,14 kWh/ m2/ day.

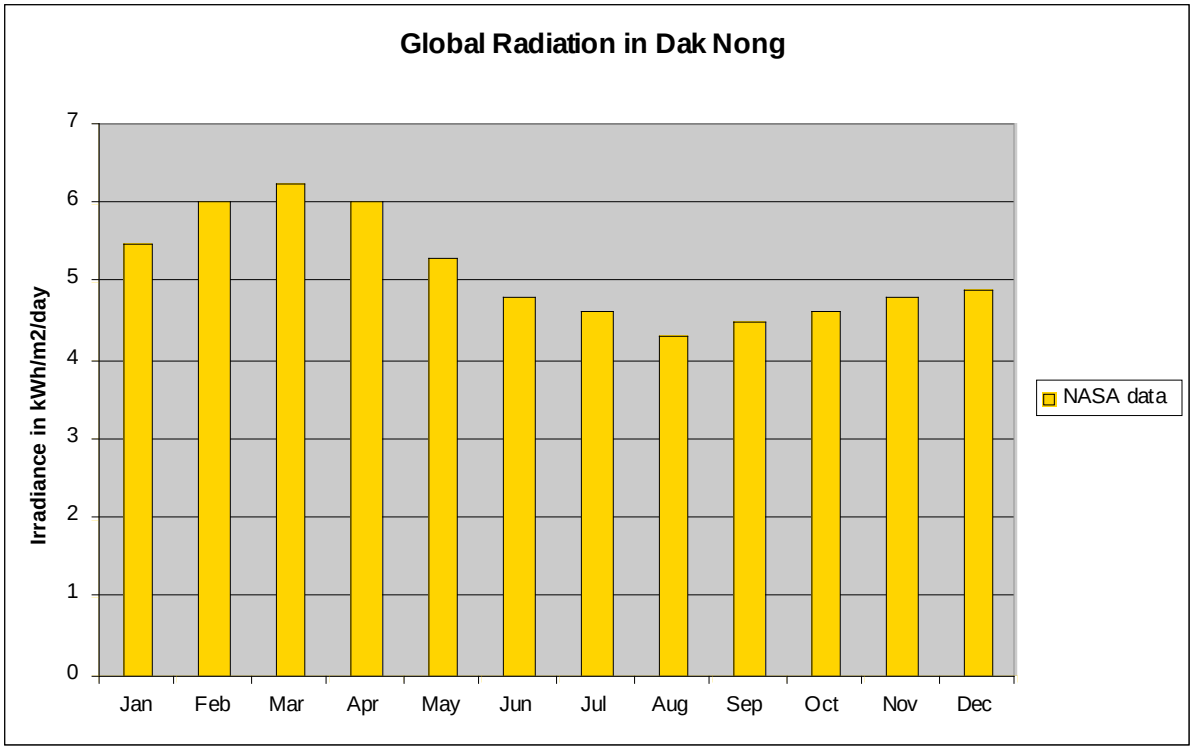

Fig. 10: Monthly average global radiation in Dak Nong

Solar photovoltaic potential in Kampong Thom province, Cambodia

1.) Location

The coordinates of Kampong Thom province are Latitude 12 and Longitude 104 (see figure below). The province is located at an elevation of 31 meters and presents a mostly flat relief.

Fig. 11: Location of Kampong Thom province

2.) Climate in Cambodia

Cambodia's climate – like that of the rest of Southeast Asia – is dominated by the monsoons, which are known as tropical wet and dry because of the distinctly marked seasonal differences.

Short transitional periods, which are marked by some difference in humidity but by little change in temperature, intervene between the alternating seasons. Temperatures are fairly uniform throughout the Tonle Sap Basin area, with only small variations from the average annual mean of around 25°C. The maximum mean is about 28°C; the minimum mean, about 22°C. Maximum temperatures higher than 32°C, however, are common and, just before the start of the rainy

season; they may rise to more than 38°C. Minimum temperatures rarely fall below 10°C. January is the coldest month, and April is the warmest.

Rainfall from April to September in the Tonle Sap Basin-Mekong Lowlands area averages 130 to 190 centimetres annually, but the amount varies considerably from year to year. Rainfall around the basin increases with elevation.

The relative humidity is high at night throughout the year; usually it exceeds 90 percent. During the daytime in the dry season, humidity averages about 50 percent or slightly lower, but it may remain about 60 percent in the rainy period.

3.) Solar Radiation

The coordinates of Kampong Thom provincial capital considered for the NASA database are: 12° 42' 0'' N, 104° 54' 0'' E
Kompong Thom has constant daylight hours throughout the year similar to Dak Nong province. The longest day is 12,82 hours long in June. The shortest day is in December with 11,43 hours of daylight.

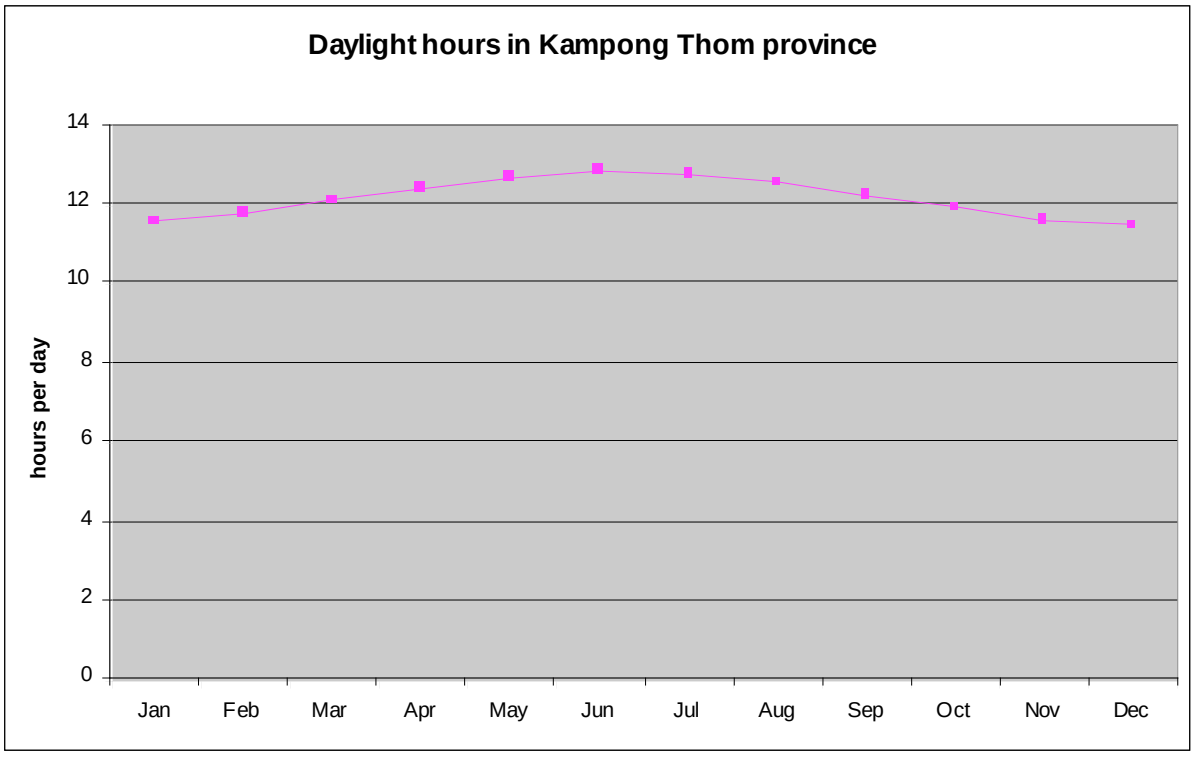

Fig. 12: Monthly average daylight hours in Kampong Thom, Kampong Thom Province

The map of the solar potential is indicated below:

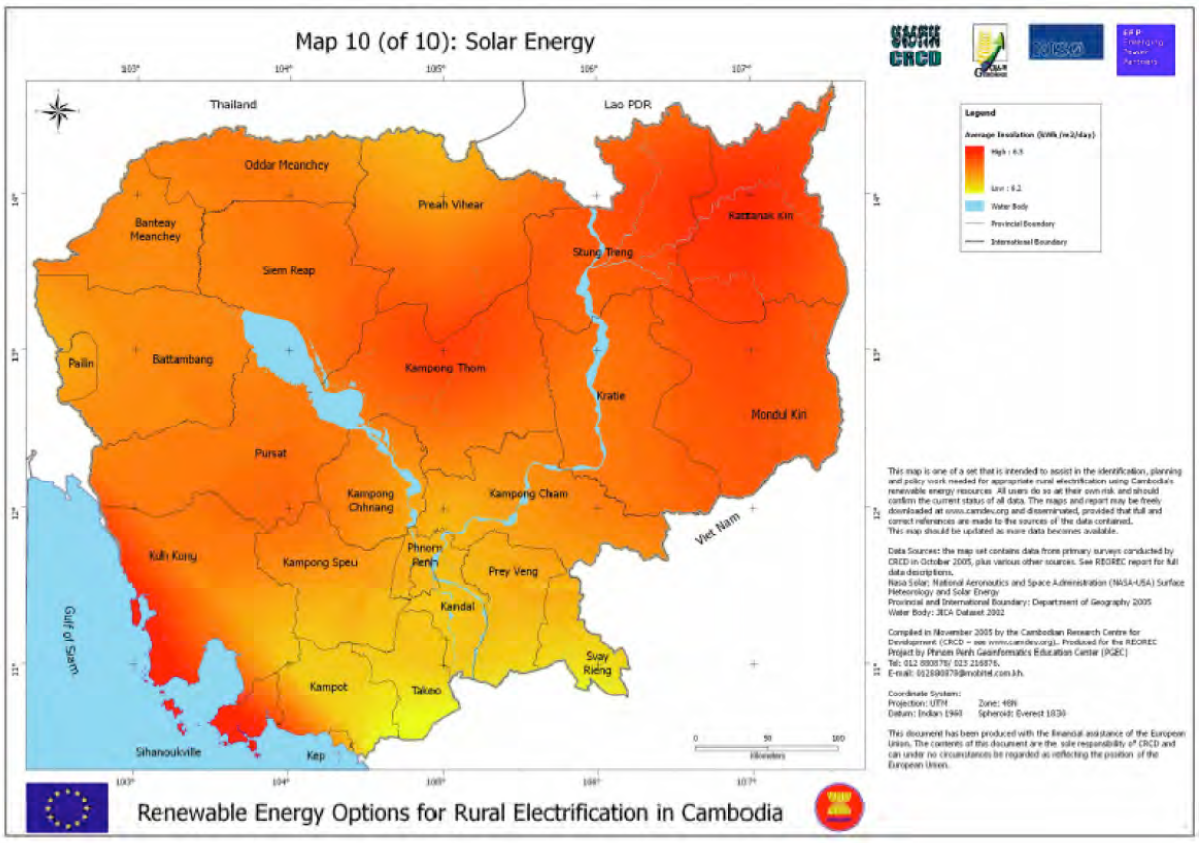

Fig 13: Solar radiation in Cambodia
Source: http://www.camdev.org/Publications/REOREC%20Task%202%20Report-final.pdf

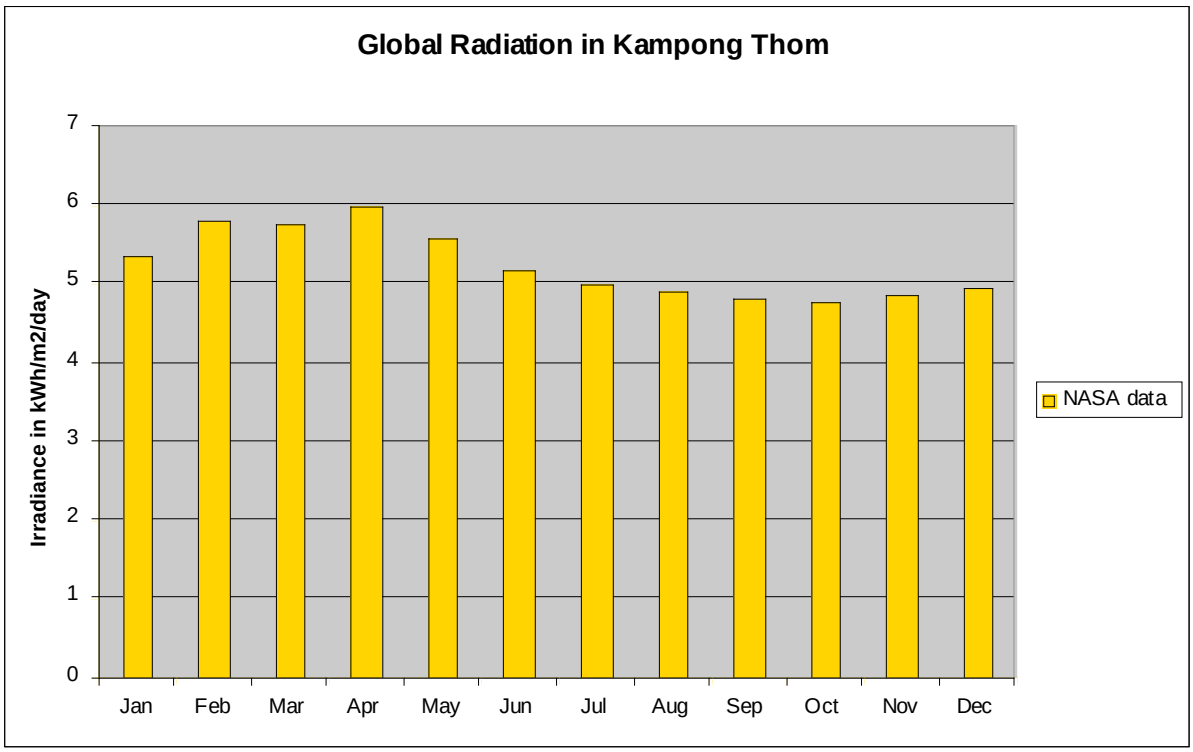

Fig. 14: Monthly average global radiation in Kampong Thom

With an annual average Global Radiation of 5,24 kWh/ m2/ day Kampong Thom has the highest irradiance of all three provinces and the most regular radiation

throughout the year. The solar radiation is highest in April with 5,96 kWh/ m2/ day and lowest in October with 4,75 kWh/ m2/ day.

Comparison of the three provinces

Comparing the data of the three provinces one can say that Kampong Thom and Dak Nong have more regular daylight hours than Oudomxay where the number of daylight hours is higher in May, June and July.

This can be explained by the fact that Oudomxay province is located northern than the two other provinces. However this disparity is not significant.

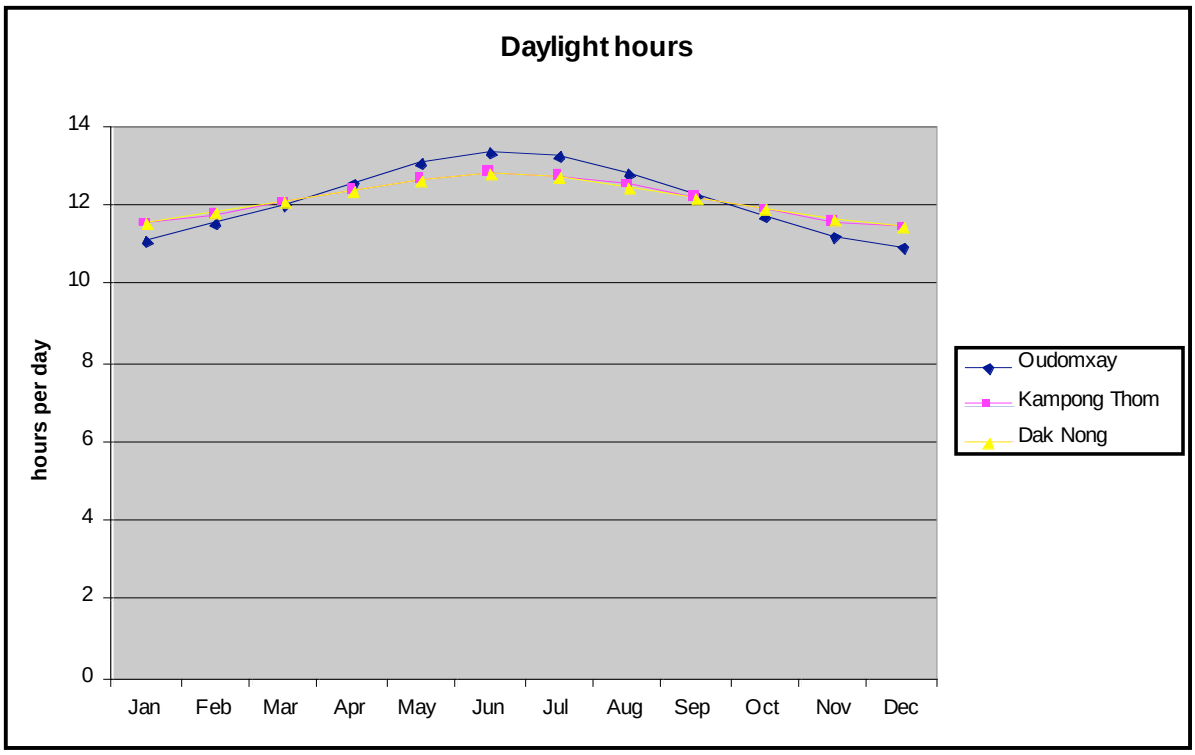

Fig. 15: Monthly average daylight hours in the three provinces[10]

Comparing the global radiation data one can say that all three provinces have similar curves throughout the year and far higher radiation than Central Europe.

[10] NASA

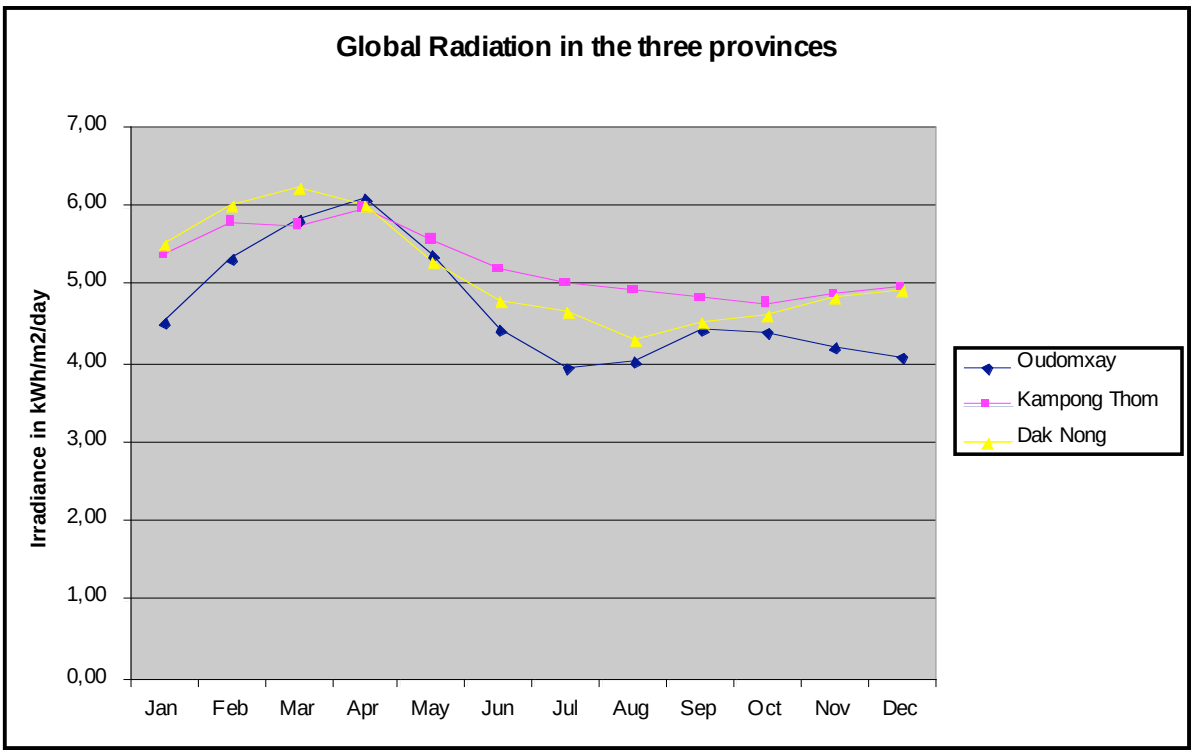

Fig. 16: Monthly average global radiation in the three provinces[10]

Radiation drops down during **rainy season** and has a peak in April during the dry season.
Kampong Thom has the **most regular** curse during the year, which is easier for designing PV-Systems.
Oudomxay province has **the biggest variations**, which have to be considered for the dimensioning of the solar generator and the days of autonomy through sizing of the battery or battery bank.