Final Report

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Internationale Zusammenarbeit (GIZ) GmbH

Development of a Solar Potential Map of the City of Calama/Chile

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DISCLAIMER

The development of a solar roof cataster for the city of Calama was commissioned by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH within the scope of the Renewable Energy Project implemented by the Chilean Energy Ministry and GIZ. This report summarizes the methodological approach and the results of the work. However, any reference to a company, product, brand, manufacturer or similar shall under no circumstances be regarded as a recommendation by the Government of Chile or by GIZ.

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ABBREVIATIONS

DSM	Digital Surface Model
LiDAR	Light detection and ranging
FiT	Feed in tariff
GIS	Geographic Information System
kWh	kilowatt hour
kW_p	kilowatt peak
MWh	megawatt hour
PV	Photovoltaic
WebGIS	internet based Geographic Information system

1. Executive Summary

The Chilean Ministry of Energy[1] and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, within the frame of an intergovernmental cooperation agreement between Chile and Germany, since 2004 are jointly executing the Project "Renewable Energy" in Chile. Part of this cooperation is the SUN-AREA project for the city of Calama. This solar potential analysis gives information about the suitability of every roof in Calama concerning solar use.
With this innovative project, the first solar cadastre for Latin America is realised. In particular solar energy is considered - together with wind energy – to be a very future-oriented form of generating energy. The sun is an abundant source of energy which disposes a variety of option for generating electricity.
A web-based solar roof cadastre enables enormous advantages giving information about photovoltaic and solar thermal applications for residential and industrial use. Additionally, a solar roof cadastre aims at helping cities, municipalities, administrative districts, energy suppliers and the regional economy to select the most suitable areas for solar energy applications. Solar potential analyses enable the selection of most suitable roof areas for the implementation of solar energy systems. It can help planning and supporting appropriate strategies (e.g. the selection of large industrial buildings) for the use of solar power as well as the conception of solar plants. Thereby important environmental and energy policy tasks are fulfilled with positive external impacts by promoting particularly well suitable solar applications.

The first solar potential map of Chile covers the area of the city of Calama (approx. 25 km^2). The exact area is shown in Figure 1, p. 8.

The solar potential map consists of a database and a WebGIS for the web-based presentation of the solar potential map. A WebGIS is a geographic information system for interactive applications via Internet. Information of related geodatabases can be shown using map mapping technologies. The map covers two applications:

- Electric power generation (photovoltaic systems: on-roof installations)
- Solar thermal applications (hot water generation or air conditioning systems).

The solar potential map provides information on the suitability of all buildings in the study area for photovoltaic and solar thermal applications in the form of qualitative and quantitative information (PV only).

- Photovoltaic: all buildings are colour coded in 4 classes (from very well suited to not suited). For each registered property the database provides 5 parameters: a) the size of the area (roof) which is suitable for power generation, b) the annual energy production (kWh/year), c) CO_2 savings due to the replacement of conventional power generation (kg/year), d) the possible installed capacity in kilowatt peak and e) the electricity consumption (number of persons). The energy production data takes into account the local level of radiation, the roof orientation, the average efficiency of PV modules, and the shadowing effect of buildings, trees, and other nearby structures. 77% of all buildings in Calama are suitable for pv installations. Using only 8% of them could cover the whole demand of electricity of Calama.

- Solar thermal: all buildings are colour coded and classified in 2 classes (suitable and not suitable or insufficient data). As complementary information the size of

[1] The Chilean Energy Ministry was created in February 2010. Before, the National Energy Commission (Comisión Nacional de Energía – CNE) was the official counterpart of the Project.

the suitable area is calculated in m^2 for each building. Over 45.000 buildings are suitable for solarthermal use.

- Additional information about the buildings (address, type of building etc.) can be integrated into the database, but was not possible so far since suitable data was not available (official footprints are for every block, not every building and have no address information; additionally they had the wrong data format)

The products and results as specified in the Terms of Reference (see Annex 1) were presented during a final meeting in Santiago in December 2010. The WebGIS was launched in an official meeting in the presence of the Chilean Energy Minister Ricardo Raineri on December the 16th, 2010.

The work has been carried out under the supervision of Prof. Dr. Martina Klärle by the project team as nominated in the proposal. Key team members are:

- Dr. Markus L. Rombach, Digimapas, responsible for the aerial survey and provision of 3D Laser Scanner data.
- Mrs. Sandra Lanig and Mrs. Katharina Meik, responsible for the SUN AREA analysis.
- Mr. Christian Keil, GPM (Büro für Geoinformatik, Umweltplanung und Neue Medien), responsible for the development of the WebGIS.

2. Work progress and time schedule

The project started with the signature of the contract.

Due to heavy sand storms in the area of Calama in late June and early July the aerial survey was delayed about 4 weeks. The airborne survey, in order to collect LiDAR data and digital aerial images, was only possible during the second half of July. The delay has been reported in the flight report dated July 21, 2010 by Digimapas.

In late July the Steinbeis Company started preparing the LiDAR data for the solar potential analysis.

The data quality assessment was performed by Steinbeis on the base of the data received by Digimapas for the study area.

The WebGIS for the representation of the final results has been designed by GPM and is ready for use on the following site: http://www.geopm-kom5.de/geoapp/catastrosolar/calama/.

The progress meeting in Santiago took place on October 26th, 2010. The overall results and the WebGIS application where presented to the Chilean Energy Minister, GIZ and representatives of government institutions and the private sector in a launching ceremony on December 16, 2011.

3. Location of the Study Area

The City of Calama is located in the North of Chile in the Atacama Desert at approximately 2.250 m above sea level. It is the capital of the Antofagasta Region. Calama is one of the driest cities in the world with average annual precipitation of just 5 mm and therefore has an enormously high global irradiance. Moreover, Calama is located at 2.259 meters above sea level which makes it a particularly interesting location for solar applications.

According to the work programme the solar potential map established for the whole area of the city of Calama as shown in figure 1.

Figure 1: Study area, source: Digimapas

4. DATABASE

Based on high-resolution 3D LiDAR data shared with 2D digital topographic data (building outlines) we use an automatic running computer aided analysis method to identify high potential urban roof planes for the use of solar power based on Geographic Information Systems (GIS). LiDAR data proved to be an optimal data basis for performing very exact site analyses automatically for solar roof systems in large regions. The high-resolution height information recorded for many areas is used for the most varied fields of application. With an accuracy of approximately 15cm in position and height and their point densities of 1-2 points per square meter, these data have enormous potential. Due to the data's high accuracy, homogeneous roof areas can be selected taking into account any roof superstructures, such as dormers or chimneys, and their site parameters, such as roof exposition, roof slope, size of roof area, insolation energy, can be identified. Over multiple reflection of the transmitted laser beam (first and last pulse) from an airplane a Digital Surface Model (DSM) can be generated. The required LIDAR data and digital aerial images were collected and processed by Digimapas (see flight report attached in Annex 2). The main characteristics are:

REFERENCE SYSTEM

- Datum : UTMWGS 84
- Huso: 19 South.
- Geoide: EGM08
- UTM

LASER

- File LAS with all Points.
- Full Points Cloud (ASCII User Define)

MODELS	DTM	DSM
Resolution	50 cm	50 cm
Format	ASCII GRID	ASCII GRID
Dimensions	1000x1000	1000x1000
Precision	25 cm	25 cm

CAMERA

IMAGE	VIS
Resolution	25 cm
Format	Geotiff, 8 bits
Dimensions	1000x1000

GEOINFORMATION and PLANIMETRY

GEOINFORMATION	Specifications
Format	SHP

- Planimetry with closed polygons of buildings.

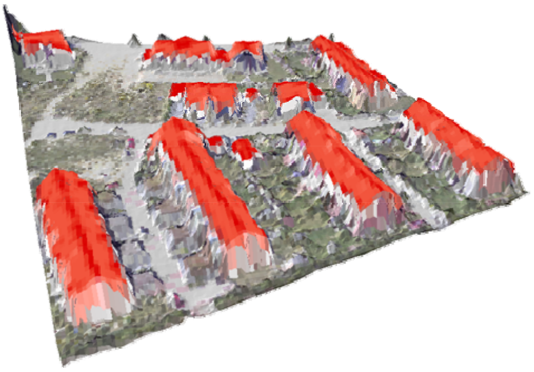

Figure 2: DSM generated out of LiDAR-data

The basis of the calculation method is the first pulse of the LiDAR data. Through Airborne Laser Scanner Data (LiDAR) it is possible to generate high-precision Digital Surface Models (DSM) for grouping analysis and derivation of the roof surface. The data preparation starts with the interpolation of the unevenly distributed clouds of points. The resulting DSM is stored as a 1 meter grid. This DSM contains all objects of the real surface such as buildings or vegetation.

Together with the LiDAR data, the building footprints are used. They were necessary to locate the position of the roofs. Germany has extensive records of this type of data in the Automated Land Register Map (ALK). In Chile, the only comparable maps are to be found for the capital city Santiago de Chile. For the calculation of the test area, building outlines were digitized by Digimapas from the high-resolution digital aerial images.

5. Parameters of the Calculation

To calculate the suitability of a roof for a solar installation several factors have to be considered. Some of them are universal; some depend on the specific location.

Shade

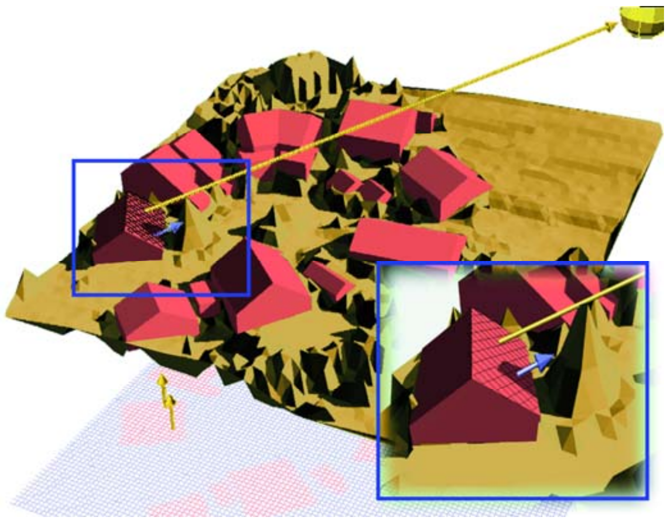

Figure 3: shade effect onto the roof

Shadows cast by vertical objects onto the solar panels can cause significantly greater power reductions than a sub-optimal orientation of the solar generator. Therefore, even partial shading of a module can diminish the overall performance of the installation. Any shading of the solar generator should therefore be avoided. The shadow modelling is based on a grid analysis. The input parameters are the high resolution 1m DSM, the geographical site, slope, orientation, and the daily and seasonal change of sun angle.

Minimum roof size

In principle there is no limitation to the size of a PV-installation. However, very small installations will rarely become cost-effective at current PV prices. Under German conditions, with low irradiation, a minimum solar panel area of 20 m² is required under economic conditions. This corresponds to an installed solar power capacity of 3 kW_p. With this rated power the cost for an installation will be amortised in about 10 to 15 years. For economical reasons this is the minimum size for PV-installations in Germany and Europe, respectively. In Chile there are different conditions like a higher solar irradiation and the absence of a fixed tariff for selling electricity generated by renewable energy. As there exists no Feed in Tariff (FiT) like in Germany and many other European countries, PV installations might be designed predominantly to cover the auto-consumption of a building. Most installations on private houses would thus be used for self-supply, trying to reduce the amount of electricity being injected into the electricity grid of the city. Therefore, the decision whether a PV-installation is cost-effective or not will depend on the amount of energy that is used in the building.

For this reason we decided to set the minimum roof size at a lower level of 2 m², although cost efficiency is going up with the size of the installation (economies of scale). The average electricity demand per household (approx. 4 persons) in Northern Chile is about 2.400 kWh. This rated power can be produced by a 2 m² PV system (the exact area needed depends on the efficiency level of the solar modules). Further datasets were built, for different sizes of the suitable area, to provide useful information to non-private investors to focus on large suitable roof areas.

Also, for solar thermal installations a minimum collector surface of 2 m² has been applied for the study area. This size is sufficient for hot water supply of a family of 4 persons in Calama.

Slope & Aspect

The optimum slope of solar panels for the best radiation profit depends on the geographical location and the angle of the incoming solar radiation to the solar panels. In general, for Calama the theoretical optimum tilt angle for solar panels is 10° to 15° (with a roof facing North). However, panels should not be mounted completely flat. A certain slope helps with self-cleaning and cleaning of the panels. On the other hand there is no need to mount panels on a steeper slope as we can see in Europe, where the optimum slope varies from 25 to 40°. In some cases it is necessary to create a steeper construction based on the supporting beams of the roof, because of unstable roof material.

Global irradiance

The intensity of the global irradiance depends on the geographical location, i.e. the relative position with respect to the equator and the geomorphologic conditions. The input data was derived from the Digital Surface Model (DSM) which represents the real surface of the whole city including buildings with their real roof structure (inclination, orientation) and vegetation. The model calculates the irradiance over the whole year considering the shading from buildings and vegetation. There is a desert-like climatic situation with very low precipitation or even clouding in Calama. Therefore the calculation parameters are set for generally clear sky conditions and have not been measured. The solar radiation analysis algorithm is taking these factors into account and based on algorithms developed by Rich et al. (Rich 1990, Rich et al. 1994) and further developed by Fu and Rich (2000, 2002). Micro-climate influences remains unconsidered. The result is an irradiance value for every square meter of all roof areas. Out of these values the solar irradiation for every roof area is calculated based on a weighted mean approach of each irradiance value per square meter contributing equally to the final average solar irradiation. In our calculation the maximum irradiance onto an undisturbed surface amounts to 2.420 kWh per m² and year. This value goes considerably down if a surface is not well oriented or if it is overshadowed. The minimum irradiance which is considered as “well suitable” (class 3) has been set at 1.500 kWh per m² and year.

Suitability classes:

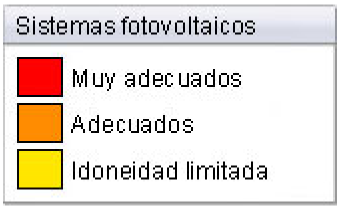

Table 1: classes of suitability

class		**description**
1	most suitable	global irradiance higher than 2.100 kWh/m^2/year
2	well suitable	global irradiance values from 2.000 to 2.100 kWh/m^2/year
3	suitable	global irradiance is smaller than 2.000 kWh/m^2/year and higher than 1.500 kWh/m^2/year

A comparison with real local measurements (see Solar Radiation Report, Digimapas) was helpful to enhance the accuracy of the calculation.

Efficiency of the PV-panels

We calculate with an efficiency of the photovoltaic modules of 12 % for the conversion of radiation energy into electric energy. The market offers modules with efficiencies from 8 % (cheap, thin layer technique) up to 18 % (high performance, expensive).

At 12 % efficiency an active PV-area of approximately 8.5 m² is required to generate 1 kW_p of electrical power.

CO_2-savings

The achievable CO_2 reduction depends on the CO_2 production rate in the existing power mix and on current power production techniques in Chile.

We used an average CO_2-equivalent of 790 g CO_2e per kWh, which is quoted by Price Waterhouse Coopers (column: co212 in the database) for the Northern Interconnected System (SING) of Chile.

Investment volume

The cost of a PV-installation depends on the cost of – mainly imported – components and the local labour content. In coordination with the GIZ an average cost of 2.800 € per kW_p was used. This is a typical value for medium size installations in Chile. This value is flexible and can be re-calculated with regard to changing prices.

Electricity coverage

In the northern part of Chile an average household consists of 4 members with an electricity demand of approx. 2.400 kWh/a. One person therefore has an electricity demand of about 650 kWh/a. The number of persons, whose electricity demand can be covered is calculated out of this value and is based on the potential amount of electricity (kWh/a) that can be produced on every single roof.

Table 2: Summary of assumptions

Parameter	**Used Value**
Efficiency of the solar module	12%
Performance Ratio	75%
CO_2-Savings (CO_2e)	0,79 tCO_2e/MWh (Source: Price Waterhouse Coopers)
Minimum roof size for the suitability of photovoltaic plants (classes)	2 m^2 10 m^2 50 m^2 100 m^2
Minimum roof size for the suitability of solarthermal systems for heating water	2 m^2 The typical size of a solar thermal module is 2 m^2 which should be sufficient for the supply of hot water of a family in Calama. For bigger constructions this varies.
kWp-capacity	1 kWp = 8,5 m^2 This factor does not vary in different regions of the world. What varies is the electricity production because of the higher irradiation in Calama
Investment volume PV	1 kWp installed = 2.800 €
Investment volume ST	1 m^2 installed = 700 €

6. Results

The solar potential has been calculated for all roof areas which have been identified in the sample (59.069 buildings). The graphic representation (WebGIS) uses a colour coding to show the suitability of each individual roof.

There are separate maps for the suitability of roof areas for solar thermal systems and for PV systems.

Figure 4: Screenshot of the WebGIS presenation

Photovoltaic systems (Solarpotential_Calama_PV_per_footprint)

The lower limits have been set at an irradiance level of 1.500 kWh per m² and year and a minimum size of 2 m² (see suitability of classes on page 12).

Solar thermal systems (Solarpotential_Calama_TH_per footprint)

The lower limits have been set at an irradiance level of 1.500 kWh per m² and year and a minimum size of 2 m². No segmentation into classes was made, because the installed size of a solar thermal system depends on the demand for hot water in each building. Mostly, 2-5 m² are sufficient for a one family house.

Additional tasks

As a result of the evaluation of the test area, we decided to go two steps further to make the results more usable as a tool for finding the most suitable roof areas for PV-installations in the city of Calama. Therefore, the city of Calama was visited and some buildings were inspected in October 2010.

In the city centre of Calama most buildings, especially the outbuildings, are not stable enough to carry the weight of heavy solar systems, even if they are relatively small. As shown in figure 5 there are sometimes canvas covering buildings, which the system can misleadingly recognize as roof structures. Therefore new housing areas, with higher structural stability, were identified. Parts of them are new buildings of the state owned copper mining company Codelco. The solar cadastre could be an adequate tool for Codelco to assembly the security of energy and hot water supply of their employees in terms of sustainability. This can create autonomy and help constructing a public energy supply for the whole city of Calama. These areas are shown in the map as priority areas because of a better building and roof structure. For all buildings, located in one of the new housing areas, this information was added to the database.

Figure 5: unstable (left) and new housing areas (right) in the city of Calama

As a second step for a better usability of the roof cadastre a separate database with different classes of roof sizes was generated (see data sets delivered). Regarding the stability of the roofs or buildings, it was noted that large buildings often seem to be the more stable ones. The WebGIS map offers the possibility to activate a layer where only these buildings are shown (green hatching). This additional information will be helpful to focus on more stable buildings.

WebGIS

As described in detail in the ToRs the WebGIS-Solarcadastre as a Service is hosted by GPM with a annual fee (status quo).

There is also the possibility to transfer the application to a server in Chile hosted by the ministry of energy.
(Server provision by Department of Energy and Server installation by GPM with a once-only payment for installation and optional an annual fee for server administration.)

Requirements are: Linux Server with English Centos distribution (Version 5.5 in original state) with remote Access and full root privileges for installation and maintenance.

Hardware guideline values:
2x300GB Harddisk (SAS)
4GB RAM
Intel Xeon Quad-Core E5620 or comparable Processor 100 or better 500 Mbit/s bandwidth

7. DATA SETS DELIVERED

The following datasets are delivered:

- 6 FeatureClasses in one FileGeodataBase (planimetric features including calculated parameters for all suitable roof areas and per footprint).

Table 3: File identification

Data set	Description
Solarpotential_Calama_TH_perfootprint	results for solar thermal system per house outline
Solarpotential_Calama_PV_perfootprint	all results for photovoltaic use per house outline larger than 2 m²
Solarpotential_Calama_PV_perfootprint _gr2to10sqm	all results for photovoltaic use per house outline from 2 to 10 m²
Solarpotential_Calama_PV_perfootprint _gr10to50sqm	all results for photovoltaic use per house outline from 10 to 50 m²
Solarpotential_Calama_PV_perfootprint _gr50to100sqm	all results for photovoltaic use per house outline from 50 to 100 m²
Solarpotential_Calama_PV_perfootprint _gr100sqm	all results for photovoltaic use per house outline larger than 100 m²

8. DESCRIPTION OF DATA SUPPLIED

The following terms have been used in the data sets. For PV the description is valid for all of the five datasets

Table 4: Data content of „Solarpotential_Calamatestarea_PV_perfootprint"

Field Name	Description
Sum_Modularea	Suitable roof area in m²
Sum_totIrrad	Effective irradiance onto the area specified
Sum_Electr12	Potential power generation at the specified surface if 12 % efficiency panels are used
Sum_co212	CO_2 -savings 0,79 tCO_2e/MWh (Source: Price Waterhouse Coopers)
Sum_kWp	Nominal power if potential is fully used (1kWp = 7m²)
Sum_Invest	Cost of pv generator (1KWp = 2.800€)
Sum_Class	Suitability classes, • 1 = most suitable • 2 = well suitable • 3 = suitable
Sum_Suitability	Comment on the suitability of the building
Sum_SumtotIrradPerFootprint	Accumulated annual global irradiance onto the roof area
Sum_MeantotIrradPerFootprint	Average of annual global irradiance onto the roof area
ElectrDemandPerP	The electricity demand of how many persons can be covered

erson	
Pref	information whether the building lies inside a new housing area or not 1 = yes 0 = no

Table 5: Data content of **„Solarpotential_Calama_TH_perfootprint“**

Field Name	**Description**
Sum_Modularea	Potential collector surface in m²
Sum_totIrrad	Effective irradiance onto the area specified
Suitability	„suitable“ or „not suitable“ – no further differentiation
Sum_SumtotIrradPer Footprint	Accumulated annual global irradiance onto the roof area
Sum_MeantotIrradPe rFootprint	Average of annual global irradiance onto the roof area
Sum_Invest_TH	Cost of solar thermal plant (1sqm = 700€)
Suitability	Comment on the suitability of the building for solar thermal plants
Pref	information whether the building lies inside a new housing area or not 1 = yes 0 = no

10. Results of the calculated solar potential – statistics

The solar potential analysis has been applied to a total of 59.069 buildings in the area of Calama. Out of this sample buildings have a certain potential for PV power generation according to the parameters mentioned in the chapter “Parameters of the calculation” of this report. The following table lists the statistics of the suitable buildings.

Table 6: statistics of suitable buildings

Description	**Value**
Buildings	59.069
Building-Area	5.539.100 m²
Average/Building	117m²
Inhabitants	ca. 135.000
Roof area/Inhabitant	41m²

Table 7: Statistical evaluation of the solar roof cadastre in Calama

Suitability	PV-area in m²	Power generation in MWh/a	CO_2– savings in t /a	Coverage of electricity demand (no. of persons)	Accumulated nominal generator power in kW
Most suitable	1.499.163	288.099	277.599	480.165	176.372
Well suitable	2.075.495	384.287	303.587	640.478	244.176
Suitable	718.007	125.986	99.529	209.977	84.471
Total	**4.292.667**	**798.373**	**630.714**	**1.228.267**	**505.020**

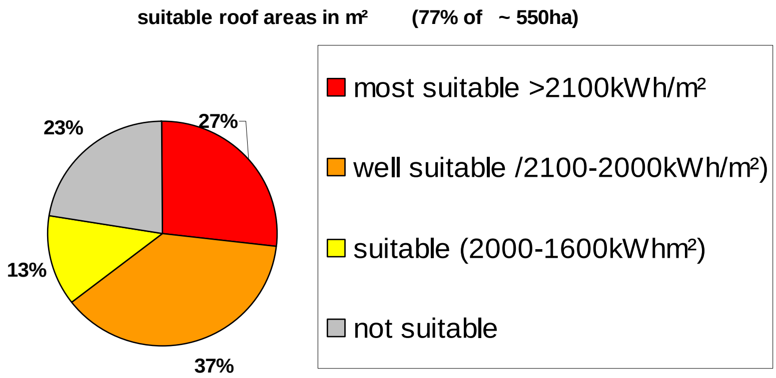

Figure 6 Visualization of the statistical evaluation of the solar roof cadastre in Calama

If the 429 hectares of suitable roof tops would be used for electricity generation by photovoltaics, 798.373 MWh per year could be produced and 630.714 t of CO_2 could be saved. This in turn means that only 8 % of the theoretically possible electricity generation is necessary to satisfy the private electricity consumption of Calama.

Moreover, the final statistics conclude that 77 % of the whole building area of Calama is suitable for the implementation of PV-systems. This result needs to be evaluated carefully since the roof cadastre cannot give any information on the statics of each building and does not exclude fully the existence of canvas being mistaken for real roof areas.

Backing of electricity demand

The electric private power consumption in Calama:

- private household (4 persons): 2.400kWh/a
- Per person: 600kWh/a
- Complete private consumption: **81.000MWh**
- **8%** of the suitable roofs can produce **100%** of Calamas private consumption

Table 8: summary of suitable classes

	Potential in MWh	**% of Consumption**
most suitable	288.100	443
well suitable	384.300	591
suitable	126.000	193
SUM:	798.400	1.228

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Rich, P. M., and P. Fu. 2000. "Topoclimatic Habitat Models." Proceedings of the Fourth International Conference on Integrating GIS and Environmental Modeling.

ANNEX

1. ToR (original version)
2. Flight Report Project Renewable Energy
3. Solar Radiation Report (Digimapas)
4. Final presentation (Prof. Dr. Martina Klärle)
5. Leaflet about SUN AREA (Spanish version)

Terms of Reference for Consultancy

Development of a Solar Potential Map of the City of Calama/Chile

Project: Renewable Energy, Chile
PN: 2007.2079.7-001.00

1. Introduction

The Chilean Ministry of Energy[1] and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, within the frame of an intergovernmental cooperation agreement between Chile and Germany, since 2004 are jointly executing the Project “Renewable Energy” in Chile.

The overall objective of the Project is to increase the participation of grid-connected renewable energy in the electricity market, thereby contributing to more sustainable energy supply. The project focuses on the removal of legal, regulatory and other barriers that are impeding the development of renewable energy and its integration into the electricity market. The project also aims at creating favourable conditions for political and public acceptance of non-conventional renewable energy (RE) and to encourage private investment in renewable energy technologies in order to accelerate their participation in the energy market.

The main areas of cooperation are:

- Development of policies, regulatory framework and instruments to support renewable energy;
- Generation of useful information in order to encourage private investment in RE development (assessment of RE potentials and measurements, publication of guidelines, pre-feasibility studies etc.);
- Capacity building and international exchange.

In the past few years, the Chilean Government has made substantial progress in removing barriers of renewable energy development. The regulatory framework was improved in order to allow grid access and market integration of small and medium size renewable energy technologies. In March 2008, a renewable energy portfolio standardhas been enacted. The law establishes an obligation for the electric utilities to supply 5% of all commercialized electricity from renewable energy sources from January 2010 onwards. The obligation will increase gradually until reaching 10% in 2024. Regarding solar thermal systems, the Chilean government approved in August 2009 a tax deduction for the installation of solar water heaters on newly constructed buildings. Other important mechanisms to support renewable energy investment have been the implementation of financial instruments including subsidies for pre-investment studies, bank guaranties and loans with preferential conditions, and improved knowledge on renewable energy resources.

At the end of 2009, projects representing aprox. 2.500 MW of capacity had been approved or were being processed under Chile’s environmental impact assessment system. Installed renewable energy capacity reached about 515 MW at the end of 2009. The current RE portfolio,

[1] The Chilean Energy Ministry was created in February 2010. Before, the National Energy Commission (Comisión Nacional de Energía – CNE) was the official counterpart of the Project.

in terms of capacity, is dominated by wind energy, followed by small hydropower, biomass and solar energy. Several sites are also being studied for geothermal development.

2. Solar energy in Chile

GTZ is supporting the Chilean Energy Ministry in executing solar measurements in order to create a database of the solar energy potential in the North of Chile. The field measurements also serve to validate the already existing meteorological model (solar-wind explorer) on the webpage of the Ministry: www.minenergia.cl. The Chilean Government also has announced to support two larger solar energy pilot projects for electricity generation in the Atacama desert, including a 500 kW photovoltaic (PV) installation and an approx. 10 MW concentrating solar power plant (CSP). Financial support for the projects will be made available through an international competition; it is expected that the tender documents will be published within the next months.

Since 2008, GTZ has been supporting solar irradiation field measurements by installing and operating five meteostations at the following locations in the North of Chile:

- Pozo Almonte (operating since August 2008)
- San Pedro de Atacama (operating since May 2009)
- Crucero (operating since August 2009)
- Pampa Camarones (operating since February 2010)
- Inca de Oro (operating since March 2010)

Measurement results are made available to private project developers and investors and are published on the webpage of the Energy Ministry:
http://www.minenergia.cl/minwww/opencms/03_Energias/Otros_Niveles/renovables_noconvencionales/Tipos_Energia/energia_solar.html

3. Objectives and tasks of the International Consultant

Overall objective

The objective is to develop a SUN AREA analysis of the potential for solar power generation on buildings (Solar Potential Map) of the City of Calama in the North of Chile, and the development of a WebGIS (Web based **G**eographic **I**nformation **S**ystems Resource) for the detailed and interactive representation of the Solar Potential Map.

Specific objectives

The specific objectives of the consulting services are:

1. Data collection and generation of high resolution laser scanner data (LIDAR) of the City of Calama by an airborne survey;

2. Development of a solar potential map of Calama based on the SUN-AREA method and analysis, providing information on the photovoltaic and solar thermal potential of each building (roof);

3. Development of an internet based interactive map and database (WebGIS) for the detailed presentation of the solar potential map in the internet.

Tasks and activities

The solar potential map shall cover the area of the city of Calama (approx. 25 km^2). The exact area shall be agreed upon at the start of the project.

The solar potential map shall consist of a database and a WebGIS for the web-based presentation of the solar potential map. The map shall cover two applications:

- Electric power generation (photovoltaics)
- Solar thermal applications (hot water generation or air conditioning systems).

The solar potential map shall provide information on the suitability of all buildings in the area for photovoltaic and solar thermal applications in the form of qualitative and quantitative information (PV only).

- Photovoltaic: all buildings are colour coded in 5 classes (from very well suited to not suited or no classification. For each registered property the database will provide 3 parameters a) the size of the area (roof) which is suitable for power generation, b) the annual energy production and c) CO_2 savings due to the replacement of conventional power generation. The energy production data take into account the local level of radiation, the orientation of the roof, the average efficiency of PV modules, and the shadowing effect of buildings, trees, and other nearby structures.

- Solar thermal: all buildings are colour coded and classified in 2 classes (suitable and not suitable or insufficient data).

- Additional information about the buildings (address, type of building etc.) can be integrated into the database.

The **specific tasks** and activities of the International Consultant comprise:

<u>Task 1 regarding specific objective no. 1: data collection</u>

- Collection of existing geo-data from previous surveys, especially planimetric features;

- Generation of laser-scanner data (LIDAR) by an airborne survey of the area under investigation;

- Processing of LIDAR data in order to generate a digital surface model (DSM) suitable for the solar potential analysis;

<u>Task 2 regarding specific objective no. 2: SUN-AREA analysis</u>

- Data quality assessment;

- Integration of DSM, ortho images and planimetric features in order to identify relevant roof areas;

- Generation of a status report and discussion at a meeting in Santiago or Calama;

- Calculation of the total solar radiation at each roof point of the DSM, including the effect of shadowing from roof structures, trees and other buildings and structures. Direct and indirect radiation components will be taken into account;

- Generation of a database providing detailed information for each roof area;

- Statistical analysis of the overall potential for solar powe generation at Calama;

Task 3 regarding specific objective no. 3: Development of WebGIS

- Design of the WebGIS with respect to the specific requirements of the client (Ministry of Energy / GTZ) and the potential users. Details to be agreed upon as part of the project.

- Integration of the database;

- Implementation of the WebGIS on a server provided by the Steinbeis Company. The server and the application can be approached via web link from Chile.

Additional Tasks:

All necessary data to perform the specified tasks mentioned above will have to be provided by the Consultant. This also concerns:

- Delivery of precise polygon shape, autocad.dwg or kmz of the areas to be mapped;
- Cartographic information material; e.g. topographic maps, digital elevation models; areal photos for flight planning management and cadastral information;
- Cartographic reference points for quality control purposes;
- Ground control measurements within the area of observation;
- Cartographic and geodetic parameters necessary for the transformation into the reference system requested by the client.

4. Products

The International Consultant is responsible to deliver the following products to the client:

Products related to Task 1:

- Laser scanner data

Products related to Task 2:

- Status report on the quality of the collected data;
- Database of the “Solar Potential Map” in a format ready to be implemented into a WebGIS;
- Statistical analysis of the potential for solar power generation at Calama;
- Final report and documentation in English (3 hard copies and electronic version)

Products related to Task 3:

- WebGIS with user interface in Spanish. The design of the WebGIS and the user interface will broadly follow the design of the Solar Potential Map already in operation in Wiesbaden / Germany (www.wiesbaden.de/solarkataster). It will also take into account the the specific requirements of the Ministry of Energy / GTZ. The details will be agreed upon during the project.

- The WebGIS will be hosted for 1 year on the server provided by the International Consultant in Germany. It is intended to transfer the application to a server provided by the Ministry of Energy in Chile at any time, if the server is suitable for the application.

- Documentation of the WebGIS in English.

5. Time schedule and submission of reports / products

The contract will start on May 28, 2010 and end on October 31, 2010.

1. Work on task 1 shall start within three weeks after signing of the contract. The aerial survey will be completed within 9 weeks after signing of the contract, i.e. 30.07.2010. Weather related delays will be reported to the client.

2. The Status Report will be submitted until 30.08.2010.

3. The final report, including the database of the solar potential of roofs in Calama (Product No. 2), will be submitted until 31.10.2010

4. The final report, including the generation and functioning of the interactive map and database on the Internet (WebGIS) as well as the WebGIS itself (Product No. 3), will be submitted until 31.10.2010.

All reports will have to be submitted in English.

6. Meetings and travel to Chile

The Consultant shall participate in the following meetings with Ministry of Energy / GTZ.

1. A preparatory meeting shall take place in Santiago before starting the aerial survey, within the first two weeks after signing of the contract. The meeting could be held with the Chilean representative responsible for the data collection.

2. A progress meeting with participation of the International Consultant shall take place in Santiago after submission of the Status Report (approx. 30.08.2010).

3. A final meeting, including the demonstration of the Solar Potential Map in Santiago, shall take place after delivery of all items. The exact date of the meeting will have to be coordinated with the GTZ Project.

Two representatives of the International Consultant shall participate in the second and third meeting in Chile. The exact dates will have to be coordinated with the GTZ Project. The Consultant will have to make flight and travel arrangements based on a travel duration of 5 working days for each of the travels. Costs for accommodation and daily allowance will be paid according to GTZ standards. The Consultant will have to specify in his financial offer the exact number of flights to Calama.

7. Obligation of the client

The client will provide as much support as possible, for the acquisition of local administrative information, such as cadastral maps, house numbers, property tax numbers etc. For the case of digital or analog existence of these information, the client will use his local governmental relations for the liberation and delivery of these information to Digimapas Chile. Apart from this support, the client will arrange the official communication with the respective local authorities if requested by Digimapas Chile (official letter, direct phone calls) to facilitate the requests of Digimapas Chile to these authorities.

8. Product property

The product property of the Laser Scanner Data generated by Digimapas Chile (Products related to Task 1) is personal, not for client resale use. Digimapas Chile reserves its copyrights in respect of all raw data generated.

9. Confidentiality

The consultants commit themselves to full confidentiality of the information that they are managing regarding the compliance of the assigned task. The consultants commit themselves not to submit or communicate any data to a third party, except for the case that GTZ and/or the Energy Ministry (MINENERGIA) explicitly allow the contrary and/or that such information is in the public domain.

10. Payment

- 40% of the total contract value is due after signing of the contract
- 30% of the total contract value is due after the progress meeting or within 6 weeks after submission of the status report if the progress meeting has not yet taken place.
- 30% of the total contract value is due after conclusion of all activities and final acceptance of the product delivery according to the Terms of Reference.

FLIGHT REPORT

RENEWABLE ENERGY CHILE

36_1003_CALAMA3

ELABORATED BY:	REVISED BY:	*APPROVED BY:*
NAME : Carolina Rebolledo	*NOMBRE: Fulvio Cortes*	*NAME : Dr. Markus Rombach*
Roxana Trujillo		
CARGO: Production Cordinator Quality Control	*CARGO: Development Manager*	*CARGO: Director*
DATE : July 2010	*DATE: July 2010*	*DATE: July 2010*
:		

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1.0 INTRODUCTION

DIGIMAPAS CHILE LTDA. under contract with Steinbeis from Germany for the project "Renewable Energy Chile" PN: 2007.2079.7-001.00 and whose applicants are GTZ and the Ministry of Energy of Chile, is making flights mapping the area required with the LIDAR system "HARRIER 56" which also includes two image sensors with digital cameras.

The objectives of this project are building a Solar Potential Map by analyzing the impact of the sun on roof surfaces in the city of Calama Chile and develop a Geographic Information System through a Web page (WebGIS) with the attributes of the solar potential map to be generated.

The LIDAR system (Light Detection And Ranging), is an active remote sensing system that emits pulses of laser light in the electromagnetic spectrum band capturing the reflected signal (echo) in the topographic surface swept, obtaining the elevations as faithful to reality by ALS (Airborne Laser Scanning), The LIDAR also is composed for a satellite georreceptor that provides the position and height of the aircraft at all times of the laser pulse emission which is the system GNSS and finally incorporates an Inertial Navigation System INS, which provides information about the twists and trajectory of the aircraft in flight. In summary the LIDAR system is composed of three subsystems (ALS, GNSS and INS) which independently record their own observations, with the common parameter for synchronization and post processing the GPS time which records each measure.

The LIDAR system is trained to capture two types of data: height and intensity of which will derivate the products that this system gives and the most common data used of these two is the height for the production of Digital Surface Model (DSM) and Digital Terrain Model (DTM).

The purpose of this report is to establish the progress of flights and coverage captured of the project area according to the flights planning made, for subsequent processing of LIDAR products, RGBA Imaging and Digital Mapping.

2.0 GENERAL

2.1 GEODESIC ANTECEDENTES

Reference System WGS84-SIRGAS, Cartographic Projection UTM Huso 19 S and Global Elevation Model Geoidal EGM08 are used for flight planning and surveying systems used. These parameters are used for standard products made by DIGIMAPAS Chile, with the exception of the geoid models of ripple.

Datum: WGS84 (SIRGAS)

Projection: UTM, Huso 19 South

Figure Nº 1: Project Location

Reference: Google Earth

2.2 FLIGHT METHODOLOGY

2.2.1 FLIGHT PLAN DEVELOPMENT

This part of the methodology defines the height of the flights, the direction of the lines, also makes an estimate of time and the movements necessary to completely cover the project area. The planning process gives the following results:

• Number of flight lines.
• Number of linear kilometers.
• Calculation of flight time.
• Calculation of average number of flights
• Calculation of flight movements.

2.2.2 FLIGHT STUDY

Were sought the best alternatives of movement from the aerodrome and the best flight path for the planned lines

2.2.3 WEATHER CONDITIONS VERIFICATION

Constantly is checked the weather for the flight area in order to choose the best flying areas according to weather conditions. For this were used satellite images and local weather forecasts.

2.2.4 QUALITY CONTROL OF FLIGHTS MADE

Is controlled the coverage of laser flights from a file in ASCII format, generated only with real-time navigation with an accuracy of 5 meters and a lower density of points that the final product, this file is known as coverage. For flights with digital camera is performed a low resolution global mosaic and the navigation is superimposed with the centers of each photos taken. Using these tools, we have a visualization and a complete control of each flight performed and therefore the first quality control of the process

3.0 FLIIGHT OPERATIONS

DIGIMAPAS Chile following the methodology previously raised has made two flights. The detail of each day of flight is defined below.

PRIORITY CALAMA3

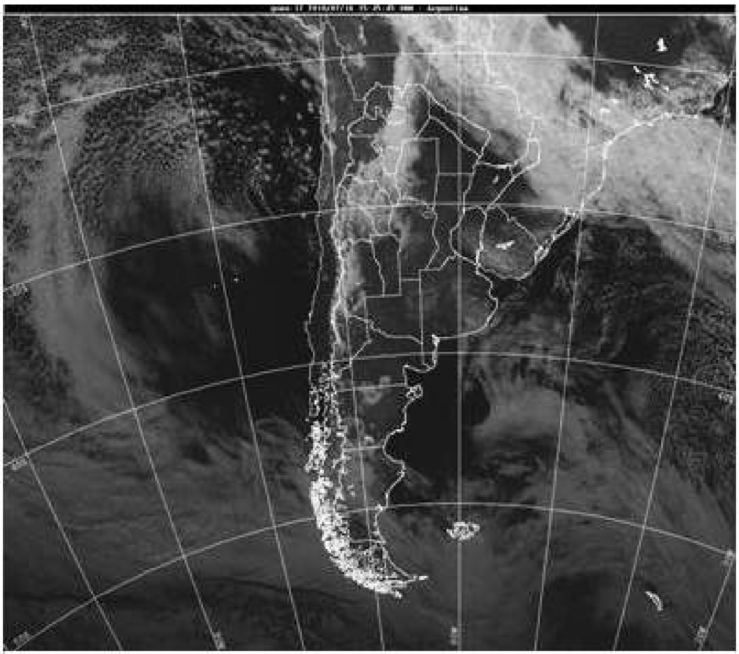
Day 16/07/2010

- Weather Report

Global Weather: Clear with Dust Storms.


Historial meteorológico hora a hora para CALAMA/EL LOA & a 4 Km. de Calama.
Elevación: 2270m. (mapa)
viernes 16 jul
Más estaciones: CALAMA/EL LOA &

Hora local	Tiempo	Temp.
0:00	Buen tiempo	4 °C
8:00	Buen tiempo	5 °C
9:00	Buen tiempo	4 °C
10:00	Buen tiempo	7 °C
11:00	Buen tiempo	11 °C
12:00	Dust Storm	13 °C
13:00	Dust Storm	14 °C
14:00	Dust Storm Despejado	11 °C
15:00	Dust Storm Despejado	13 °C
16:00	Dust Storm Despejado	14 °C
17:00	Dust Storm Despejado	14 °C
18:00	Dust stormen los Alrededores Despejado	13 °C



- Coverage made: No flights for this day, unfavourable weather conditions due to strong wind gusts recorded in the study area.

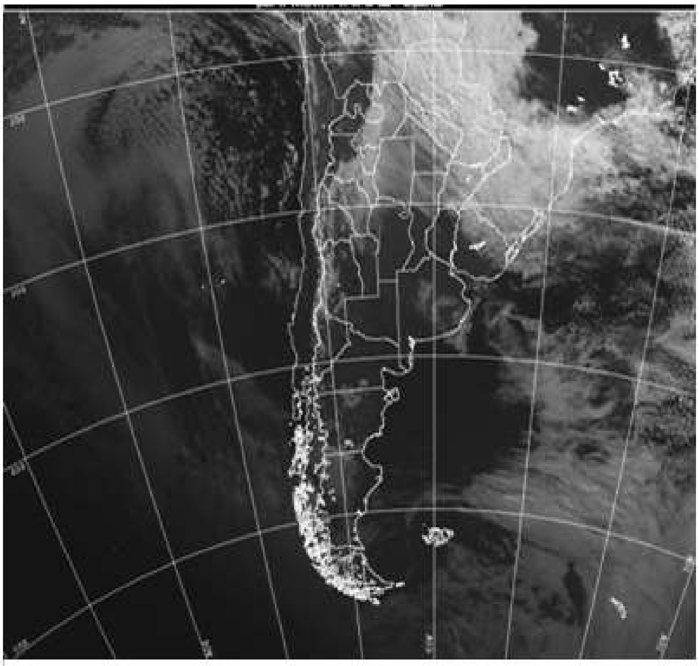
Day 17/07/2010

- Weather Report

Global Weather: Clear with Dust Storms

Histonal meteorológico hora a hora para CALAMA/EL LOA &
Calama,
Elevación 2270m. (mapa)
sábado 17 jul
Más estaciones
CALAMA/EL LOA &

Hora local	Tiempo	Temp.
8:00	Buen tiempo	3 °C
9:00	Buen tiempo	3 °C
10:00	Buen tiempo	7 °C
11:00	Buen tiempo	11 °C
12:00	Buen tiempo	12 °C
13:00	Buen tiempo	13 °C
14:00	Dust Storm	14 °C
15:00	Dust Storm Despejado	15 °C
16:00	Dust Storm Despejado	15 °C
17:00	Dust Storm Despejado	14 °C
18:00	Buen tiempo	11 °C

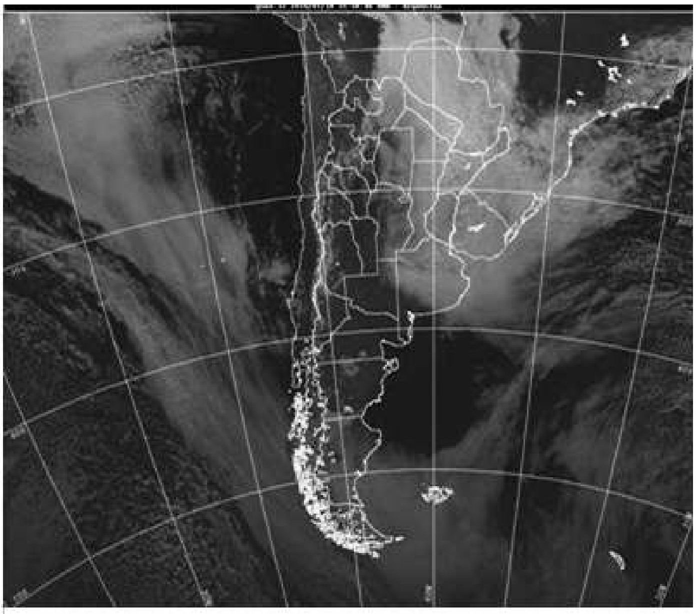


- Coverage made: No flights for this day, unfavourable weather conditions due to strong wind gusts recorded in the study area

Day 18/07/2010

- Weather Report

Global Weather: Clear.

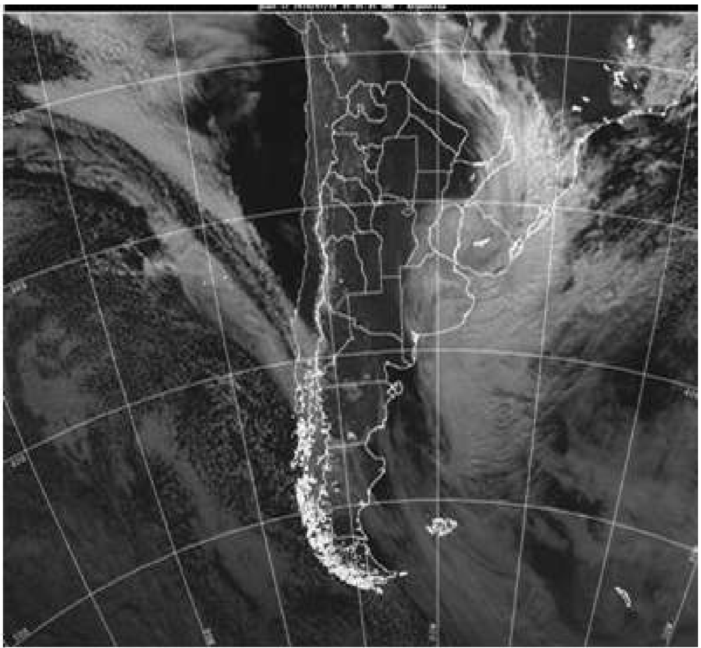


- Coverage made: No flights for this day. Flight team had other commitments previously to the project acquired for this particular day.

Day 19/07/2010

- Weather Report.

Global Weather: Clear



Coverage made: No flights for this day. Flight Team restarts mobilization towards the study area because the previous day had to make other prior commitments outside the designated area for flying in the city of Calama. On Tuesday is expected to start scheduled flights if weather conditions permit

Day 20/07/2010

- Weather Report

Global Weather: Clear with dust Storm.

TAF del 20/07/2010 a las 15:50 UTC
Periodo de validés: desde el 20 a las 18:00 UTC hasta las 18:00 UTC del 21
Viento Dirección: 300 grados, Velocidad: 20 Nudos
CAVOK: Visibilidad 10 km o más, sin nubes bajo los 5.000 pies o bajo el MSA (el cual es mayor) no cúmulos,y sin fenómenos significativos de tiempo el aeródromo o sus cercanías
Temperatura máxima: 18°C a las 2018:00 UTC
TNM04/2110Z
De vez en cuando entre las 18:00 y las 22:00:
Viento Dirección: 300 grados, Velocidad: 20 Nudos, con ráfagas de velocidad máxima de 30Nudos
Visibilidad 3000 metros
Tormenta de polvo
Despejado

***Source: General Direction of Civil Aeronautics – DGAC according to TAF of the Airport of The Loa, date 20 -07 - 2010.*

Coverage made: No flights for this day. Adverse weather conditions do not allow flights in the area of study. There are strong wind gusts that are reaching to have picks of 40 knots and gusts with 30 knots of velocity so the planned flight that is dated July 20 is suspended pending to improve weather conditions in the area.

Day 21/07/2010

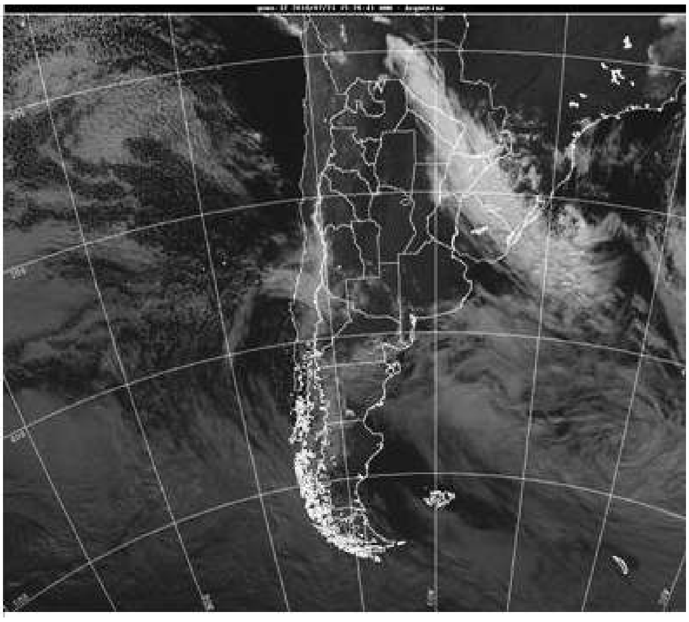
- Weather Report

Global Report: Clear.

Historial meteorológico hora a hora para CALAMA/EL LOA & a 4 Km. de Calama.
Elevación: 2270m. (mapa)

miércoles 21 jul | Más estaciones: CALAMA/EL LOA &

Hora local	Tiempo		Temp.
8:00		Buen tiempo	-3 °C
9:00		Buen tiempo	-5 °C
10:00		Buen tiempo	6 °C
11:00		Buen tiempo	9 °C
12:00		Buen tiempo	11 °C
13:00		Buen tiempo	14 °C
14:00		Buen tiempo	14 °C
15:00		Buen tiempo	15 °C
16:00		Buen tiempo	15 °C



TAF del 21/07/2010 a las 15:30 UTC
Período de validés: desde el 21 a las 18:00 UTC hasta las 18:00 UTC del 22
Viento Dirección: 250 grados, Velocidad: 20 Nudos
CAVOK: Visibilidad 10 km o más, sin nubes bajo los 5.000 pies o bajo el MSA (el cual es mayor) no cúmulos,y sin fenómenos significativos de tiempo el aeródromo o sus cercanías
Temperatura máxima: 18ºC a las 2118:00 UTC
TNM05/2210Z
Entre las 18:00 y las 22:00 (de vez en cuando), hay 30% de probabilidad de que:
Viento Dirección: 270 grados, Velocidad: 25 Nudos, con ráfagas de velocidad máxima de 35Nudos
Visibilidad 5000 metros
Tormenta de polvo
Despejado

***Source: General Direction of Civil Aeronautics – DGAC according to TAF of the Airport of The Loa, date 21 -07 - 2010.*

Coverage made: Laser flight makes for the entire area of study in this day 21 July. Flight for Camera must be done the next day because the weather in the afternoon are less appropriate due to the increasing wind gusts that have occurred in recent days in city of Calama.

Day 22/07/2010

- Weather Report

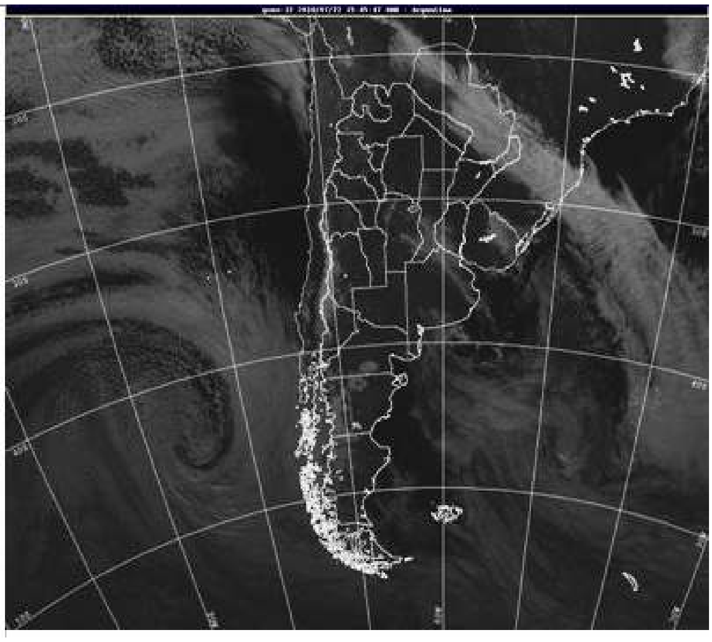
Global Weather: Clear.

Historial meteorológico hora a hora para CALAMA/EL LOA &
Calama.
Elevación: 2270m. [mapa]

jueves 22 jul

Más estaciones: CALAMA/EL LOA &

Hora local	Tiempo	Temp.
8:00	Buen tiempo	-5 °C
9:00	Buen tiempo	-5 °C
10:00	Buen tiempo	-3 °C
11:00	Buen tiempo	10 °C
12:00	Buen tiempo	15 °C
13:00	Buen tiempo	16 °C
14:00	Buen tiempo	18 °C
15:00	Buen tiempo	16 °C
16:00	Buen tiempo	15 °C
17:00	Buen tiempo	15 °C



TAF del 22/07/2010 a las 15:40 UTC
Período de validés: desde el 22 a las 18:00 UTC hasta las 18:00 UTC del 23
Viento Dirección: 340 grados, Velocidad: 25 Nudos
CAVOK: Visibilidad 10 km o más, sin nubes bajo los 5.000 pies o bajo el MSA (el cual es mayor) no cúmulos, y sin fenómenos significativos de tiempo el aeródromo o sus cercanías
Temperatura máxima: 18ºC a las 2218:00 UTC
TNM02/2310Z
De vez en cuando entre las 18:00 y las 22:00:
Viento Dirección: 340 grados, Velocidad: 25 Nudos, con ráfagas de velocidad máxima de 35Nudos
Entre las 00:00 y las 02:00 cambiará a:
Viento Dirección: 090 grados, Velocidad: 15 Nudos
Entre las 14:00 y las 16:00 cambiará a:
Viento Dirección: 340 grados, Velocidad: 20 Nudos

*** Source: General Direction of Civil Aeronautics – DGAC according to TAF of the Airport of The Loa, date 22 -07 - 2010.*

Coverage made: Flight camera is made for the entire study area in this day. It ends the data collection for both laser and camera.

Coverage of Laser and Images made.

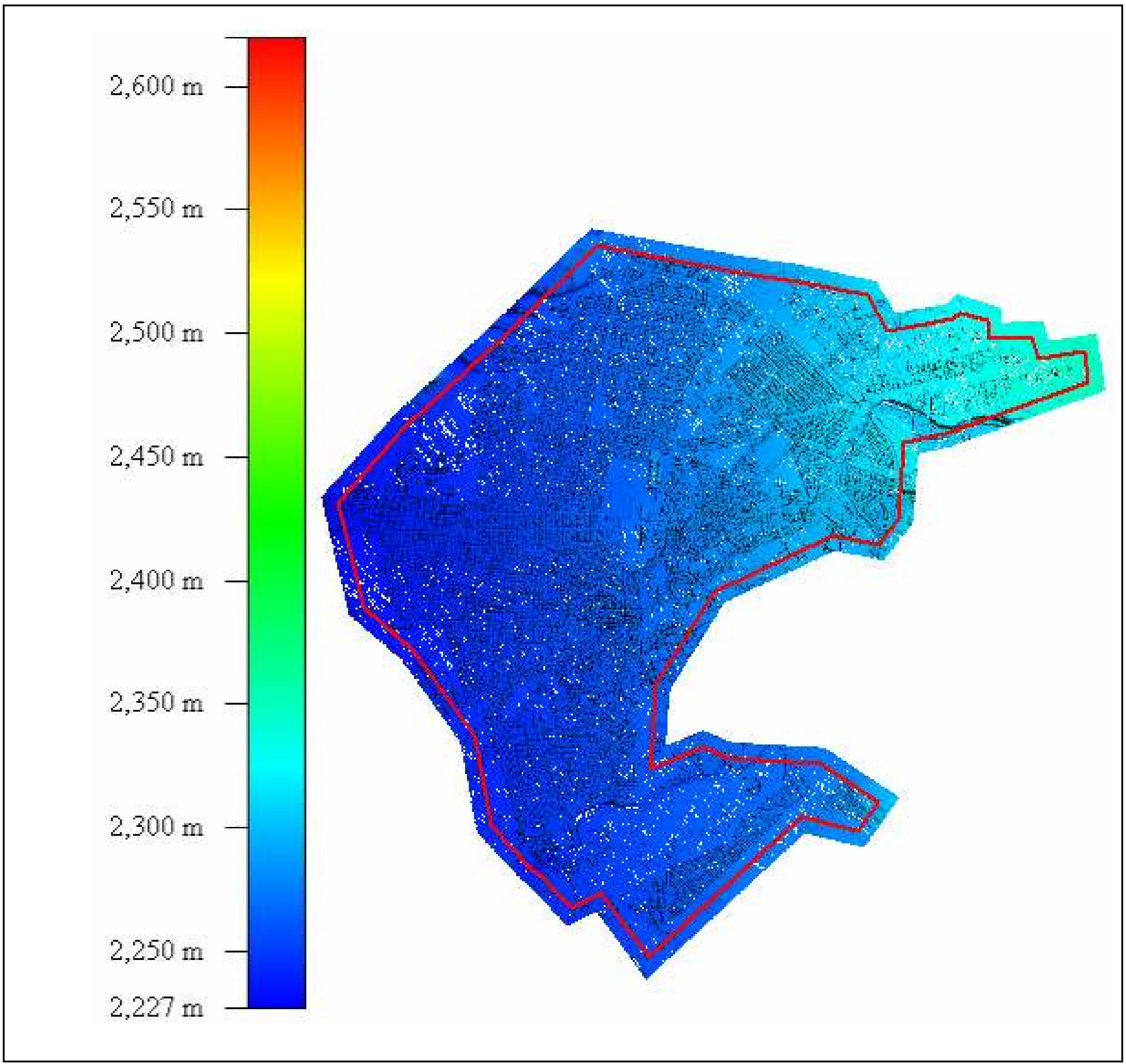
Flight Code: Boot 1279(L) - 1280(L+VIS) - 1281(L+VIS)

Hectares Covered: Total area 2881 (ha), (Surface includes areas of overlap),
Total area of Polygon Project 2500 (ha)

Lines Flown: Laser: 28 lines; Camera: 14 lines (272 images)

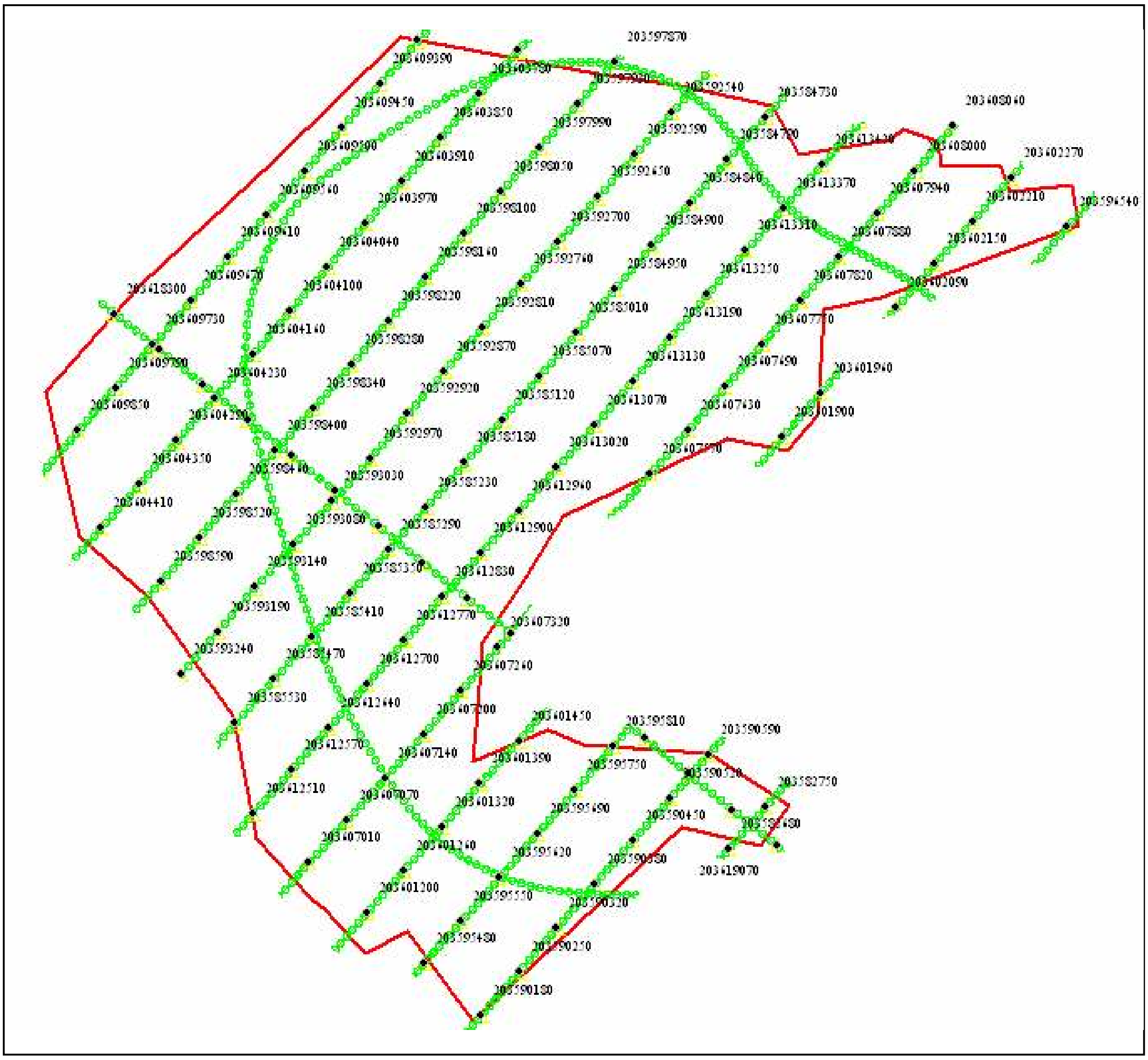
Laser Coverage:

28 lines



Camera Coverage

14 lines (272 images)



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Santiago, 06. 08. 2010

Project: 36_1003_Calama3

Solar Information for Renewable Energy Project

Solar Radiation Information

According to the project “Renewable Energies Chile”, which is in actual progress, Digimapas Chile has mad a research and hence after a data collection from several specialized institutions, to fulfil the requirement of supporting the project with solar potential long term measurements near the city of Calama, Chile.

One can find below three different types of information, which covers a range of years, starting from 1961 until 2010 approximately:

- Global solar radiation incident on a horizontal surface
- Diffuse solar radiation incident on a horizontal surface
- Direct Solar Radiation

Measurements that will be represented through monthly and annual averages across the range of years.

The data was retrieved from 3 different sources for better understanding and handling.

Specifications and Features of the Data:

GROUP I

These data correspond to solar measurement stations located in the north of Chile near the city of Calama. These stations have been installed by GTZ to support the Ministry of Energy of Chile and are operational since 2008. For this project we have considered two stations near the study area. The records were obtained from August 2008 until February 2010.

- **POZO ALMONTE METEOSTATION**

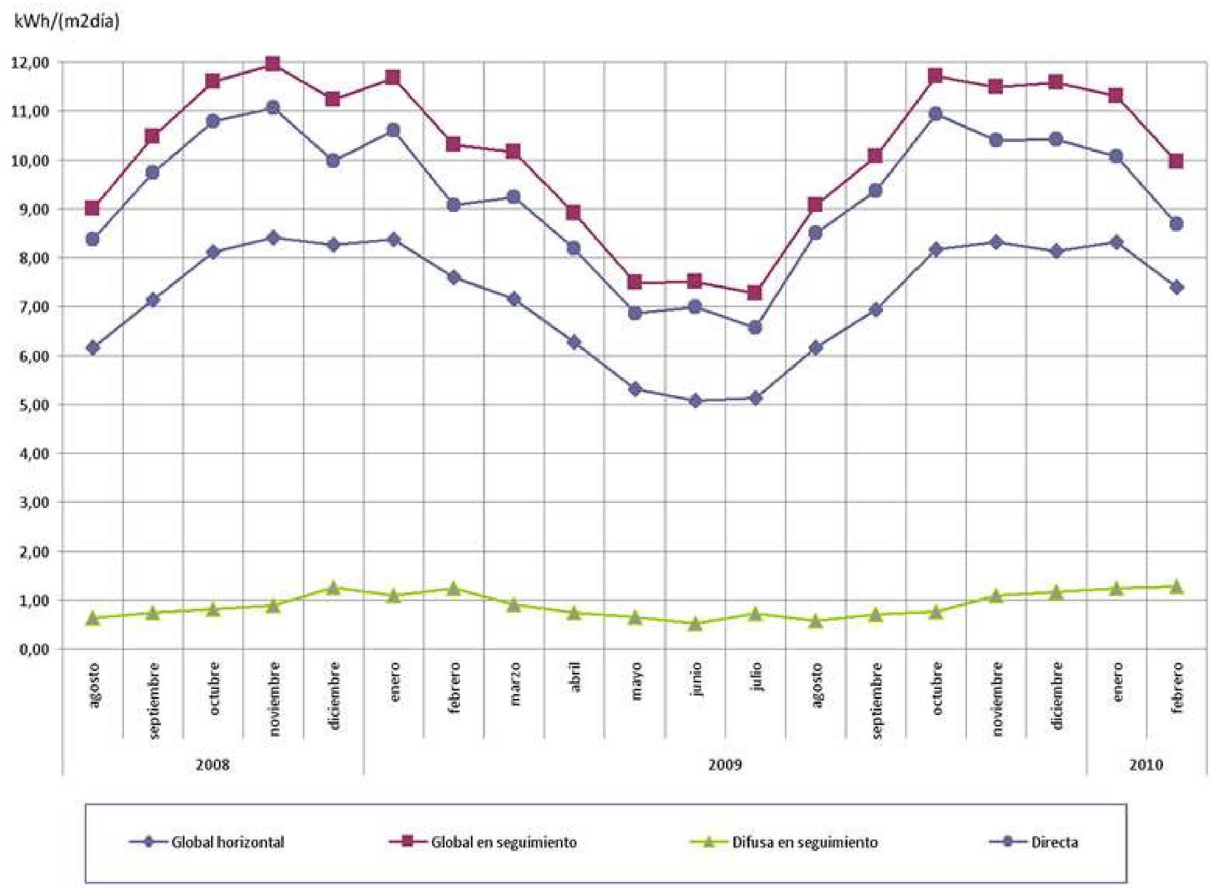
Location Meteostation Pozo Almonte, Chile.

Reference: Google Earth

Characteristics of the measurements:

1. Time Range: August 2008 to February 2010 (average monthly and annual)
2. Types of Solar Measurement: Global Solar Radiation on a horizontal surface; Diffuse Solar Radiation and Direct Solar Radiation.
3. Measurement unit: KWh/m2 day.
4. Data presentation: Graphical and statistical tables.

Graphic representation for years 2008, 2009 and 2010



STATISTICS FROM POZO ALMONTE METEOSTATION

		Solar Radiation [kWh/m²day]			
		Global horizontal	Global Monitoring	Diffuse Monitoring	Direct
2008	August	6,15	8,99	0,62	8,37
	September	7,14	10,47	0,73	9,74
	October	8,11	11,6	0,81	10,79
	November	8,41	11,95	0,88	11,06
	December	8,26	11,22	1,25	9,97
2009	January	8,37	11,67	1,08	10,59
	February	7,6	10,3	1,23	9,06
	March	7,16	10,15	0,91	9,24
	April	6,26	8,91	0,73	8,18
	May	5,31	7,49	0,64	6,85
	June	5,07	7,5	0,51	6,99
	July	5,13	7,27	0,72	6,56
	August	6,16	9,07	0,57	8,5
	September	6,94	10,06	0,7	9,36
	October	8,16	11,7	0,75	10,94
	November	8,31	11,48	1,09	10,39
	December	8,12	11,58	1,17	10,41

Average 2009	**6,88**	**9,77**	**0,84**	**8,92**

2010	January	8,31	11,3	1,24	10,06
	February	7,4	9,96	1,28	8,68

Average 2010	**7,18**	**10,14**	**0,89**	**9,25**
Maximum	8,41	11,95	1,25	11,06
Minimum	5,07	7,27	0,51	6,56

- **SAN PEDRO METEOSTATION**

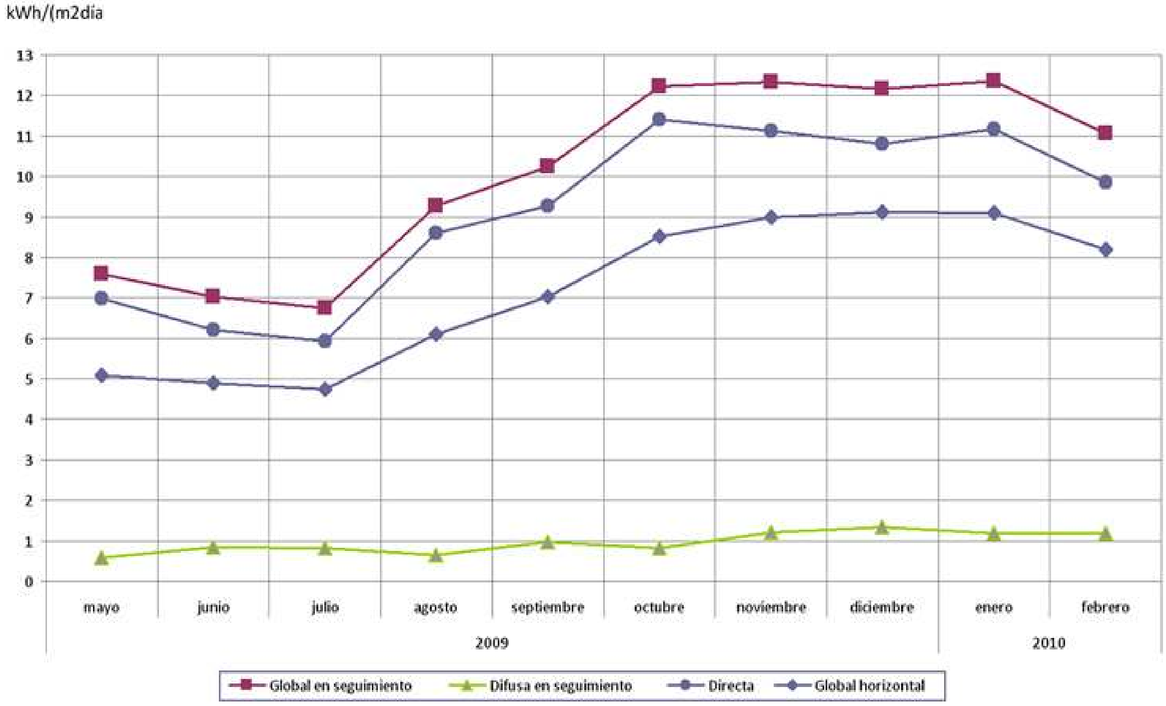
Location Meteostation San Pedro, Chile

Reference: Google Earth

Characteristics of the measurements:

1. Time Range: May 2009 to February 2010 (average monthly and annual)
2. Types of Solar Measurement: Global Solar Radiation on a horizontal surface; Diffuse Solar Radiation and Direct Solar Radiation.
3. Measurement unit: KWh/m2 day.
4. Data presentation: Graphical and statistical tables.

Graphic representation for years 2009 and 2010



STATISTICS FROM SAN PEDRO METEOSTATION

		Solar Radiation [kWh/m²day]			
		Global horizontal	**Global Monitoring**	**Difusse Monitoring**	**Direct**
2009	**May**	5,10	7,58	0,59	6,99
	June	4,90	7,03	0,83	6,20
	July	4,74	6,75	0,82	5,93
	August	6,10	9,26	0,65	8,61
	September	7,04	10,24	0,96	9,28
	October	8,51	12,23	0,83	11,40
	November	8,99	12,33	1,21	11,12
	December	9,12	12,16	1,34	10,81
2010	**January**	9,10	12,35	1,18	11,17
	February	8,19	11,05	1,19	9,86

Average	**7,18**	**10,10**	**0,96**	**9,14**
Maximum	9,12	12,35	1,34	11,4
Minimum	4,74	6,75	0,59	5,93

GROUP II

These data correspond to measurements made by the Atmospheric Science Data Center of NASA as part of its support for the development of Renewable Energy. These data have been obtained through more than 200 meteorological and solar energy parameters derived from Satellites (ref. Dr. Paul W. Stackhouse and Dr. Charles H. Whitlock)

Location Calama Chile, Longitude and latitude used for data collection

Reference: Google Earth.

Characteristics of the measurements:

1. Time Range: 22 years (Jul 1983 - Jun 2005) monthly and annual average for this period.
2. Types of Solar Measurement: Global Solar Radiation on a horizontal surface; Diffuse Solar Radiation and Direct Solar Radiation.
3. Measurement unit: KWh/m2 day.
4. Data presentation: Statistical tables.

Table I.

Monthly Averaged Insolation Incident on a Horizontal Surface (*22-year* Average*)*

The monthly average amount of the total solar radiation incident on a horizontal surface at the surface of the earth for a given month, averaged for that month over the 22-year period (Jul 1983 - Jun 2005). Each monthly averaged value is evaluated as the numerical average of 3-hourly values for the given month.

Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m^2/day)													
Lat. -22 Lon -68	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	7.33	7.16	6.70	6.23	5.37	4.84	5.09	5.87	7.07	7.97	8.53	8.19	**6.69**

Table II

Minimum and Maximum Difference from Monthly Averaged Insolation

The minimum and maximum values for a given month indicate the percent difference between the year that has the least (minimum) or most (maximum) monthly averaged insolation and the 22-year monthly averaged insolation.

Minimum And Maximum Difference From Monthly Averaged Insolation (%)												
Lat -22 Lon -68	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	-17	-18	-14	-7	-6	-16	-13	-13	-10	-9	-21	-15
Maximum	14	16	11	6	7	7	5	5	6	7	9	9

Table III

Monthly Averaged Direct Normal Radiation (*22-year Average)*

The monthly average amount of solar radiation incident on a surface oriented normal to the solar radiation for a given month, averaged for that month over the 22-year period (Jul 1983 - Jun 2005).

Monthly Averaged Direct Normal Radiation (kWh/m^2/day)													
Lat -22 Lon -68	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	7.36	7.54	7.76	8.70	8.68	8.37	8.57	8.73	9.46	9.77	10.0	9.06	**8.68**

Table IV

Minimum and Maximum Difference from Monthly Averaged Direct Normal Radiation

The minimum and maximum values for a given month indicate the percent difference between the year that has the least (minimum) or most (maximum) monthly averaged direct normal radiation and the 22-year monthly averaged value.

Minimum And Maximum Difference From Monthly Averaged Direct Normal Radiation (%)												
Lat -22 Lon -68	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	-14	-14	-11	-3	n/a	-12	-10	-11	n/a	n/a	n/a	-13
Maximum	13	14	7	3	4	-1	-1	-1	1	3	0	4

Table V

Monthly Averaged Diffuse Radiation Incident on a Horizontal Surface (***22-year Average)***
The monthly average amount of solar radiation incident on a horizontal surface at the surface of the earth under all-sky conditions with the direct radiation from the sun's beam blocked by a shadow band or tracking disk for a given month, averaged for that month over the 22-year period (Jul 1983 - Jun 2005).

Monthly Averaged Diffuse Radiation Incident On A Horizontal Surface (kWh/m^2/day)													
Lat -22 Lon -68	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	2.19	1.93	1.53	0.94	0.66	0.60	0.61	0.79	0.95	1.25	1.49	1.88	**1.23**
Minimum	1.74	1.37	1.15	0.71	n/a	0.37	0.44	0.59	n/a	n/a	n/a	1.49	**n/a**
Maximum	2.52	2.33	1.89	1.17	0.85	0.99	0.95	1.20	1.33	1.61	2.26	2.36	**1.62**
22-year Average K	0.62	0.64	0.67	0.73	0.75	0.74	0.75	0.74	0.75	0.75	0.74	0.69	**0.71**
Minimum K	0.52	0.52	0.57	0.68	0.70	0.62	0.65	0.64	0.68	0.68	0.59	0.59	**0.62**
Maximum K	0.71	0.74	0.74	0.77	0.80	0.79	0.78	0.78	0.80	0.80	0.81	0.75	**0.77**

NOTE:	*Diffuse radiation, direct normal radiation and tilted surface radiation are not calculated when the clearness index (K) is below 0.3 or above 0.8.*

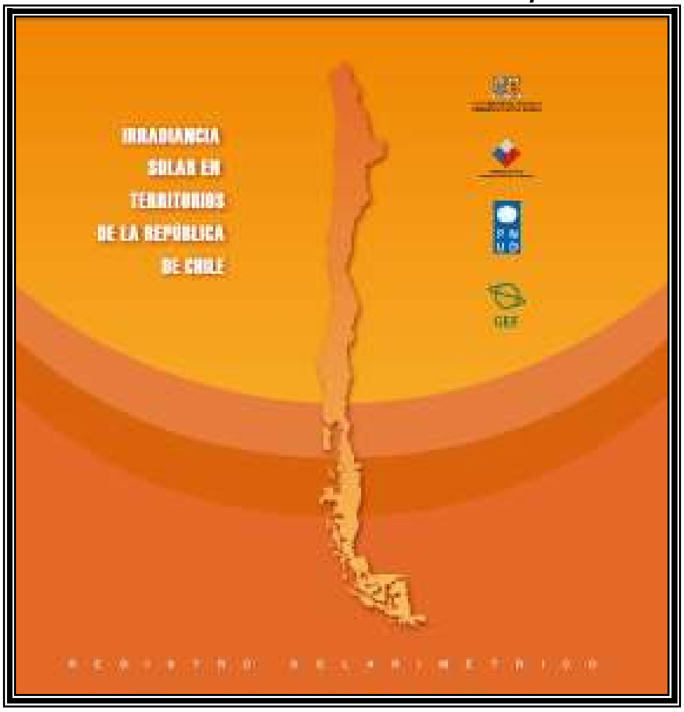
Group III

This information has been gathered over an extensive range of years, thanks to the cooperation of various educational institutions, government and research, an extensive study under the direction of Professor Pedro Sarmiento M. (Technical University Federico Santa Maria) which gathers more than 40 years of global solar radiation Measurements in horizontal plane, incorporating more than 100 measurement points throughout Chile.

The data presented here are originated in the Laboratory of Solar Energy and Evaluation of the Technical University Federico Santa Maria, Founded in 1960 by Professor of the Faculty of Mechanics of the time, Julio R. Hirschmann, and covers roughly from the years 1961-1995 approximately.

The study, whose full results are described in a book called "Solar Irradiance in Territories of the Republic of Chile" was published by the National Energy Commission of Chile, the United Nations Programme for Development, Global Environment Facility and the Technical University Federico Santa Maria

Front “Solar Irradiance in Territories of the Republic of Chile"



Characteristics of the measurements:

1. Time Range: 1961-1995 approximately, monthly and annual average for this period.
2. Types of Solar Measurement: Global Solar Radiation on a horizontal surface; Diffuse Solar Radiation and Global Solar Radiation in different inclinations and azimuth.
3. Measurement unit: KWh/m^2, MJ/m^2
4. Data presentation: Statistical tables.

Digimapas Chile

SOLARIMETRIC RECORD CALAMA

Study under the direction of Professor Pedro Sarmiento M. (Technical University Federico Santa Maria) which gathers more than 40 years of global solar radiation measurements in horizontal plane, incorporating more than 100 measurement points throughout Chile.

The data presented here originate in the Laboratory of Solar Energy and Evaluation of the Technical University Federico Santa Maria, founded in 1960 by Professor of the Faculty of Mechanics of the time, Julio R. Hirschmann thereafter by the teachers Adolfo Arata A. and Pedro Roth U. and now, by Professor of the Department of Mechanics, Pedro Sarmiento M.

TABLE A

MONTHLY AND ANNUAL GLOBAL IRRADIATION IN HORIZONTAL PLANE FOR DIFFERENT LOCATIONS OF CHILE WITH UNITS MJ/m2

LOCALIDAD	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC	ANUAL
II Región													
QUILLAGUA	696,6	618,8	650,4	516,2	458,1	371,5	418,1	518,9	591,8	718,6	709,9	757,4	7026,4
PARSHALL-2	752,1	663,4	697,8	578,3	535,3	467,7	509,5	599,5	696,5	799,2	834,0	873,2	8006,3
TOCOPILLA	604,0	540,8	499,5	420,8	352,9	281,5	261,3	372,7	479,2	598,0	586,9	623,2	5620,5
CHUQUICAMATA	858,4	648,2	675,7	555,0	460,9	431,9	469,4	639,8	628,4	772,3	809,7	856,7	7806,5
EL TATIO	733,9	663,0	789,1	637,2	574,8	484,2	581,8	664,1	732,5	889,0	887,4	877,6	8514,3
COYA SUR	798,9	668,9	663,3	560,6	448,8	398,5	460,1	536,9	627,2	739,3	752,1	808,8	7463,4
CALAMA ●	841,6	716,0	710,9	578,3	525,4	450,0	502,1	612,3	669,1	821,8	851,4	899,3	8178,1
SAN PEDRO DE ATACAMA	809,8	673,5	734,7	602,6	497,0	451,3	495,8	575,5	691,2	810,0	859,6	898,3	8099,4
ANTOFAGASTA	739,0	618,5	627,7	483,2	368,8	336,2	369,2	433,4	524,3	653,4	710,8	772,3	6636,6
TALTAL	728,3	579,8	533,0	432,7	347,7	340,9	326,2	370,7	456,8	602,8	624,2	763,1	6106,2
EL SALVADOR	876,7	731,6	711,4	558,4	426,7	382,2	442,1	511,3	639,1	793,1	812,0	876,4	7760,9

** NOTE: ***1 (MJ) = 0, 2777 (Kwh.),*** City of Calama is the marked with a circle in the List.
** These Values are a monthly Average for a period between year 1961 and 1995 approximately and in the final column in the table is the annual value.

TABLE B

MONTHLY AND ANNUAL GLOBAL IRRADIATION IN DIFFERENTS INCLINATIONS AND AZIMUTH WITH UNITS MJ/m2 (CALAMA)

LOCALIDAD: CALAMA
LATITUD: 22,46 [GRADOS] SUR

Az	INCL	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC	ANUAL
180 al Norte	12	812,5	733,1	728,8	618,1	588,3	514,7	569,7	670,4	697,0	822,0	464,5	860,1	8079,1
	22	764,4	707,6	730,1	643,6	637,1	566,8	623,4	711,8	709,0	803,0	446,0	801,4	8144,3
	32	700,3	666,0	714,4	653,7	670,3	605,1	661,8	735,9	703,8	765,4	419,6	724,5	8020,7
	42	620,2	609,9	682,2	648,4	686,7	628,2	683,7	741,7	681,8	709,3	386,0	631,5	7709,5
	90	205,1	222,4	326,2	411,5	519,1	509,4	537,7	507,3	363,7	263,4	184,6	200,7	4251,1
150	12	809,5	729,9	714,1	605,4	576,2	504,6	558,0	655,7	682,3	812,6	463,7	857,4	7969,4
	22	759,6	701,3	700,9	618,7	613,3	547,2	600,9	682,8	679,6	784,2	444,4	795,3	7928,3
	32	692,5	657,1	671,5	617,3	635,1	576,3	628,4	693,6	661,1	737,9	417,2	715,7	7703,8
	42	623,2	582,6	627,3	601,8	641,8	591,2	640,5	686,6	627,4	660,5	384,4	645,0	7312,4
	90	347,8	350,0	412,9	409,9	441,4	452,2	470,9	448,5	414,2	418,6	239,3	322,0	4727,6
120	12	813,1	727,8	696,0	583,8	548,9	478,8	529,9	627,2	662,2	802,6	464,3	862,1	7796,6
	22	765,6	697,1	665,6	575,8	559,0	495,9	545,0	626,8	639,4	764,8	445,8	805,4	7586,3
	32	716,5	635,1	641,8	558,9	556,3	501,4	547,3	612,9	618,0	711,0	417,0	795,0	7311,1
	42	712,0	657,7	676,2	567,9	502,7	444,4	489,2	591,2	657,8	745,0	413,7	747,3	7205,1
	90	577,5	522,8	519,3	437,7	414,8	359,0	400,3	478,9	498,5	592,5	310,4	615,4	5727,0
90	12	820,9	726,8	679,9	558,9	513,3	443,4	492,7	592,6	641,1	795,7	466,5	874,3	7606,1
	22	781,8	695,0	633,8	526,4	489,5	426,9	471,8	559,4	598,8	750,4	449,8	829,2	7212,8
	32	737,5	646,1	647,8	516,0	464,9	408,5	450,1	527,5	623,4	721,6	421,0	837,0	7001,4
	42	757,0	674,5	610,1	529,9	507,4	379,0	462,2	578,9	586,7	724,3	428,9	798,2	7037,1
	90	677,7	619,4	470,9	411,1	407,4	365,5	400,3	454,7	455,8	634,5	349,9	719,8	5966,9
0 al Sur	12	850,9	733,1	676,3	525,0	449,7	374,8	422,5	539,4	625,0	801,3	474,3	916,3	7388,5
	22	840,6	707,6	626,2	459,8	364,2	291,2	333,2	454,1	566,9	762,3	465,5	911,8	6783,4
	32	810,6	666,0	562,1	384,9	271,2	213,6	240,6	359,0	496,0	705,3	448,0	885,8	6043,3
	42	763,0	609,9	486,6	302,8	196,2	153,3	172,7	260,9	415,2	633,0	422,5	838,8	5255,0
	90	236,9	239,7	174,9	142,7	120,0	106,5	113,5	130,0	156,5	215,8	203,8	200,7	2041,1

TABLE C

MONTHLY AND ANNUAL GLOBAL IRRADIATION IN DIFFERENTS INCLINATIONS AND AZIMUTH WITH UNITS Kwh/m2 (CALAMA)

LOCALIDAD: CALAMA
LATITUD: 22,46 [GRADOS] SUR

Az	INCL	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC	ANUAL
180 al Norte	12	225,6	203,6	202,4	171,6	163,4	142,9	158,2	186,2	193,6	228,3	129,0	238,8	2243,6
	22	212,3	196,5	202,7	178,7	176,9	157,4	173,1	197,7	196,9	223,0	123,9	222,5	2261,7
	32	194,5	184,9	198,4	181,5	186,1	168,0	183,8	204,4	195,4	212,6	116,5	201,2	2227,3
	42	172,2	169,4	189,4	180,1	190,7	174,5	189,9	206,0	189,3	197,0	107,2	175,4	2140,9
	90	57,0	61,8	90,6	114,3	144,2	141,5	149,3	140,9	101,0	73,1	51,3	55,7	1180,5
150	12	224,8	202,7	198,3	168,1	160,0	140,1	155,0	182,1	189,5	225,7	128,8	238,1	2213,1
	22	210,9	194,8	194,6	171,8	170,3	152,0	166,9	189,6	188,7	217,8	123,4	220,9	2201,7
	32	192,3	182,5	186,5	171,4	176,4	160,0	174,5	192,6	183,6	204,9	115,9	198,7	2139,3
	42	173,1	161,8	174,2	167,1	178,2	164,2	177,9	190,7	174,2	183,4	106,7	179,1	2030,7
	90	96,6	97,2	114,7	113,8	122,6	125,6	130,8	124,5	115,0	116,2	66,5	89,4	1312,9
120	12	225,8	202,1	193,3	162,1	152,4	133,0	147,2	174,2	183,9	222,9	128,9	239,4	2165,1
	22	212,6	193,6	184,8	159,9	155,2	137,7	151,3	174,1	177,6	212,4	123,8	223,7	2106,7
	32	199,0	176,4	178,2	155,2	154,5	139,2	152,0	170,2	171,6	197,4	115,8	220,8	2030,3
	42	197,7	182,6	187,8	157,7	139,6	123,4	135,9	164,2	182,7	206,9	114,9	207,5	2000,9
	90	160,4	145,2	144,2	121,5	115,2	99,7	111,2	133,0	138,4	164,5	86,2	170,9	1590,4
90	12	228,0	201,8	188,8	155,2	142,5	123,1	136,8	164,6	178,0	221,0	129,5	242,8	2112,2
	22	217,1	193,0	176,0	146,2	135,9	118,6	131,0	155,3	166,3	208,4	124,9	230,3	2003,0
	32	204,8	179,4	179,9	143,3	129,1	113,4	125,0	146,5	173,1	200,4	116,9	232,4	1944,3
	42	210,2	187,3	169,4	147,2	140,9	105,2	128,4	160,8	162,9	201,1	119,1	221,7	1954,2
	90	188,2	172,0	130,8	114,2	113,1	101,5	111,2	126,3	126,6	176,2	97,2	199,9	1657,0
0 al Sur	12	236,3	203,6	187,8	145,8	124,9	104,1	117,3	149,8	173,6	222,5	131,7	254,5	2051,8
	22	233,4	196,5	173,9	127,7	101,1	80,9	92,5	126,1	157,4	211,7	129,3	253,2	1883,8
	32	225,1	184,9	156,1	106,9	75,3	59,3	66,8	99,7	137,7	195,9	124,4	246,0	1678,2
	42	211,9	169,4	135,1	84,1	54,5	42,6	48,0	72,5	115,3	175,8	117,3	232,9	1459,3
	90	65,8	66,6	48,6	39,6	33,3	29,6	31,5	36,1	43,5	59,9	56,6	55,7	566,8

TABLE D

TABLE OF RADIATION TOTAL TIME, AVERAGE MONTHLY FOR DIFFERENT DIRECTIONS (AZIMUTH, AZ) AND SLOPES SURFACE WITH UNIT W/m2 (CALAMA)

LOCALIDAD: CALAMA
LATITUD: 22,47 [GRADOS] SUR

AZ	INCL	ENERO HORA SOLAR 6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL		89,9	267,3	466,6	663,9	831,6	944,4	984,1	944,4	831,6	663,9	466,6	267,3	89,9
180	12	71,6	243,6	441,3	441,0	813,1	929,6	970,8	929,6	813,1	641,0	441,3	243,6	71,6
al	22	55,2	218,7	409,6	605,1	775,3	891,1	932,2	891,1	775,2	605,1	409,6	218,7	55,2
NORTE	32	53,0	189,7	369,0	554,9	718,3	830,2	870,0	830,2	718,3	554,9	369,0	189,7	53,0
	90	36,9	88,5	121,1	137,3	145,4	162,4	175,1	162,4	145,4	137,3	121,1	88,5	36,9
-135 NO	90	36,9	88,5	121,1	137,3	145,4	150,2	168,3	305,5	397,4	425,0	380,8	275,9	143,2
135 NE	90	143,2	275,9	380,8	425,0	397,4	305,5	168,3	150,2	145,4	137,3	121,1	88,5	36,9
-90 O	90	36,9	88,5	121,1	137,3	145,4	150,2	151,9	357,7	518,9	598,8	573,4	448,7	269,6
90 E	90	269,6	448,7	573,4	598,8	518,9	357,7	151,9	150,2	145,4	137,3	121,1	88,5	36,9
-45 SO	90	36,9	88,5	121,1	137,3	145,4	150,2	151,9	288,2	421,6	502,3	501,0	410,4	259,7
45 SE	90	259,7	410,4	501,0	502,3	421,6	288,2	151,9	150,2	145,4	137,3	121,1	88,5	36,9
0 SUR	90	119,3	183,6	206,1	191,9	162,5	150,2	151,9	150,2	162,5	191,9	206,1	183,6	119,3

AZ	INCL	FEBRERO HORA SOLAR 6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL		54,0	228,3	428,0	628,3	799,9	915,8	956,8	915,8	799,9	628,3	428,0	228,3	54,0
180	12	44,3	216,8	418,8	625,2	804,0	925,5	968,5	925,5	804,0	625,2	418,8	216,8	44,3
al	22	35,5	202,6	401,1	606,2	785,4	907,5	950,8	907,5	785,3	606,2	401,1	202,6	35,5
NORTE	32	34,1	184,7	374,7	572,9	747,2	866,5	908,9	866,5	747,2	572,9	374,7	184,7	34,1
	90	23,4	80,1	117,1	172,1	232,4	275,4	291,1	275,4	232,4	172,0	117,1	80,1	23,4
-135 NO	90	23,4	80,1	117,1	135,3	143,8	148,4	249,8	387,9	473,9	487,0	419,8	288,9	136,0
135 NE	90	136,0	288,9	419,8	487,0	473,9	387,9	249,8	148,4	143,8	135,3	117,1	80,1	23,4
-90 O	90	23,4	80,1	117,1	135,3	143,8	148,4	150,1	360,1	522,1	596,0	556,8	415,3	226,0
90 E	90	226,0	415,3	556,8	596,0	522,1	360,1	150,1	148,4	143,8	135,3	117,1	80,1	23,4
-45 SO	90	23,4	80,1	117,1	135,3	143,8	148,4	150,1	208,3	348,6	435,1	436,2	345,3	197,3
45 SE	90	197,3	345,3	436,2	435,1	348,6	208,3	150,1	148,4	143,8	135,3	117,1	80,1	23,4
0 SUR	90	66,7	120,0	128,6	135,3	143,8	148,4	150,1	148,4	143,8	135,3	128,6	120,0	66,7

AZ	INCL	MARZO HORA SOLAR 6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL		9,8	174,0	367,6	565,0	736,1	852,4	893,6	852,4	736,1	565,0	367,6	174,0	9,8
180	12	8,3	175,3	376,7	585,6	768,1	892,5	936,5	892,5	768,1	585,6	376,7	175,3	8,3
al	22	7,0	172,8	375,4	587,5	773,7	900,8	945,9	900,8	773,7	587,5	375,4	172,8	7,0
NORTE	32	6,7	166,9	365,8	575,4	760,0	886,1	930,9	886,1	760,0	575,4	365,8	166,9	6,7
	90	4,5	83,2	178,4	272,5	353,4	408,7	428,4	408,7	353,4	272,5	178,4	83,2	4,5
-135 NO	90	4,5	65,3	107,0	127,6	136,6	181,3	344,7	479,4	554,0	545,5	448,0	286,5	114,5
135 NE	90	114,5	286,5	448,0	545,5	554,0	479,4	344,7	181,3	136,6	127,6	107,0	65,3	4,5
-90 O	90	4,5	65,3	107,0	127,6	136,6	141,1	142,7	351,9	510,0	573,7	517,9	360,3	166,6
90 E	90	166,6	360,3	517,9	573,7	510,0	351,9	142,7	141,1	136,6	127,6	107,0	65,3	4,5
-45 SO	90	4,5	65,3	107,0	127,6	136,6	141,1	142,7	141,1	247,3	340,6	347,0	261,3	123,8
45 SE	90	123,8	261,3	347,0	340,6	247,3	141,1	142,7	141,1	136,6	127,6	107,0	65,3	4,5
0 SUR	90	11,1	65,3	107,0	127,6	136,6	141,1	142,7	141,1	136,6	127,6	107,0	65,3	11,1

AZ	INCL	ABRIL HORA SOLAR 6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL			111,6	289,2	474,6	637,3	748,8	788,4	748,8	637,3	474,6	289,2	111,6	
180	12		123,1	314,6	517,6	696,7	819,3	862,7	819,3	696,7	517,6	314,6	123,1	
al	22		130,1	328,4	540,0	727,2	855,0	900,3	855,0	727,2	540,0	328,4	130,1	
NORTE	32		134,5	334,8	549,5	739,2	868,6	914,4	868,6	739,2	549,5	334,8	134,5	
	90		107,3	233,3	358,2	462,5	531,4	555,5	531,4	462,5	358,2	233,3	107,3	
-135 NO	90		45,0	90,2	113,2	122,7	270,9	430,5	555,1	611,9	576,8	447,1	259,0	
135 NE	90		259,0	447,1	576,8	611,9	555,1	430,5	270,9	122,7	113,2	90,2	45,0	
-90 O	90		45,0	90,2	113,2	122,7	127,1	128,6	328,0	474,8	523,9	451,8	285,3	
90 E	90		285,3	451,8	523,9	474,8	328,0	128,6	127,1	122,7	113,2	90,2	45,0	
-45 SO	90		45,0	90,2	113,2	122,7	127,1	128,6	127,1	131,4	230,3	244,7	170,8	
45 SE	90		170,8	244,7	230,3	131,4	127,1	128,6	127,1	122,7	113,2	90,2	45,0	
0 SUR	90		45,0	90,2	113,2	122,7	127,1	128,6	127,1	122,7	113,2	90,2	45,0	

AZ	INCL	MAYO HORA SOLAR 6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL			66,8	235,3	414,9	574,7	684,9	724,2	684,9	574,7	414,9	235,3	66,8	
180	12		87,7	277,9	482,5	663,5	787,1	830,9	797,1	663,5	482,5	277,9	87,7	
al	22		103,1	306,4	525,7	718,7	849,6	895,8	849,6	718,7	525,7	306,4	103,1	
NORTE	32		116,2	327,7	555,6	755,0	889,3	936,6	889,3	755,0	555,6	327,7	116,2	
	90		131,0	290,3	447,0	573,6	654,7	682,6	654,7	573,6	447,0	290,3	131,0	
-135 NO	90		26,1	67,8	87,6	171,9	344,4	513,1	641,1	695,8	649,7	495,3	274,1	
135 NE	90		274,1	495,3	649,7	695,8	641,1	513,1	344,4	171,9	87,6	67,8	26,1	
-90 O	90		26,1	67,8	87,6	96,3	101,7	103,9	311,5	466,8	523,1	449,9	271,9	
90 E	90		271,9	449,9	523,1	466,8	311,5	103,9	101,7	96,3	87,6	67,8	26,1	
-45 SO	90		26,1	67,8	87,6	96,3	101,7	103,9	101,7	96,3	141,5	180,7	125,8	
45 SE	90		125,8	180,7	141,5	96,3	101,7	103,9	101,7	96,3	87,6	67,8	26,1	
0 SUR	90		26,1	67,8	87,6	96,3	101,7	103,9	101,7	96,3	87,6	67,8	26,1	

AZ	INCL	JUNIO HORA SOLAR 6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL			43,3	198,2	365,4	515,2	618,8	655,8	618,8	515,2	365,4	198,2	43,3	
180	12		64,3	242,1	436,0	608,6	726,8	768,8	726,8	608,6	436,0	242,1	64,3	
al	22		80,4	272,7	483,1	669,4	796,0	840,6	796,0	669,4	483,1	272,7	80,4	
NORTE	32		94,6	296,8	518,1	712,6	843,8	890,0	843,8	712,6	518,1	296,8	94,5	
	90		121,9	286,6	451,9	585,7	670,8	699,9	670,8	585,7	451,9	286,6	121,9	
-135 NO	90		17,9	61,2	82,8	199,9	364,7	523,7	640,4	682,1	621,8	456,7	235,8	
135 NE	90		235,8	456,7	621,8	682,1	640,4	523,7	364,7	199,9	82,8	61,2	17,9	
-90 O	90		17,9	61,2	82,8	91,7	96,4	98,2	291,4	432,7	476,0	395,1	222,0	
90 E	90		222,0	395,1	476,0	432,7	291,4	98,2	96,4	91,7	82,8	61,2	17,9	
-45 SO	90		17,9	61,2	82,8	91,7	96,4	98,2	96,4	91,7	99,9	137,9	88,6	
45 SE	90		88,6	137,9	99,9	91,7	96,4	98,2	96,4	91,7	82,8	61,2	17,9	
0 SUR	90		17,9	61,2	82,8	91,7	96,4	98,2	96,4	91,7	82,8	61,2	17,9	

AZ	INCL	JULIO HORA SOLAR 6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL			54,2	218,8	395,4	553,1	662,1	701,0	662,1	553,1	395,4	218,8	54,2	
180	12		77,9	266,4	470,0	650,0	772,9	816,4	772,9	650,0	470,0	266,4	77,9	
al	22		95,7	299,4	519,3	712,2	842,7	888,7	842,7	712,2	519,3	299,4	95,7	
NORTE	32		111,2	325,1	555,2	755,4	889,8	936,9	889,8	755,4	555,2	325,1	111,2	
	90		138,0	307,0	472,0	603,6	687,0	715,5	687,0	603,6	472,0	307,0	138,0	
-135 NO	90		21,0	61,3	80,0	189,0	364,7	534,4	662,4	716,6	668,6	508,5	278,3	
135 NE	90		278,3	508,5	668,6	716,6	662,4	534,4	364,7	189,0	80,0	61,3	21,0	
-90 O	90		21,0	61,3	80,0	88,7	94,7	97,1	305,2	461,8	520,4	448,0	267,9	
90 E	90		267,9	448,0	520,4	461,8	305,2	97,1	94,7	88,7	80,0	61,3	21,0	
-45 SO	90		21,0	61,3	80,0	88,7	94,7	97,1	94,7	88,7	114,3	161,0	112,7	
45 SE	90		112,7	161,0	114,3	88,7	94,7	97,1	94,7	88,7	80,0	61,3	21,0	
0 SUR	90		21,0	61,3	80,0	88,7	94,7	97,1	94,7	88,7	80,0	61,3	21,0	

AZ	INCL	AGOSTO HORA SOLAR 6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL			99,0	287,2	485,3	660,3	780,4	823,2	780,4	660,3	485,3	287,2	99,0	
180	12		121,0	330,5	551,9	745,8	877,7	924,4	877,7	745,8	551,9	330,5	121,0	
al	22		136,4	357,9	591,9	795,5	933,1	981,7	933,1	795,5	591,9	357,9	136,4	
NORTE	32		148,7	376,6	616,5	824,0	963,3	1012,3	963,3	823,9	616,5	376,6	148,7	
	90		146,2	300,3	447,4	566,1	643,0	669,7	643,0	566,1	447,4	300,3	146,2	
-135 NO	90		33,7	69,1	85,1	127,6	318,4	505,0	651,7	728,7	708,5	574,4	352,0	
135 NE	90		352,0	574,4	708,5	728,7	651,7	505,0	318,4	127,6	85,1	69,1	33,7	
-90 O	90		33,7	69,1	85,1	95,2	103,8	107,5	339,5	520,2	604,4	552,6	371,3	
90 E	90		371,3	552,6	604,4	520,2	339,5	107,5	103,8	95,2	85,1	69,1	33,7	
-45 SO	90		33,7	69,1	85,1	95,2	103,8	107,5	103,8	95,2	196,2	247,5	192,9	
45 SE	90		192,9	247,5	196,2	95,2	103,8	107,5	103,8	95,2	85,1	69,1	33,7	
0 SUR	90		33.7	69.1	85.1	95.2	103.8	107.5	103.8	95.2	85.1	69.1	33.7	

AZ	INCL	SEPTIEMBRE HORA SOLAR 6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL			153,8	348,9	549,7	724,6	843,8	886,1	843,8	724,6	549,7	348,9	153,8	
180	12		161,3	368,3	584,3	773,2	901,8	947,4	901,8	773,2	584,3	368,3	161,3	
al	22		163,9	375,2	597,3	791,8	924,2	971,1	924,2	791,8	597,3	375,2	163,9	
NORTE	32		163,2	373,6	595,5	790,1	922,4	969,2	922,4	790,1	595,5	373,6	163,2	
	90		100,8	212,5	322,6	416,1	479,1	501,4	479,1	416,1	322,6	212,5	100,8	
-135 NO	90		54,6	92,5	110,2	118,9	216,0	391,7	534,6	613,7	604,8	498,0	317,6	
135 NE	90		317,6	498,0	604,8	613,7	534,6	391,7	216,0	118,9	110,2	92,5	54,6	
-90 O	90		54,6	92,5	110,2	118,9	124,6	126,9	349,9	521,5	597,2	545,9	380,4	
90 E	90		380,4	545,9	597,2	521,5	349,9	126,9	124,6	118,9	110,2	92,5	54,6	
-45 SO	90		54,6	92,5	110,2	118,9	124,6	126,9	124,6	193,4	304,5	328,3	252,3	
45 SE	90		252,3	328,3	304,5	193,4	124,6	126,9	124,6	118,9	110,2	92,5	54,6	
0 SUR	90		54,6	92,5	110,2	118,9	124,6	126,9	124,6	118,9	110,2	92,5	54,6	

AZ	INCL	OCTUBRE HORA SOLAR 6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL		41,2	225,1	437,7	652,0	836,5	961,2	1005,4	961,2	836,5	652,0	437,7	225,1	41,2
180	12	32,3	216,6	435,1	659,0	853,1	984,8	1031,4	984,8	853,1	659,0	435,1	216,6	32,3
al	22	24,3	204,6	421,7	646,6	842,6	975,9	1023,1	975,9	842,6	646,6	421,7	204,6	24,3
NORTE	32	23,3	188,4	398,4	617,9	810,3	941,4	987,8	941,4	810,3	617,9	398,4	188,4	23,3
	90	16,4	68,5	121,6	203,2	278,2	331,6	350,9	331,5	278,2	203,2	121,6	68,5	16,4
-135 NO	90	16,4	68,5	98,5	113,1	122,9	131,0	287,5	443,4	542,8	564,7	497,2	351,6	172,8
135 NE	90	172,8	351,6	497,2	564,7	542,8	443,4	287,5	131,0	122,9	113,1	98,5	68,5	16,4
-90 O	90	16,4	68,5	98,5	113,1	122,9	131,0	134,3	372,3	561,5	661,6	639,2	493,1	277,8
90 E	90	277,8	493,1	639,2	661,6	561,5	372,3	134,3	131,0	122,9	113,1	98,5	68,5	16,4
-45 SO	90	16,4	68,5	98,5	113,1	122,9	131,0	134,3	159,8	323,3	437,2	464,5	385,8	229,7
45 SE	90	229,7	385,8	464,5	437,2	323,3	159,8	134,3	131,0	122,9	113,1	98,5	68,5	16,4
0 SUR	90	54,7	92,7	98,5	113,1	122,9	131,0	134,3	131,0	122,9	113,1	98,5	92,7	56,7

AZ	INCL	NOVIEMBRE HORA SOLAR 6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL		84,9	272,6	484,5	695,0	874,5	995,2	1037,8	995,2	874,5	695,0	484,5	272,6	84,9
180	12	64,6	247,8	460,2	675,4	861,0	986,6	1031,0	986,6	861,0	675,4	460,2	247,8	64,6
al	22	46,7	221,5	428,0	640,5	825,3	951,0	995,5	951,0	825,3	640,5	428,0	221,5	46,7
NORTE	32	44,7	190,9	386,1	589,7	768,5	890,7	934,0	890,7	768,5	589,7	386,1	190,8	44,7
	90	32,0	79,1	106,1	119,9	143,1	185,8	201,7	185,8	143,1	119,9	106,1	79,1	32,0
-135 NO	90	32,0	79,1	106,1	119,9	129,5	137,0	183,6	336,2	439,4	475,1	433,2	321,5	173,1
135 NE	90	173,1	321,5	433,2	475,1	439,4	336,2	183,6	137,0	129,5	119,9	106,1	79,1	32,0
-90 O	90	32,0	79,1	106,1	119,9	129,5	137,0	140,1	369,9	554,2	656,1	645,9	520,6	323,2
90 E	90	323,2	520,6	645,9	656,1	554,2	369,9	140,1	137,0	129,5	119,9	106,1	79,1	32,0
-45 SO	90	32,0	79,1	106,1	119,9	129,5	137,0	140,1	267,2	420,2	523,0	542,4	461,1	302,8
45 SE	90	302,8	461,1	542,4	523,0	420,2	267,2	140,1	137,0	129,5	119,9	106,1	79,1	32,0
0 SUR	90	123,7	177,8	183,3	153,8	129,5	137,0	140,1	137,0	129,5	153,8	183,3	177,8	123,7

AZ	INCL	DICIEMBRE												
		HORA SOLAR												
		6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL		105,1	292,3	501,7	708,2	883,6	1001,2	1042,7	1001,2	883,6	708,2	501,7	292,3	105,1
180	12	79,1	259,8	467,4	676,6	856,5	978,1	1021,1	978,1	856,5	676,6	467,4	259,8	79,1
al	22	56,1	226,7	426,7	631,6	809,7	930,7	973,6	930,7	809,7	631,6	426,7	226,7	56,1
NORTE	32	53,6	189,3	376,4	571,2	742,3	859,3	900,9	859,3	742,3	571,2	376,4	189,3	53,6
	90	38,7	83,4	109,2	122,6	131,9	139,1	142,0	139,1	131,9	122,6	109,2	83,4	38,7
-135 NO	90	38,7	83,4	109,2	122,6	131,9	139,1	142,0	284,7	388,3	429,1	397,8	301,2	167,7
135 NE	90	167,7	301,2	397,8	429,1	388,3	284,7	142,0	139,1	131,9	122,6	109,2	83,4	38,7
-90 O	90	38,7	83,4	109,2	122,6	131,9	139,1	142,0	365,6	545,6	646,7	641,2	525,9	339,0
90 E	90	339,0	525,9	641,2	646,7	545,6	365,6	142,0	139,1	131,9	122,6	109,2	83,4	38,7
-45 SO	90	38,7	83,4	109,2	122,6	131,9	139,1	148,6	313,8	460,5	557,4	573,0	491,4	334,5
45 SE	90	334,5	491,4	573,0	557,4	460,5	313,8	148,6	139,1	131,9	122,6	109,2	83,4	38,7
0 SUR	90	156,6	218,0	233,0	213,3	182,9	159,7	151,3	159,7	182,9	213,3	233,0	218,0	156,6

TABLE E

TABLE OF PERCENTAGE OF TIME DIFFUSE RADIATION RESPECT TO TOTAL RADIATION FOR DIFFERENT DIRECTIONS, IN UNITS% (CALAMA)

LOCALIDAD: CALAMA
LATITUD: 22,47 [GRADOS] SUR

ENERO — HORA SOLAR

AZ	INCL	6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL		71,7	59,1	46,5	36,0	28,8	24,8	23,6	24,8	28,8	36,0	46,5	59,1	71,7
180	12	83,1	62,3	47,9	36,7	29,1	25,0	23,8	25,0	29,1	36,7	47,9	62,3	83,1
al	22	99,0	66,0	49,6	37,7	29,9	25,7	24,4	25,7	29,9	37,7	49,6	66,0	99,0
NORTE	32	100,0	71,3	52,3	39,4	31,1	26,8	25,5	26,8	31,1	39,4	52,3	71,3	100,0
	90	100,0	100,0	100,0	100,0	100,0	93,6	88,7	93,6	100,0	100,0	100,0	100,0	100,0
-135 NO	90	100,0	100,0	100,0	100,0	100,0	100,0	91,7	56,6	46,9	44,9	46,5	48,3	44,5
135 NE	90	44,5	48,3	46,5	44,9	46,9	56,6	91,7	100,0	100,0	100,0	100,0	100,0	100,0
-90 O	90	100,0	100,0	100,0	100,0	100,0	100,0	100,0	50,5	39,7	37,3	38,1	38,9	35,5
90 E	90	35,5	38,9	38,1	37,3	39,7	50,5	100,0	100,0	100,0	100,0	100,0	100,0	100,0
-45 SO	90	100,0	100,0	100,0	100,0	100,0	100,0	100,0	59,2	45,1	40,9	40,5	40,3	35,9
45 SE	90	35,9	40,3	40,5	40,9	45,1	59,2	100,0	100,0	100,0	100,0	100,0	100,0	100,0
0 SUR	90	48,4	60,6	67,6	76,9	91,2	100,0	100,0	100,0	91,2	76,9	67,6	60,6	48,4

FEBRERO — HORA SOLAR

AZ	INCL	6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL		75,2	62,3	49,1	37,8	30,0	25,6	24,3	25,6	30,0	37,8	49,1	62,3	75,2
180	12	85,7	64,1	49,6	37,9	29,9	25,6	24,2	25,6	29,9	37,9	49,6	64,1	85,7
al	22	99,2	66,2	50,5	38,4	30,3	25,9	24,6	25,9	30,3	38,4	50,5	66,2	99,2
NORTE	32	100,0	69,2	52,0	39,4	31,2	26,7	25,4	26,7	31,2	39,4	52,0	69,2	100,0
	90	100,0	100,0	100,0	82,7	68,2	60,8	58,6	60,8	68,2	82,7	100,0	100,0	100,0
-135 NO	90	100,0	100,0	100,0	100,0	100,0	100,0	65,9	47,6	41,9	41,7	43,8	45,3	38,2
135 NE	90	38,2	45,3	43,8	41,7	41,9	47,6	65,9	100,0	100,0	100,0	100,0	100,0	100,0
-90 O	90	100,0	100,0	100,0	100,0	100,0	100,0	100,0	50,1	39,6	37,6	38,5	39,0	33,1
90 E	90	33,1	39,0	38,5	37,6	39,6	50,1	100,0	100,0	100,0	100,0	100,0	100,0	100,0
-45 SO	90	100,0	100,0	100,0	100,0	100,0	100,0	100,0	75,6	51,0	44,3	43,0	41,9	34,3
45 SE	90	34,3	41,9	43,0	44,3	51,0	75,6	100,0	100,0	100,0	100,0	100,0	100,0	100,0
0 SUR	90	51,6	74,9	93,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	93,0	74,9	51,6

MARZO — HORA SOLAR

AZ	INCL	6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL		79,4	66,2	52,2	40,0	31,3	26,5	25,0	26,5	31,3	40,0	52,2	66,2	79,4
180	12	88,4	65,6	51,4	39,3	30,7	26,0	24,6	26,0	30,7	39,3	51,4	65,6	88,4
al	22	99,4	65,6	51,1	39,1	30,7	26,1	24,7	26,1	30,7	39,1	51,1	65,6	99,4
NORTE	32	100,0	65,9	51,3	39,3	31,0	26,5	25,1	26,5	31,0	39,3	51,3	65,9	100,0
	90	100,0	83,9	69,1	57,4	49,2	44,6	43,2	44,6	49,2	57,4	69,1	83,9	100,0
-135 NO	90	100,0	100,0	100,0	100,0	100,0	81,2	50,1	40,3	37,6	38,6	41,2	42,0	28,4
135 NE	90	28,4	42,0	41,2	38,6	37,6	40,3	50,1	81,2	100,0	100,0	100,0	100,0	100,0
-90 O	90	100,0	100,0	100,0	100,0	100,0	100,0	100,0	49,3	39,3	37,7	38,7	38,5	27,4
90 E	90	27,4	38,5	38,7	37,7	39,3	49,3	100,0	100,0	100,0	100,0	100,0	100,0	100,0
-45 SO	90	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	62,9	49,9	46,5	43,6	28,1
45 SE	90	28,1	43,6	46,5	49,9	62,9	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
0 SUR	90	55,9	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	55,9

AZ	INCL	ABRIL HORA SOLAR 6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL			70,6	55,8	42,5	32,9	27,5	25,9	27,5	32,9	42,5	55,8	70,6	
180	12		66,0	53,0	40,6	31,6	26,6	25,0	26,6	31,6	40,6	53,0	66,0	
al	22		63,1	51,4	39,7	31,1	26,2	24,7	26,2	31,1	39,7	51,4	63,1	
NORTE	32		60,9	50,3	39,1	30,9	26,2	24,8	26,2	30,9	39,1	50,3	60,9	
	90		56,5	53,0	45,6	39,5	35,9	34,8	35,9	39,5	45,6	53,0	56,5	
-135 NO	90		100,0	100,0	100,0	100,0	55,3	40,5	35,1	34,2	36,1	38,8	38,2	
135 NE	90		38,2	38,8	36,1	34,2	35,1	40,5	55,3	100,0	100,0	100,0	100,0	
-90 O	90		100,0	100,0	100,0	100,0	100,0	100,0	48,4	39,0	37,7	38,7	37,0	
90 E	90		37,0	38,7	37,7	39,0	48,4	100,0	100,0	100,0	100,0	100,0	100,0	
-45 SO	90		100,0	100,0	100,0	100,0	100,0	100,0	100,0	94,6	59,6	51,6	44,9	
45 SE	90		44,9	51,6	59,6	94,6	100,0	100,0	100,0	100,0	100,0	100,0	100,0	
0 SUR	90		100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	

AZ	INCL	MAYO HORA SOLAR 6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL			68,7	51,8	37,0	27,0	22,0	20,6	22,0	27,0	37,0	51,8	68,7	
180	12		58,1	41,2	34,4	25,5	21,0	19,7	21,0	25,5	34,4	47,2	58,1	
al	22		52,6	44,6	33,1	24,9	20,6	19,4	20,6	24,9	33,1	44,6	52,6	
NORTE	32		48,9	42,8	32,3	24,6	20,6	19,4	20,6	24,6	32,3	42,8	48,9	
	90		40,0	40,7	34,8	29,8	27,0	26,3	27,0	29,8	34,8	40,7	40,0	
-135 NO	90		100,0	100,0	100,0	62,9	39,1	30,6	27,3	27,3	29,9	33,2	32,2	
135 NE	90		32,2	33,2	29,9	27,3	27,3	30,6	39,1	62,9	100,0	100,0	100,0	
-90 O	90		100,0	100,0	100,0	100,0	100,0	100,0	41,8	33,0	32,5	34,3	32,3	
90 E	90		32,3	34,3	32,5	33,0	41,8	100,0	100,0	100,0	100,0	100,0	100,0	
-45 SO	90		100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	69,2	51,7	40,6	
45 SE	90		40,6	51,7	69,2	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	
0 SUR	90		100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	

AZ	INCL	JUNIO HORA SOLAR 6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL			72,1	55,3	40,2	29,5	24,0	22,3	24,0	29,5	40,2	55,3	72,1	
180	12		56,5	49,4	36,8	27,6	22,6	21,2	22,6	27,6	36,8	49,4	56,5	
al	22		49,9	46,1	35,1	26,7	22,1	20,7	22,1	26,7	35,1	46,1	49,9	
NORTE	32		45,6	43,8	34,0	26,1	21,8	20,6	21,8	26,1	34,0	43,8	45,6	
	90		36,2	39,7	34,6	29,6	26,7	25,9	26,7	29,6	34,6	39,7	36,2	
-135 NO	90		100,0	100,0	100,0	54,8	37,0	29,9	27,3	27,7	30,5	33,6	30,9	
135 NE	90		30,9	33,6	30,5	27,7	27,3	29,9	37,0	54,8	100,0	100,0	100,0	
-90 O	90		100,0	100,0	100,0	100,0	100,0	100,0	42,7	34,2	33,8	35,2	31,3	
90 E	90		31,3	35,2	33,8	34,2	42,7	100,0	100,0	100,0	100,0	100,0	100,0	
-45 SO	90		100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	86,3	57,3	40,4	
45 SE	90		40,4	57,3	86,3	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	
0 SUR	90		100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	

AZ	INCL	JULIO HORA SOLAR 6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL			68,0	50,3	35,1	25,2	20,4	19,2	20,4	25,2	35,1	50,3	68,0	
180	12		54,7	45,2	32,4	23,7	19,5	18,3	19,5	23,7	32,4	45,2	54,7	
al	22		48,8	42,4	31,1	23,1	19,1	18,1	19,1	23,1	31,1	42,4	48,8	
NORTE	32		44,9	40,5	30,3	22,8	19,1	18,1	19,1	22,8	30,3	40,5	44,9	
	90		36,4	37,8	32,2	27,4	25,0	24,3	25,0	27,4	32,2	37,8	36,4	
-135 NO	90		100,0	100,0	100,0	54,8	35,6	28,4	25,4	25,4	28,1	31,7	30,6	
135 NE	90		30,6	31,7	28,1	25,4	25,4	28,4	35,6	54,8	100,0	100,0	100,0	
-90 O	90		100,0	100,0	100,0	100,0	100,0	100,0	40,0	31,2	30,9	32,9	30,9	
90 E	90		30,9	32,9	30,9	31,2	40,0	100,0	100,0	100,0	100,0	100,0	100,0	
-45 SO	90		100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	75,5	51,9	38,9	
45 SE	90		38,9	51,9	75,5	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	
0 SUR	90		100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	

AGOSTO														
AZ	INCL	HORA SOLAR												
		6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL			60,7	42,9	28,9	20,8	17,6	17,0	17,6	20,8	28,9	42,9	60,7	
180	12		53,8	39,9	27,4	20,0	17,1	16,5	17,1	20,0	27,4	39,9	53,8	
al	22		50,1	38,3	26,8	19,8	17,0	16,5	17,0	19,8	26,8	38,3	50,1	
NORTE	32		47,4	37,3	26,5	19,9	17,2	16,7	17,2	19,9	26,5	37,3	47,4	
	90		41,6	38,9	32,2	27,7	26,0	25,8	26,0	27,7	32,2	38,9	41,6	
-135 NO	90		100,0	100,0	100,0	77,9	40,5	30,4	25,8	24,5	26,3	30,2	31,4	
135 NE	90		31,4	30,2	26,3	24,5	25,8	30,4	40,0	77,9	100,0	100,0	100,0	
-90 O	90		100,0	100,0	100,0	100,0	100,0	100,0	38,8	29,0	28,1	30,5	31,0	
90 E	90		31,0	30,5	28,1	29,0	38,8	100,0	100,0	100,0	100,0	100,0	100,0	
-45 SO	90		100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	52,6	42,8	37,4	
45 SE	90		37,4	42,8	52,6	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	
0 SUR	90	-	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	

SEPTIEMBRE														
AZ	INCL	HORA SOLAR												
		6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL			63,0	47,6	34,7	26,1	21,8	20,5	21,8	26,1	34,7	47,6	63,0	
180	12		61,0	46,1	33,7	25,5	21,3	20,1	21,3	25,5	33,7	46,1	61,0	
al	22		59,8	45,4	33,4	25,4	21,4	20,2	21,4	25,4	33,4	45,4	59,8	
NORTE	32		59,1	45,2	33,4	25,6	21,7	20,6	21,7	25,6	33,4	45,2	59,1	
	90		65,4	55,8	46,2	39,5	36,0	35,0	36,0	39,5	46,2	55,8	65,4	
-135 NO	90		100,0	100,0	100,0	100,0	63,4	41,2	33,7	31,7	33,1	36,3	37,4	
135 NE	90		37,4	36,3	33,1	31,7	33,7	41,2	63,4	100,0	100,0	100,0	100,0	
-90 O	90		100,0	100,0	100,0	100,0	100,0	100,0	44,3	34,6	33,3	35,0	35,3	
90 E	90		35,3	35,0	33,3	34,6	44,3	100,0	100,0	100,0	100,0	100,0	100,0	
-45 SO	90		100,0	100,0	100,0	100,0	100,0	100,0	100,0	67,3	47,8	43,8	40,8	
45 SE	90		40,8	43,8	47,8	67,3	100,0	100,0	100,0	100,0	100,0	100,0	100,0	
0 SUR	90		100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	

OCTUBRE														
AZ	INCL	HORA SOLAR												
		6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL		69,8	54,5	39,8	28,4	21,6	18,5	17,8	18,5	21,6	28,4	39,8	54,5	69,8
180	12	81,7	55,6	39,9	28,4	21,5	18,5	17,8	18,5	21,5	28,4	39,9	55,6	81,7
al	22	98,9	57,0	40,4	28,7	21,8	18,9	18,1	18,9	21,8	28,7	40,4	57,0	98,9
NORTE	32	100,0	59,2	41,5	29,5	22,6	19,5	18,8	19,5	22,6	29,5	41,5	59,2	100,0
	90	100,0	100,0	84,7	62,8	51,7	46,9	45,6	46,9	51,7	62,8	84,7	100,0	100,0
-135 NO	90	100,0	100,0	100,0	100,0	100,0	100,0	53,0	38,1	33,0	32,9	35,7	38,1	32,2
135 NE	90	32,2	38,1	35,7	32,9	33,0	38,1	53,0	100,0	100,0	100,0	100,0	100,0	100,0
-90 O	90	100,0	100,0	100,0	100,0	100,0	100,0	100,0	43,1	32,4	30,5	32,1	33,8	29,6
90 E	90	29,6	33,8	32,1	30,5	32,4	43,1	100,0	100,0	100,0	100,0	100,0	100,0	100,0
-45 SO	90	100,0	100,0	100,0	100,0	100,0	100,0	100,0	84,2	46,4	37,8	36,8	36,8	30,5
45 SE	90	30,5	36,8	36,8	37,8	46,4	84,2	100,0	100,0	100,0	100,0	100,0	100,0	100,0
0 SUR	90	46,8	79,9	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	79,9	46,8

NOVIEMBRE														
AZ	INCL	HORA SOLAR												
		6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL		66,4	52,1	38,6	28,2	21,9	18,9	18,2	18,9	21,9	28,2	38,6	52,1	66,4
180	12	79,0	54,9	39,6	28,6	22,1	19,1	18,3	19,1	22,1	28,6	39,6	54,9	79,0
al	22	98,7	58,3	41,0	29,4	22,7	19,7	18,9	19,7	22,7	29,4	41,0	58,3	98,7
NORTE	32	100,0	63,2	43,2	30,8	23,8	20,7	19,8	20,7	23,8	30,8	43,2	63,2	100,0
	90	100,0	100,0	100,0	100,0	91,8	77,0	73,1	77,0	91,8	100,0	100,0	100,0	100,0
-135 NO	90	100,0	100,0	100,0	100,0	100,0	100,0	79,1	48,1	39,0	37,2	39,2	41,7	38,7
135 NE	90	38,7	41,7	39,2	37,2	39,0	48,1	79,1	100,0	100,0	100,0	100,0	100,0	100,0
-90 O	90	100,0	100,0	100,0	100,0	100,0	100,0	100,0	44,8	33,8	31,4	32,7	34,4	32,3
90 E	90	32,3	34,4	32,7	31,4	33,8	44,8	100,0	100,0	100,0	100,0	100,0	100,0	100,0
-45 SO	90	100,0	100,0	100,0	100,0	100,0	100,0	100,0	57,3	40,2	35,3	35,2	36,0	32,8
45 SE	90	32,8	36,0	35,2	35,3	40,2	57,3	100,0	100,0	100,0	100,0	100,0	100,0	100,0
0 SUR	90	44,3	57,1	66,1	81,5	100,0	100,0	100,0	100,0	100,0	81,5	66,1	57,1	44,3

		DICIEMBRE												
AZ	INCL	HORA SOLAR												
		6	7	8	9	10	11	12	13	14	15	16	17	18
HORIZONTAL		65,0	51,3	38,3	28,4	22,2	19,3	18,5	19,3	22,2	28,4	38,3	51,3	65,0
180	12	77,9	54,7	39,7	29,0	22,6	19,6	18,8	19,6	22,6	29,0	39,7	54,7	77,9
al	22	98,6	59,0	41,5	30,0	23,3	20,2	19,4	20,2	23,3	30,0	41,5	59,0	98,6
NORTE	32	100,0	65,3	44,4	31,7	24,6	21,4	20,5	21,4	24,6	31,7	44,4	65,3	100,0
	90	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
-135 NO	90	100,0	100,0	100,0	100,0	100,0	100,0	100,0	55,2	43,0	40,1	41,5	44,0	42,1
135 NE	90	42,1	44,0	41,5	40,1	43,0	55,2	100,0	100,0	100,0	100,0	100,0	100,0	100,0
-90 O	90	100,0	100,0	100,0	100,0	100,0	100,0	100,0	45,8	34,6	32,0	33,1	34,8	33,3
90 E	90	33,3	34,8	33,1	32,0	34,6	45,8	100,0	100,0	100,0	100,0	100,0	100,0	100,0
-45 SO	90	100,0	100,0	100,0	100,0	100,0	100,0	96,1	51,3	38,4	34,6	34,7	35,7	33,4
45 SE	90	33,4	35,7	34,7	34,6	38,4	51,3	96,1	100,0	100,0	100,0	100,0	100,0	100,0
0 SUR	90	43,3	52,2	57,1	64,3	75,9	88,7	94,6	88,7	75,9	64,3	57,1	52,2	43,3

Azimuth of a plane or surface of interest:
Angle conformed by the meridian of the place and the projection on the horizontal plane of the perpendicular to the plane of interest (º)

Inclination of a plane or surface of interest:
Angle conformer by the horizontal plane and the surface of interest, (º).

Global Irradiation:
Incident solar energy in a surface per area unit (MJ/m2) or (kWh/m2)

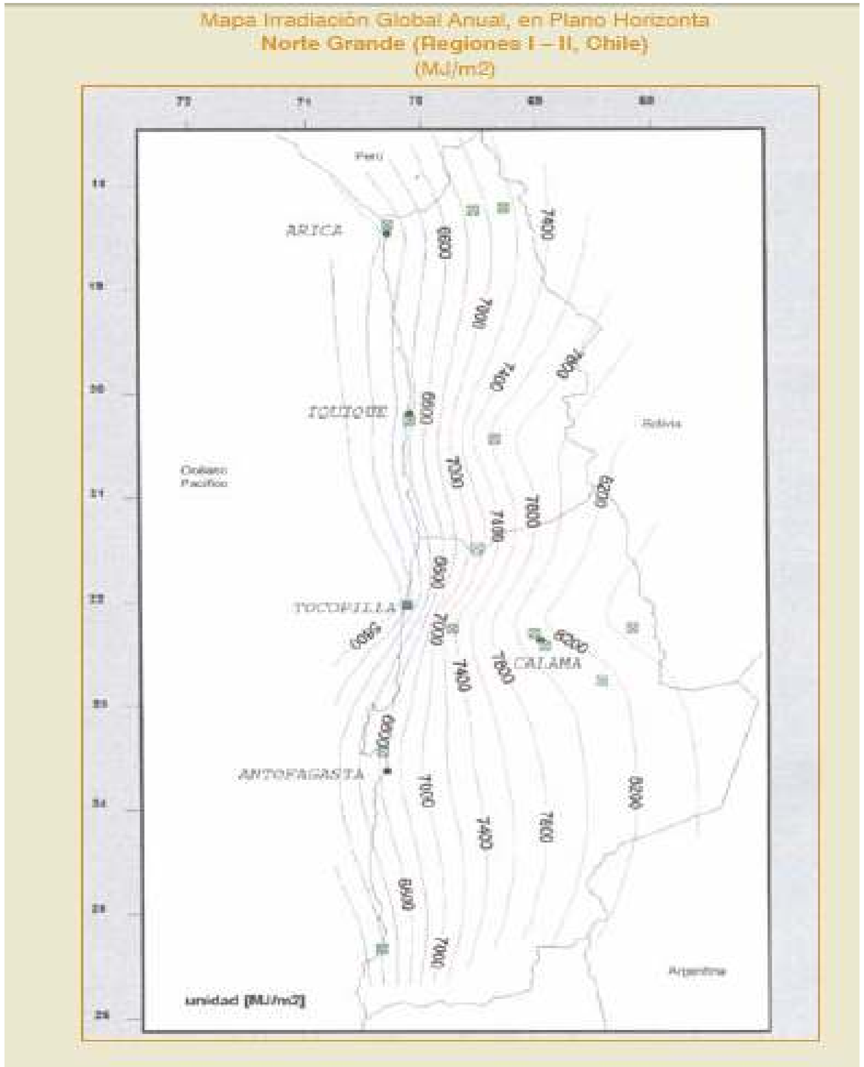
Diffuse solar radiation:
Solar radiation from the arch of heaven, (W/m2).

Direct solar radiation:
Solar radiation which is received from the solid angle of the solar disk, (W/m2)

Solar radiation reflected:
Fraction of solar radiation (direct and diffuse) that is reflected by the Earth's surface (W/m2).

Total or global solar radiation:
Incident solar potency per unit surface area, amount of solar radiation direct, diffused and reflected, (W/m2).

IRRADIATION MAP



Solar potential roof cadastre

according to the SUN-AREA research project on the basis of 3D-LIDAR-data

Calama

Scientists:

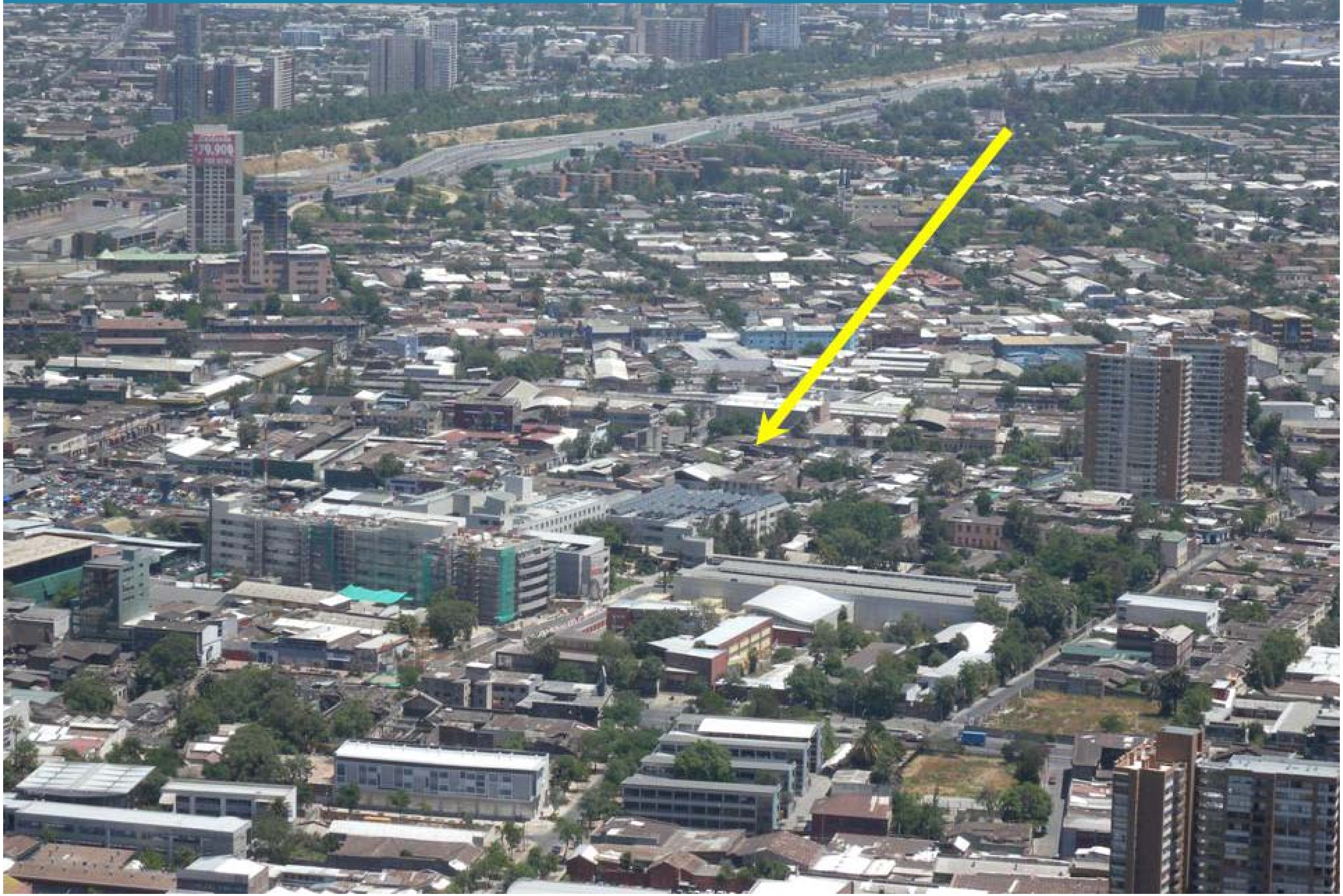
Prof. Dr. Klärle

Dipl. Geogr. Meik

Dipl.Geoinf. Lanig

Dr. Stolzenburg

Santiago

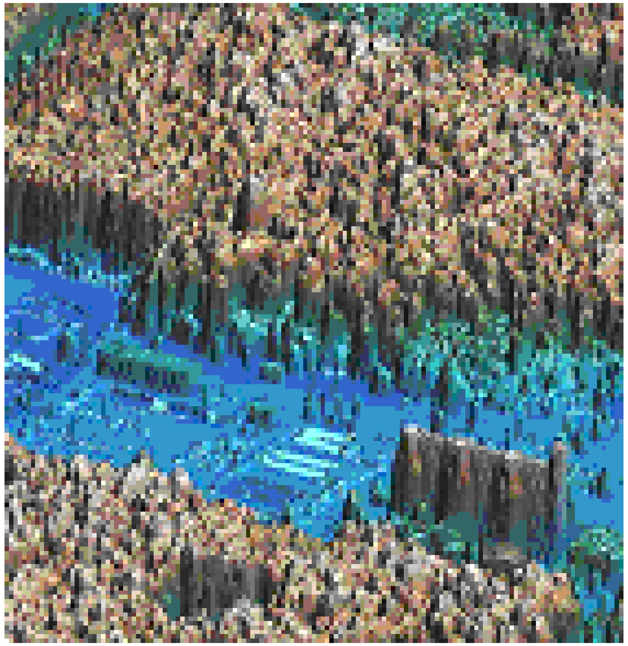


Santiago

most suitable roofs

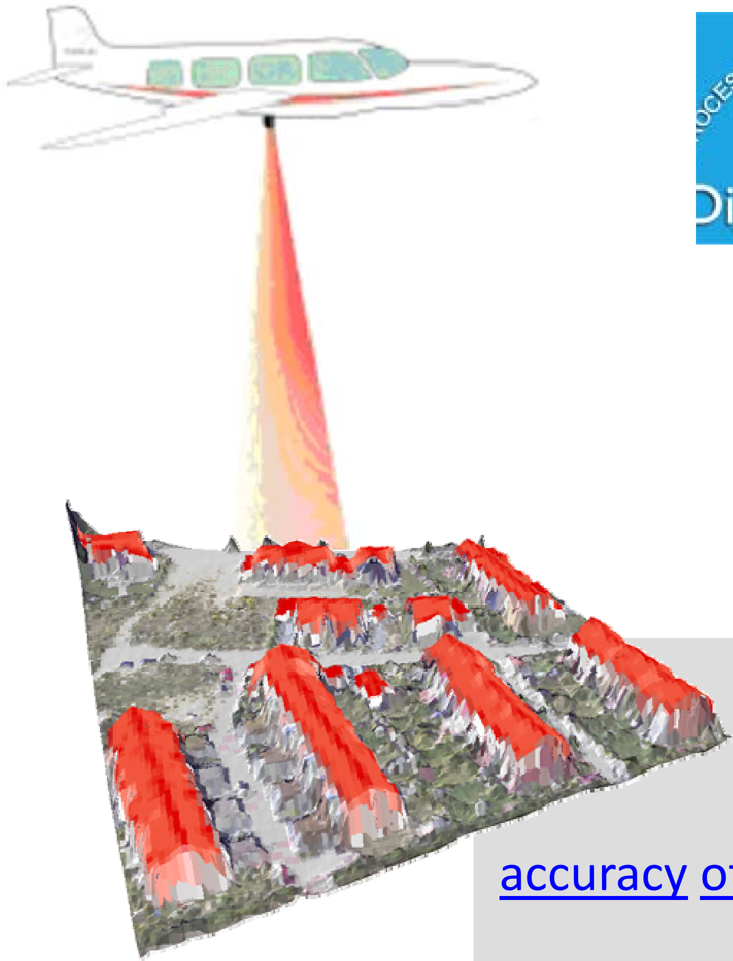
photovoltaics on existing roofs

Laserscanning-Data



Data-Basis

clip: cadastral map



Requirements:

1-4 points/m²

accuracy of measurement

0,15m

Method - formular

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Site-related factors

Roof direction (f_d)

Roof pitch (f_p)

Clouding (f_C)

Global radiation (R)

Efficience of Pannel (Ep)

Efficience of Installation (EI)

$$Sol\text{-}P_{(Pot)}=R*f_d*f_p*f_C*E_P*E_I$$

↓

Minimum size

↓

Energy potential

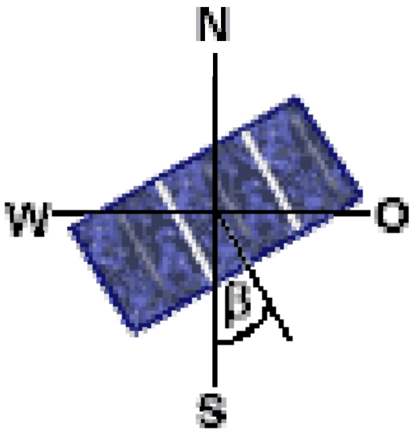
→ numerical

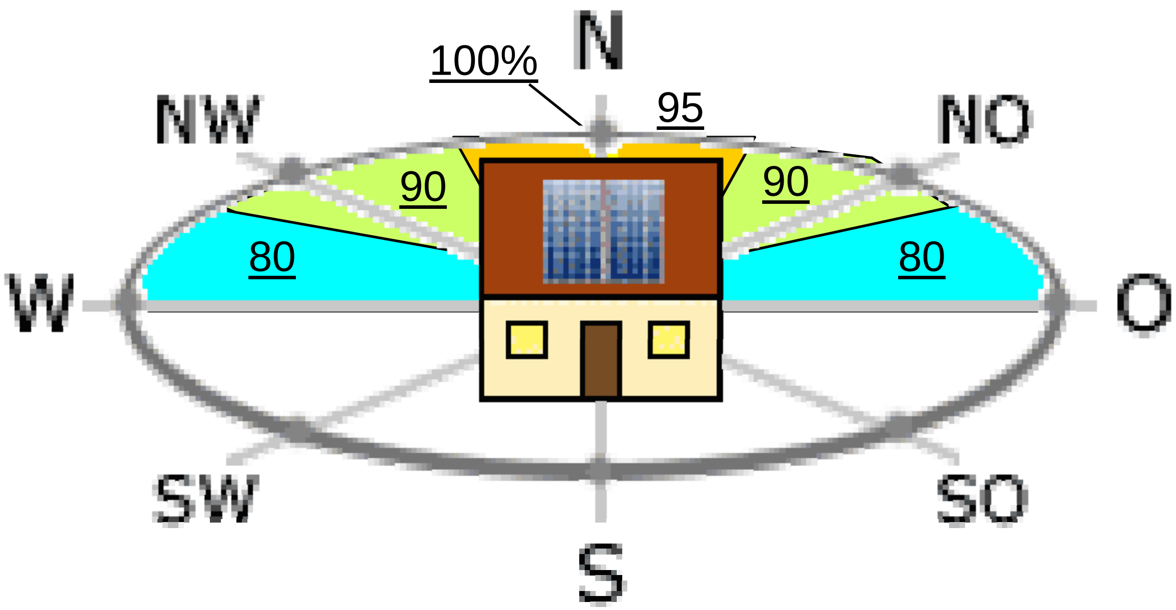
→ map

Site-related factors

Roof direction

Global radiation depending on the roof direction





Quelle: www.solarserver.de

Site-related factors

SUN · AREA

Roof pitch

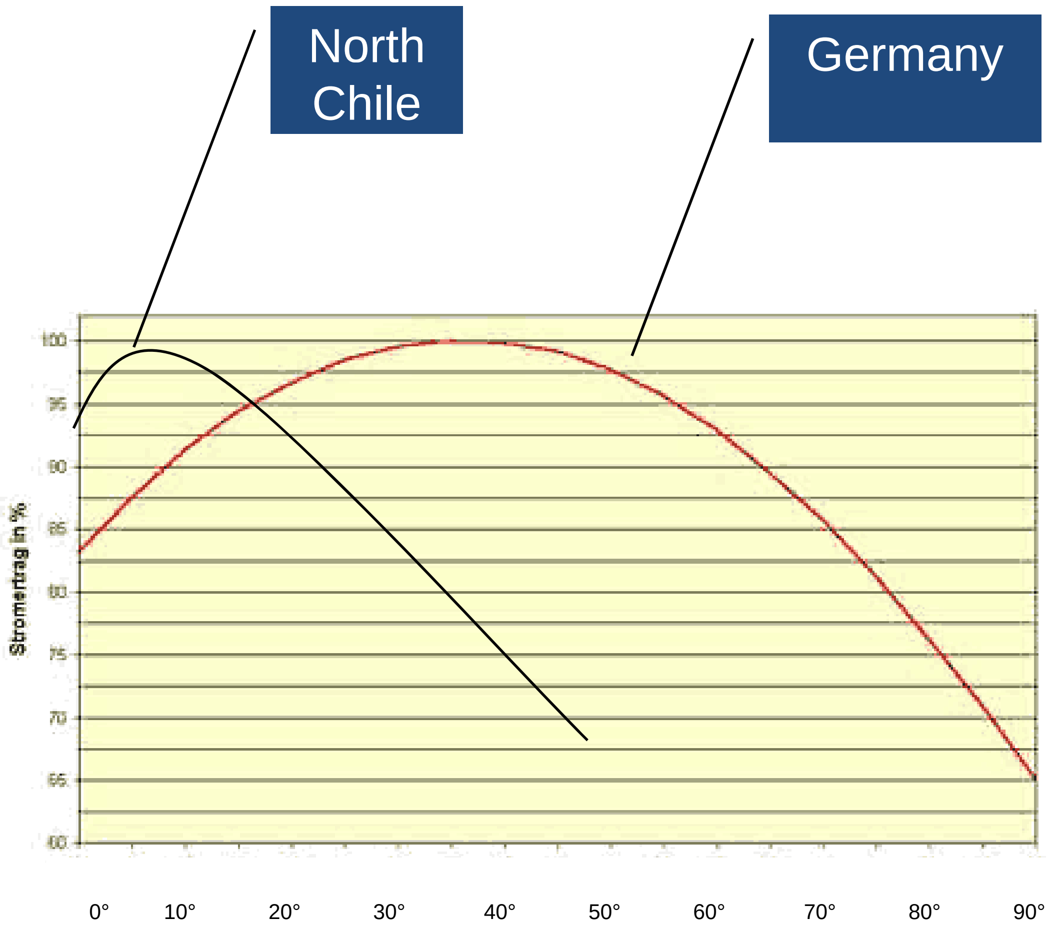
For Calama:

0° - 10°   excellent suitablity

10-20°   good suitablity

20 °-40° suitablity

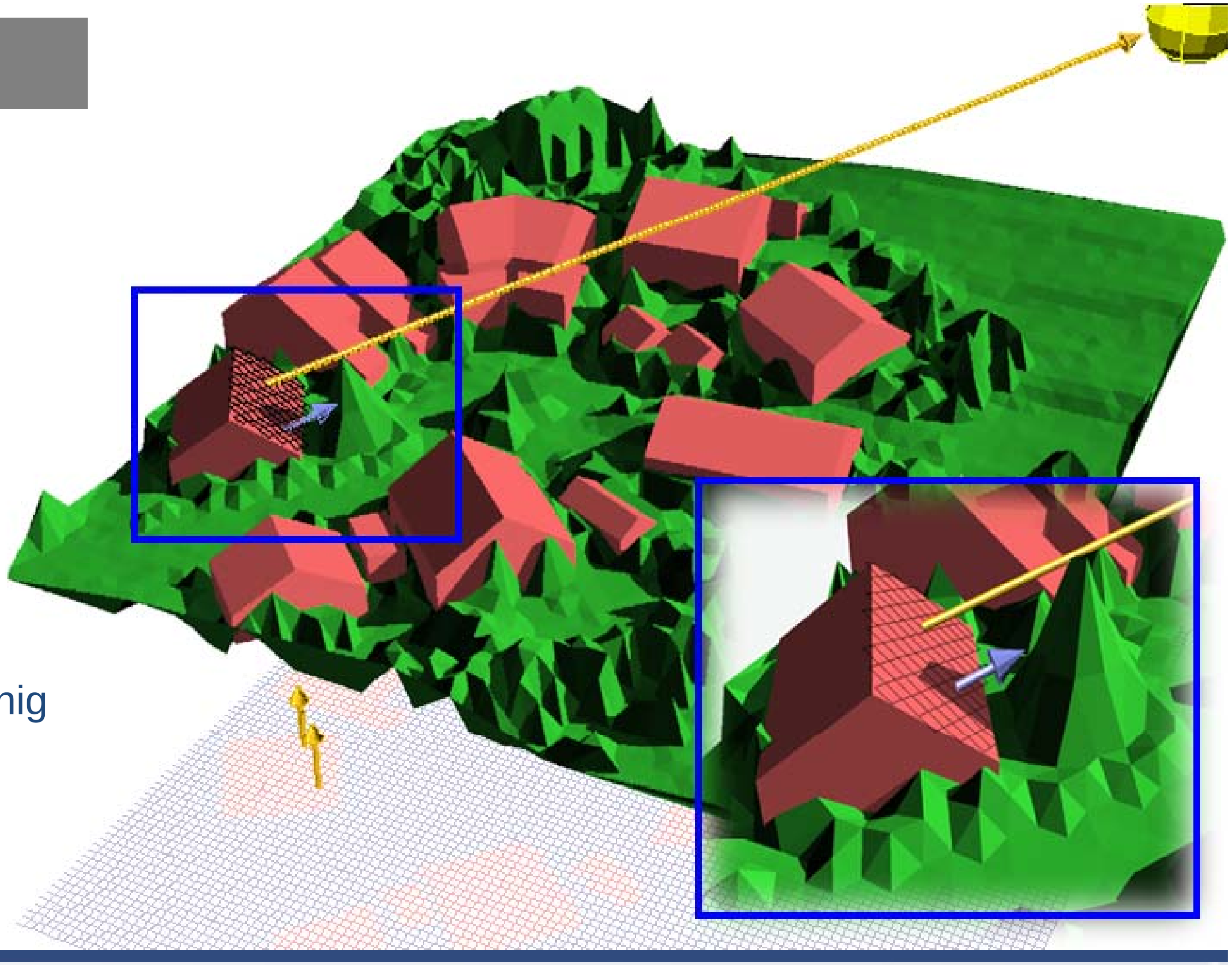
> 40°   no suitablity



Clouding

Clouding

- latitude
- time
- date (season)



scientist
Dipl.Geoinf. Sandra Lanig

Clouding

August
12 o´clock

Clouding

September
12 o´clock

Clouding

October
12 o´clock

Clouding

November
12 o´clock

Clouding

December
12 o´clock

Clouding

January
12 o´clock

Steinbeis-Transfer-Center
Geoinformations- and Land Management

Clouding

February
12 o´clock

Clouding

March
12 o´clock

Clouding

April
12 o´clock

Clouding

May
12 o´clock

Clouding

June
12 o´clock

Clouding

July
12 o´clock

farm building

suitablity

- excellent
- well suitable
- suitable

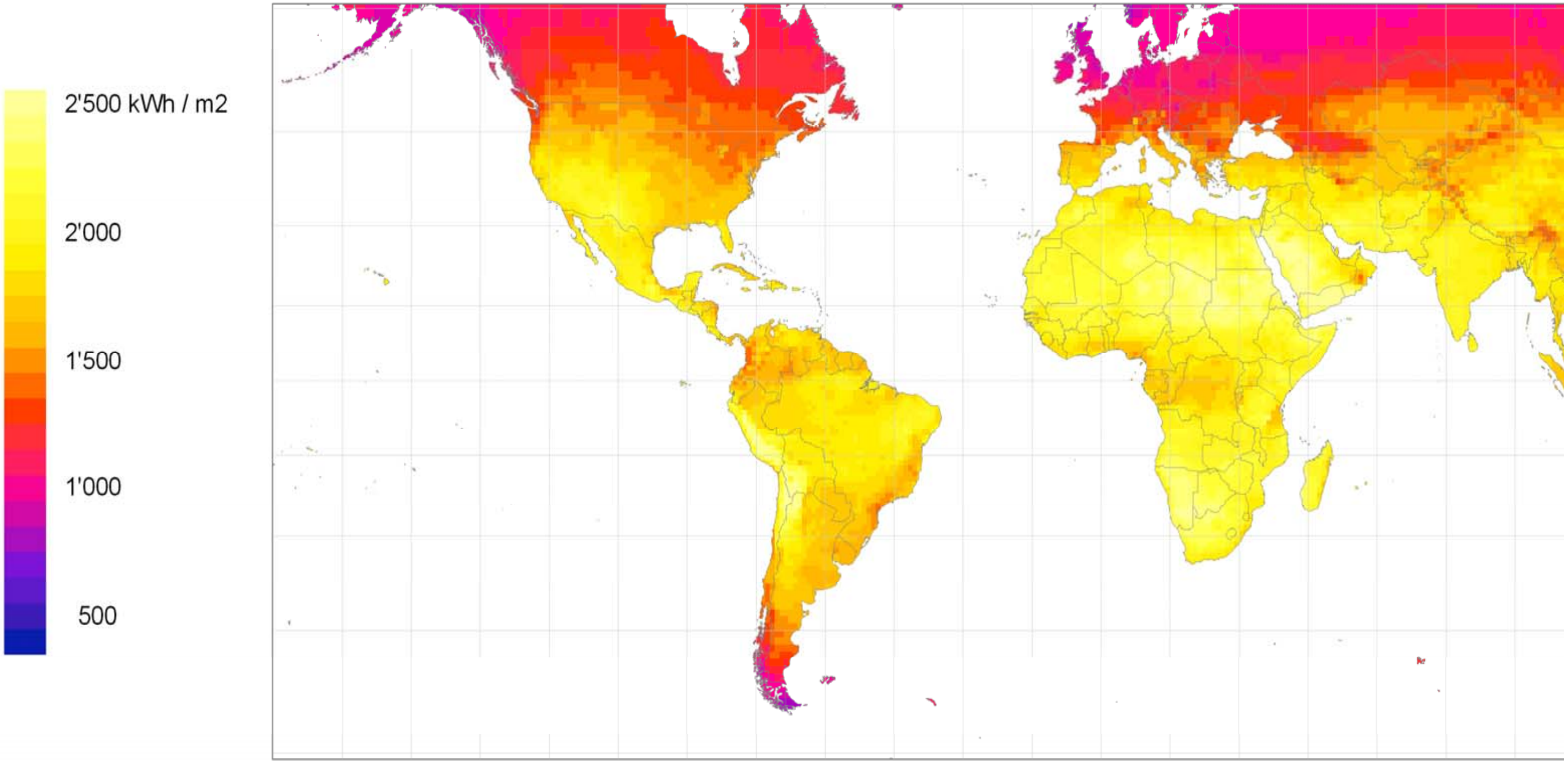
Data base:

Neigung	39
GEBKLASSE	Nebengebaeude
GEBART	Nebengebaeude
dachfl_groesse	314,69257
Stromertrag	41086,195
globalstr_gen	1160,5315
globalstrahl_prozent	99,770592
co2_einsp	21118304
Ausrichtung	173
eignung	sehr gut geeignet
dgroes_faktor	250

Suitability:	very good
Area:	315m²
Energy output:	41 MWh/a
CO_2 equivalent :	32t/a
Power for:	27 persons

Global Irradiance

SUN · AREA



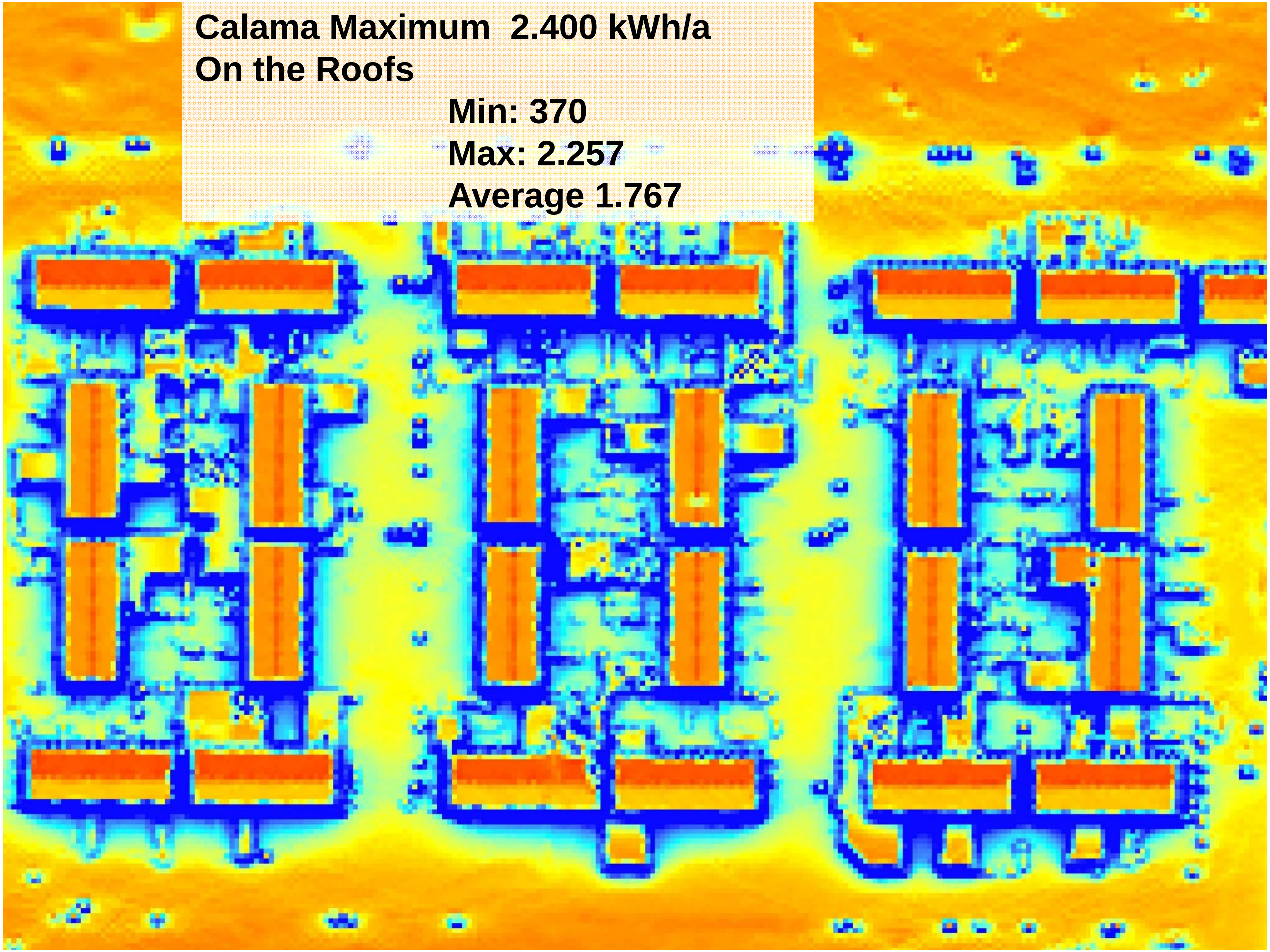
Source: Meteonorm 6.0 (www.meteonorm.com); uncertainty 10%
Period: 1981 - 2000; grid cell size: 1°

The project SUN-AREA – Calama (Chile)

Investigation Area

Particular solar radiance in Calama

Extention
peace


Calama Maximum 2.400 kWh/a
On the Roofs
Min: 370
Max: 2.257
Average 1.767

Area with good statics

New housing areas with stable roof structures

The project SUN-AREA – Calama (Chile) Statistics

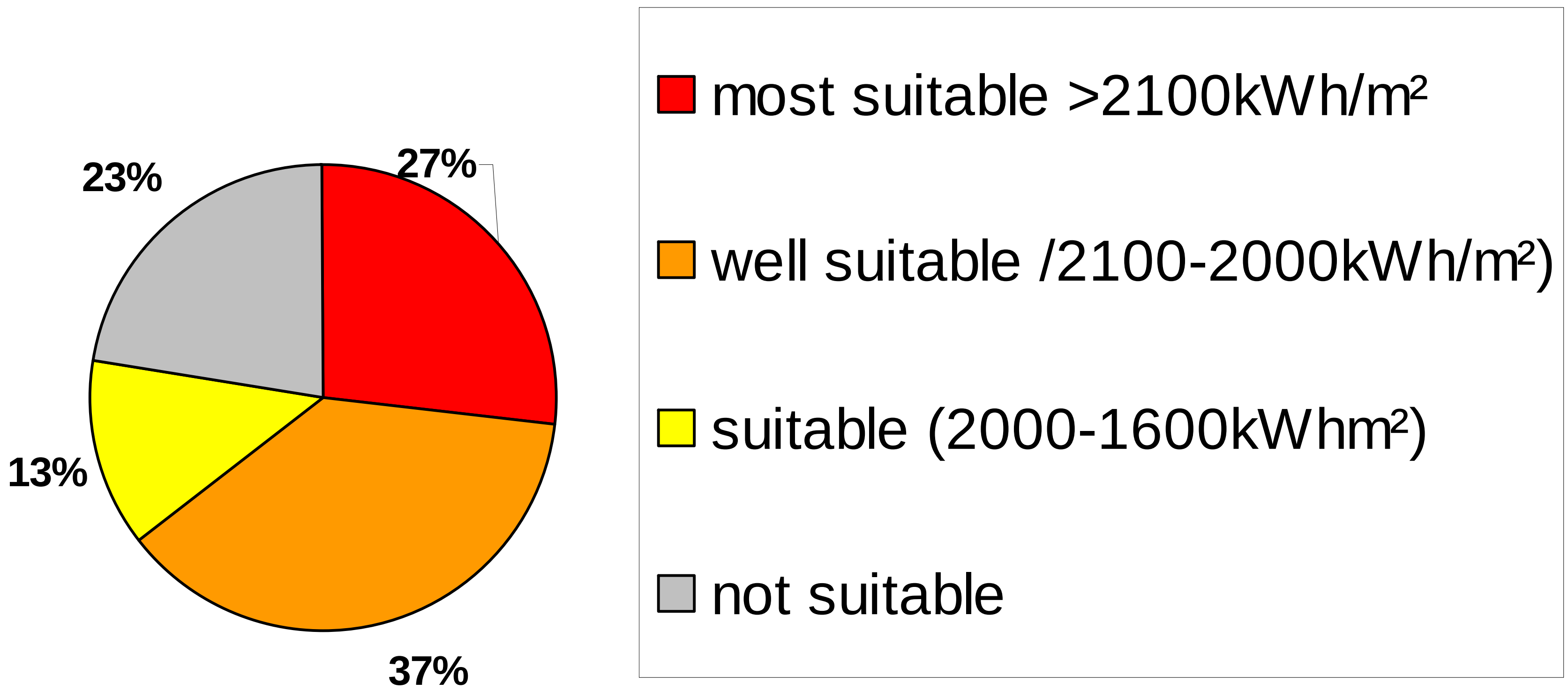
Buildings	59.069
Building-Area	5.539.100 m²
Average/Building	117m²
Inhabitants	ca. 135.000
Roof area/Inhabitants	41m²

http://www.geopm-kom5.de/geoapp/catastrosolar/calama/

The project SUN-AREA – Calama (Chile)
Statistics

SUN · AREA

suitable roof areas in m²   (77% of ~ 550ha)



Consumption - Potential

Electric private power consumption in Calama:

- private household (4 persons): 2.400kWh/a
- Per person: 600kWh/a
- Complete private consumption: **81.000MWh**

Consumption - Potential

	Potential in MWh	% of Consumption
most suitable	288.100	443
well suitable	384.300	591
suitable	126.000	193
SUM:	798.400	1228

→ **8%** of the suitable roofs will produce **100%** of Calamas private Consumption

→ **40MWp**

→ **50.000t CO_2**

We need geoinformatics to fight climate change!

Potencial solar de una superficie de techo

empleando el método SUN-AREA

El proyecto de investigación SUN-AREA ha comprobado que: Cerca del 20% de las superficies de techo en Alemania son idóneas para el aprovechamiento de la energía solar, se estima que esta energía podría cubrir completamente la demanda energética del país y a su vez aumentar el aprovechamiento en 100 veces respecto al uso actual.

A partir de datos recolectados mediante un escaneo por laser desde un avión, y con ayuda de un Sistema de Información Geográfica (SIG), SUN-AREA determina automáticamente y con precisión el Potencial solar de todas las Superficies de Techo existentes en cada ciudad del total de condados o distritos administrativos. Este proceso es necesario para determinar la idoneidad solar, la ganancia de energía, el ahorro de CO_2 y el grado de inversión para cada superficie de techo. Dicho análisis se hace mediante el cálculo del grado de inclinación del Techo, su orientación y sombreado. Los resultados se ponen a disposición general en un mapa interactivo publicado en Internet.

Por medio de SUN-AREA se contribuirá al acercamiento entre nuestra sociedad y el uso efectivo de la energía solar.

El Método SUN-AREA es el resultado del trabajo adelantado por un equipo de investigación conformado por Dorothea Ludwig y Sandra Lanig, y bajo la dirección de la Prof. Dr. Martina Klärle.

La aplicación como un mapa interactivo y una base de datos en Internet

En la ciudad Piloto de Osnabrück fueron analizados 70.000 techos. La siguiente gráfica es un extracto de ello:

Información por Superficie de Techo	
Idoneidad (Adaptación):	Muy buena
Area Apta (Idónea):	129 m²
Posible beneficio (ganancia):	16.529 kWh/a
Reducción de CO_2:	8.496 kg/a
Demanda energética:	11 Personas
Inversión:	52.000 Euros

- Muy apropiado
- apropiado
- apropiacion limitada

Ganador del Premio "GIS - Best Practice Award 2008" de la Asociacion Alemana de Topografia "DVW", bajo el auspicio del Ministro del Medio Ambiente Señor Sigmar Gabriel

Ejemplos Aplicados:

SUN-AREA ha sido implementado en varias Ciudades, a continuación se muestran 3 ejemplos de los mapas interactivos que se han publicado en Internet, actualmente estos gráficos se encuentran disponibles de manera pública.

Ciudad Osnabrück	cerca de 70.000 superficies de techo analizadas	www.osnabrueck.de/sun-area
Ciudad Gelsenkirchen	cerca de 40.000 superficies de techo analizadas	www.solar-gedacht.de
Ciudad Braunschweig	cerca de 80.000 superficies de techo analizadas (Con Catastros Solares térmicos separados)	www.braunschweig.de/sun-area

El canal de Televisión Alemán „Deutsche Welle“ y el programa científico NANO contribuyeron en la difusión de SUN AREA al público en general.

www.dw-world.de/dw/article/0,2144,3471787,00.html (Alemán)
www.dw-world.de/dw/article/0,2144,3475182,00.html (Inglés)
www.3sat.de/mediathek/?obj=7304

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