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from Meteosat Second Generation (MSG):
The Heliosat-3 Project**

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1. Introduction

This document reports the activities of DLR – “Deutsches Zentrum für Luft- und Raumfahrt” (German Aerospace Center) in Stuttgart (DLR-TT) for the WP 6020 within the Heliosat-3 project.

The efforts of the Heliosat-3 project result in very accurate irradiance data with high temporal (hourly) and spatial (1km x 1km) resolution. WP 6020 aimed at the example use of the high quality irradiance data that can be provided by the new Heliosat-3 method.

Accurate irradiance data are needed for planning e.g. photovoltaic systems or solar thermal power plants. Planners need precise information on the availability of the solar resource in order to find a good site, adjust components and to predict economic income.

As an example application, the provided irradiance information is used as input for resource assessment for solar thermal power stations and for simulation of such power plants. Therefore, the Canary Islands as example region was used to perform a detailed resource analysis for future solar thermal power plants in this region. The planning tool STEPS (Expert System for Solar Thermal Electric Power Stations), developed at DLR, was applied to perform this example study.

The document will give a short introduction into solar thermal power plants and the planning tool STEPS that will be applied within this study. After the introduction, the goal of WP6020, the performed work and the achieved results will be described.

2. Solar Thermal Power Plants

Solar thermal power plants use concentrating mirrors to generate high pressure steam from solar energy, in order to activate conventional steam turbines for electricity generation. As energy resource, the direct part of the solar irradiance is used (Direct Normal Irradiance – DNI)

Large scale solar thermal power stations require an extensive area of land which has to meet specific requirements for the erection of the power plant. Typical values for the demand of surface area amount to nearly 1 km² per 50 MW_{electric} rated power. Figure 1 gives an expression of the extent of a 5 x 30 MW_{electric} parabolic trough plant.



Figure 1: 5 x 30 MW_{electric} SEGS plant at Kramer Junction, California (Source: Flachglas Solartechnik GmbH, Köln).

If a site is identified to be technically feasible for the erection of a plant, there is still nothing said about the quality of the potential site in regard to criteria like electricity yield or costs. Finding suitable sites and, among those, identifying the optimal ones are issues project developers face in a very early stage of project development. The success in solving this problem determines the economical success of a project, not only in regard to energetic efficiency and financial benefits, but also concerning the prestige of the technology and investors' trust - an aspect which is especially relevant for high investment technologies at the verge to market introduction like solar thermal power stations.

3. STEPS

STEPS is a planning tool to provide a systematic and efficient way of identifying and assessing potential sites for solar thermal power stations (Broesamle et al., 2001). Three basic characteristics constitute the functionality of STEPS: The site analysis is carried out

- for large areas (on the country-scale),
- continuous in geographical space (i.e. for the complete area under investigation),
- in a high resolution (30 arc seconds, corresponding to less than one square kilometre).

As major results of an analysis run for a specific area STEPS allows for

- the determination of all sites that are in principal suitable for the implementation of a solar thermal power plant project (site identification),
- the classification of the identified feasible sites by several criteria of optimality (site ranking).

Figure 2 shows the modular structure of STEPS. The main module combines all relevant data that are provided by several additional modules like geography, economy, country data base.

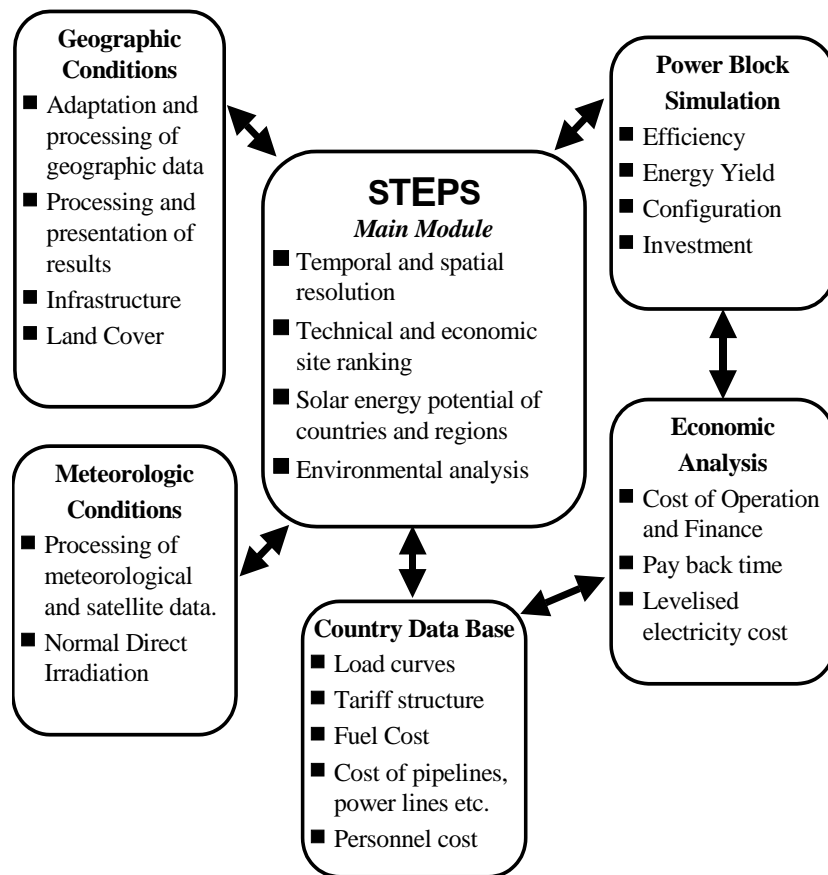


Figure 2: The modular structure of STEPS.

For the example application within WP 6020, the meteorology module was not used but the direct normal irradiance data were taken from the Heliosat-3 data output.

Generally, the results are provided as maps in a Geographic Information System (GIS) format or as single point time series. Possible criteria for the ranking process are e.g. the solar resource (DNI) to be expected at the specific site, the annual electricity yield or the resulting cost of electricity. Further on, a variety of additional information packages can be drawn from an analysis run: As examples may be mentioned maps of infrastructure costs, total investment costs, maps of heat generation of the collector field or hourly series of DNI for a specific site.

With this functionality STEPS provides the information basis for preparative studies in the field of solar thermal power projects. It helps to detect a narrow set of most promising sites to be examined in more detailed studies in a next step. With its capability of performing aggregate analyses for one or several countries (country analysis) as well as investigating custom designed areas, STEPS serves as a powerful decision support tool for project developers, both in the private and in the corporate sector (Broesamle et al. 2001, Kronshage et al. 2002).

The results of STEPS are provided in digital maps. For further data-processing and -analyzing, a Geo-Information-System (GIS) is recommended.

Results are e.g.:

- Available solar resource
- Available land resource (shown in exclusion maps)
- Costs of infrastructure
- Costs of insurance
- Levelized Electricity Costs (LEC)

Figure 3 shows the main processing steps of STEPS. The working process of STEPS can be divided into several parts:

- Determination of available solar resource (Direct Normal Irradiance)
- Identifying all potential sites that are technically suitable for solar thermal power stations. The restrictions that are made (exclusive criteria) are pre-defined (water surfaces, cities etc.) and custom-defined.
- Simulation of a solar thermal power plant for each suitable site with the determined direct solar irradiance. The configuration of the solar thermal power plant can be chosen from different pre-defined configuration specification.
- Determination of the new present value for the project
- One result is e.g. a ranking based on Levelized Electricity Cost (LEC)

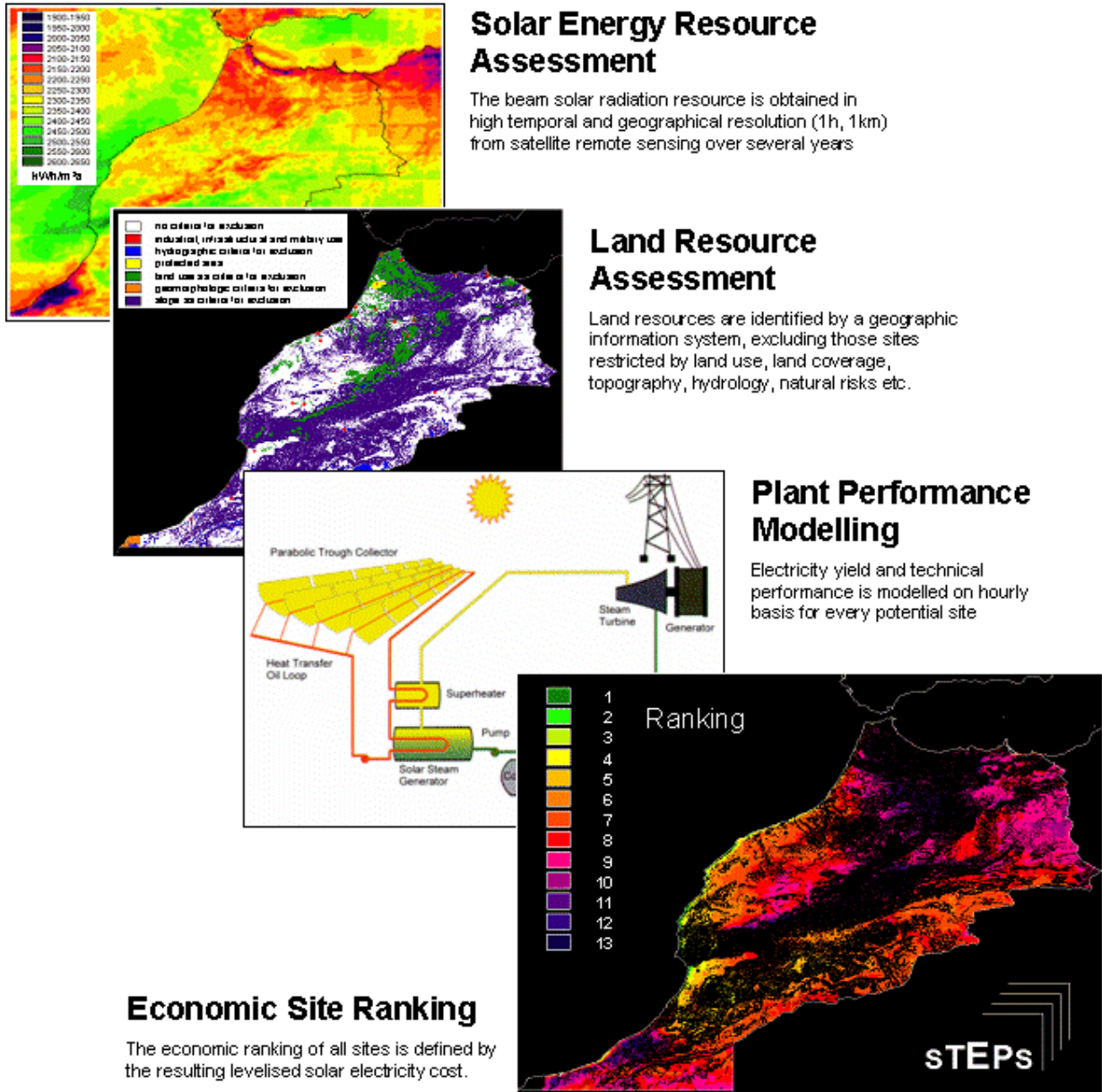


Figure 3: Example processing parts of STEPS for the example country analysis for Morocco. Steps from top left to bottom right: solar resource assessment (DNI), assessment of exclusion sites (white=suitable), power block simulation, ranking based on Levelized Electricity Cost (LEC).

4. Goal of WP 6020

WP 6020 aimed at the example use of the high quality irradiance data that can be provided by the new Heliosat-3 method. Here, the application was performed in the field of solar thermal power stations. Using the STEPS-tool, the following activities were **planned**:

1.) A first analysis for an example region with irradiance data of Heliosat-1 as input for the STEPS-tool. The results show e.g. a ranking based on levelized electricity cost for a selected power plant configuration (50MW_{electric}, DSG, solar only). The older Heliosat-1 method has a lower temporal and spatial resolution than the new Heliosat-3 method. Furthermore, the accuracy of the calculated irradiance is lower than the new method.

2.) A second analysis. All parameter are defined as in analysis 1, but the irradiance data is now taken from the new Helisoat-3 model.

The results should show, that the input of the new Heliosat-3 data leads to a more accurate and precise resource assessment and to a more accurate power plant simulations.

Unfortunately, due to the delay of data dissemination of the Meteosat Second Generation (MSG) satellite, the following **restrictions** had to be made:

- There was no overlapping time for the available data of the Heliosat-1 and Heliosat-3 method. This overlap was a pre-condition for a reliable comparison of the power plant simulation based on different irradiance input. No Heliosat-1 data were provided.
- There was no complete year of hourly irradiance data available. Some months were missing. A complete year of data is needed for the correct STEPS power plant simulation.

Therefore, there is no possibility to perform a significant comparison between results of the two methods. A fall-back position was used to get at least an idea of the more accurate Heliosat-3 irradiance data: The original STEPS-tool can calculate the Direct Normal Irradiance data using information of the Meteosat First Generation and additional atmospheric input data. The method of Schillings et al. (2004) is originally implemented in STEPS to calculate hourly direct normal irradiance data that are needed for the power plant simulation. Unfortunately, only irradiance data up to 2003 can be provided.

5. Working activities

The working activities within WP 6020 performed by DLR are described in detailed below:

- 1.) Modifying the STEPS-tool for external irradiance data input
- 2.) Re-organising of provided irradiance data (DNI) for efficient data processing within STEPS
- 3.) Modifying STEPS-tool for chosen power plant configuration
- 4.) Modifying STEPS-tool for chosen geographic region (Canary Islands / Spain) (economic parameters)
- 5.) Running STEPS for example region Canary Islands
- 6.) Analysing the results

5.1. Modify the STEPS-tool for external irradiance data input

A meteorology module within STEPS calculates the hourly Direct Normal Irradiance (DNI) using data of the satellite Meteosat First Generation (MFG) and additional atmospheric data. Using hourly data of at least one year of DNI, STEPS calculates e.g. energy output or levelized electricity cost (LEC) of the chosen type of solar thermal power plants with a spatial resolution of 1km x 1km.

The internal DNI processing scheme of the STEPS-tool was substituted with an input scheme for accessing the external Heliosat-3 irradiance data.

5.2. Re-organization of the provided irradiance data (DNI) for efficient data processing within STEPS

The Heliosat-3 irradiance data were provided in monthly files, separated for each island, in ASCII format. The data stream was organized as 744 hourly values consecutively, for each pixel.

a.) To run the STEPS power plants simulation, one complete year of hourly data is needed. Unfortunately, no complete year could be provided. Therefore, a synthetic year was created using following filling scheme:

Jan	based on 1/2005
Feb	based on 1/2005
Mar	based on 3/2004 (first half of the month missing, DNI = 0)
Apr	based on 4/2004
May	based on 5/2004
Jun	based on 6/2004
Jul	based on 7/2004
Aug	based on 8/2004
Sep	based on 9/2004
Oct	based on 10/2004
Nov	based on 11/2004
Dec	based on 12/2004

Now, a complete year (with some remaining missing values in March, hourly DNI value = 0) could be used for the power plant simulation.

To obtain data in a suitable input format for STEPS, further modifications were performed:

b.) The ASCII-data stream was converted into BINARY and all single island files were merged to one file that includes all Canary islands.

c.) The orientation of the provided solar irradiance data was with respect to a horizontal surface. For power plant simulation, the direct irradiance with respect to a surface perpendicular (normal-oriented) to the solar rays (direct normal irradiance) is needed. Therefore, all hourly values were corrected with the solar zenith angle. The solar zenith angle for each hour was calculated using the mean value of the 5-min solar zenith angle. The local time of the sunset and sunrise was taken into account for building the mean values of the zenith angle for the morning and evening hours.

d.) The data stream was reorganized from time consecutively values for each pixel into slot organized data stream. This was done to perform the next step:

e.) Re-projection from satellite projection into a plan-parallel projection, a kind of cylinder projection. All further geographic input data (e.g. landcover, slope, infrastructure data etc) exist in that plan-parallel projection.

f.) After the re-projection, the data stream was again re-organized in 744 hourly consecutively values, for each pixel. This was done to increase the speed for data access (read- the irradiance data from hard-disk).

Figure 4 shows the defined window for the example region Canary Islands. The shown values are elevation above sea level in meters.

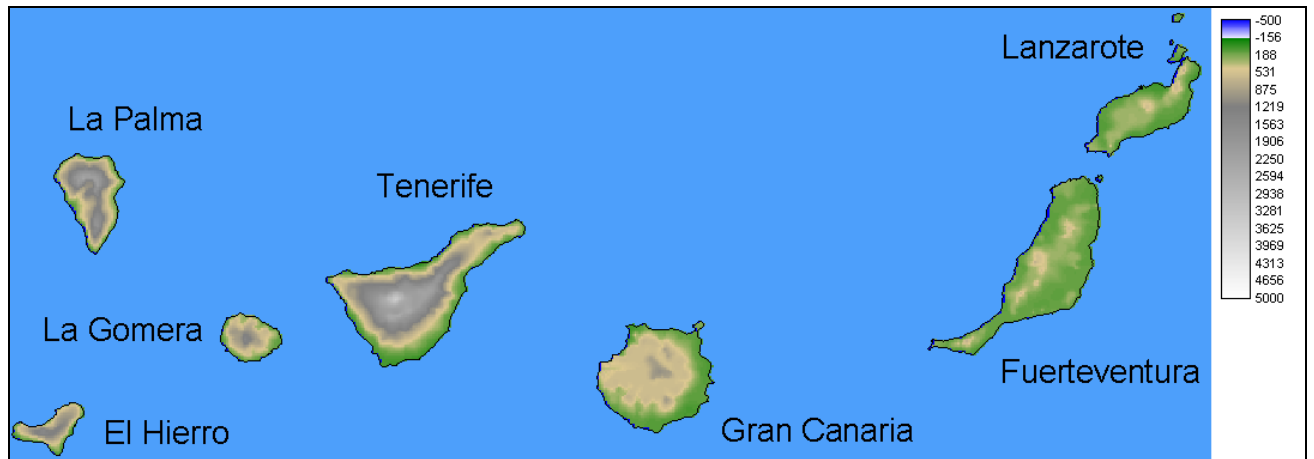


Figure 4: Defined window for example application. Elevation of Canary Islands in [m].

5.3. Modifying STEPS for chosen power plant configuration

Before a country analysis with STEPS can be performed, the desired power plant technology has to be chosen. In STEPS, different power plant configurations are available (BMU, 2003). For this application, the following power plant configuration was used:

50 MW_{electric}, Direct Steam Generation (DSG), solar only (no storage)

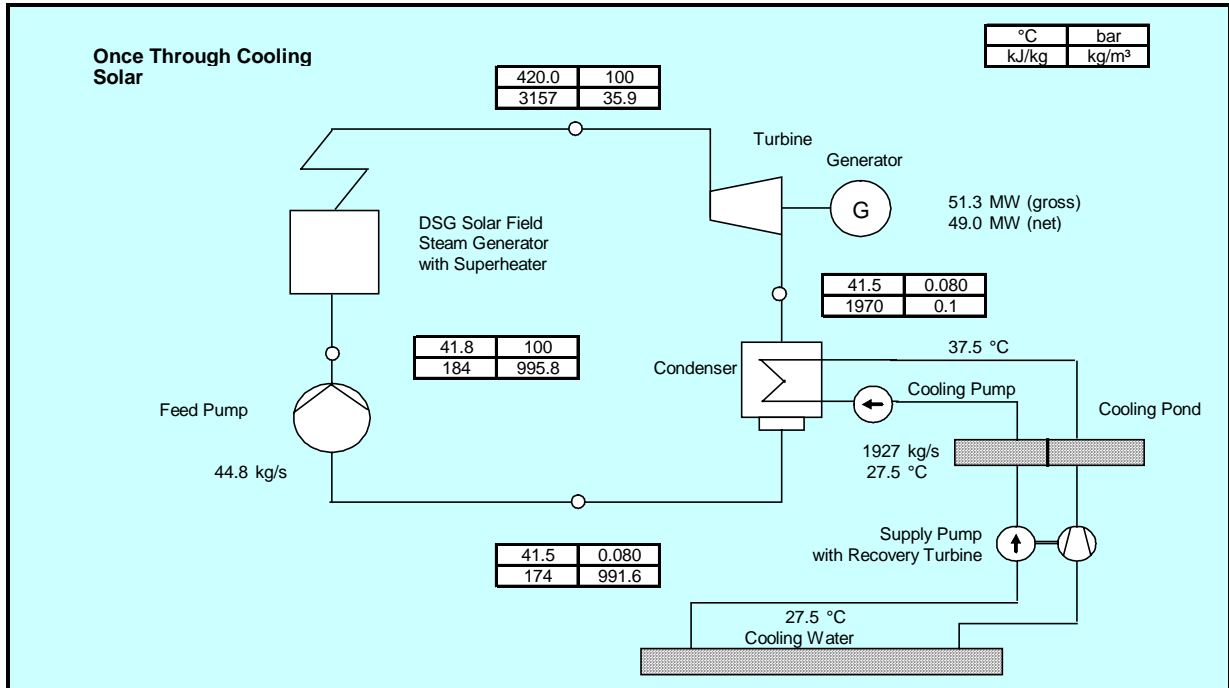


Figure 5: Schematic of the direct steam generating (DSG) concentrating solar power plant modelled with STEPS under typical operating conditions (SOKRATES, 2003)

The power plant uses parabolic trough direct steam generating collector field presently developed within the project of the European Commission INDITEP (INDITEP, 2004). The solar field is coupled to a simple Rankine steam cycle for power generation. Under nominal conditions of solar irradiance, the model plant produces 50 MW of net electric power to be fed into the grid. This is about 10 % of the capacity requirements of Gran Canaria or Tenerife of about 600 MW each (RETELGAS, 2002).

The power plant specific technical parameters can be found in the attached Table 3

5.4. Modifying STEPS for chosen geographic region (Canary Islands / Spain) (economic parameters)

STEPS can be applied for each country or region if economic and infrastructure data for the selected country are available. Country specific information is for example inflation rates, interest rates, labour costs etc. The data used in STEPS for this study refers to the economic data of Spain and Canary Island. Missing information was properly estimated. The attached Table 4 shows the scheme of cost assessment and the value of cost parameters and plant performance parameters.

5.5. Running STEPS for example region Canary Islands

Two processing runs using the modified STEPS-tool as described above were performed for the selected region as shown in

Figure 4:

- One processing run using the internal irradiance scheme. For the complete year 2001, the Direct Normal Irradiance DNI was calculated within STEPS and was used as input for the STEPS power plant simulation. The results of this DNI calculation are shown in Figure 6 (top) and Figure 7 (top).
- One processing run using the external irradiance data provided by Heliosat-3. For a synthetic year (based on months as described above), the Heliosat-3 DNI was used as input for the STEPS power plant simulation. The results of this DNI calculation are shown in Figure 6 (bottom) and Figure 7 (bottom).

The simulation process of STEPS results in maps of suitable sites for solar thermal power plants (“exclusion maps”). Such a map is shown in Figure 8. Combining exclusive data, irradiance data, the power plant simulation and information on the net present value, one resulting map is e.g. a ranking based on levelized electricity cost (LEC). Figure 9 shows the resulting LEC-ranking without (top) and with information on suitable sites (bottom). Figure 10 and Figure 11 allow a more detailed analysis of the example islands Gran Canaria and Fuerteventura.

6. Results

6.1. Irradiance

Figure 6 and Figure 7 show DNI irradiance data of annual sums for the Canary Islands in kWh/m²a. Top figures show the DNI calculated with the STEPS-DNI-algorithm for the year 2001. The spatial resolution is dominated by the Meteosat 7 resolution of 5km x 5km. Within one Meteosat pixel, the DNI varies due to the used Digital Elevation Model with a spatial resolution of 1km x 1km.

Bottom figures show the DNI calculated by the Heliosat-3 algorithm. This annual sum is not a realistic one, because of missing data for several months. A synthetic year was build as described above. The spatial resolution of DNI is 1km x 1km. The high resolution leads to an accurate reproduction of the solar regime.

The spatial variability of the solar regime shown in bottom and top figures show a significant consistency. For example, both methods show Gran Canaria with lower radiation in the north-east and higher values in the south-west. The 1km x 1km resolution of the Heliosat-3 data provides amazing details on local orographic conditions which affect the solar regime. Such detailed information is very helpful for finding high-yield potential sites for solar thermal power plants. The method imbedded in STEPS gives a good estimate of the solar regime.

6.2. Exclusion Map

STEPS can provide maps which show suitable sites for large solar thermal power plants. Restrictions for building a plant were made regarding the actual use or condition of the sites. Following sites are excluded e.g.:

- Sites used by industry, infrastructure, military
- Hydrographic sites (lake, rivers)
- Protected areas
- Sites with specific landcover (e.g. forest, agriculture, etc.)
- Sites with a too high slope (>1.5%)

Some exclusive parameters are restrictive, some are “custom-defined” (**Table 1**). **Figure 8** shows the exclusion map for the Canary Islands produced by STEPS. Some islands have only little suitable sites (which are shown as white areas in the figure), some have more, e.g. Fuerteventura. Most of the exclusive restrictions of that island are due to slope (and infrastructure of one city). The rest of the island provides potential sites for solar thermal power plants.

Table 2 gives the identified values for the suitable areas. Gran Canaria and Fuerteventura are shown as example. The values in

Table 2 are derived by multiplying the white-marked areas (suitable sites) in Figure 8 with the corresponding real size of the respective pixel (in km²) and add up all values for each island.

Exclusion Criteria for CSP Plants	compulsive	optional
Slope of Terrain		
> 2,1 %	x	
Land Cover		
Sea	x	
Inland Water	x	
Forest		x
Swamp	x	
Agriculture		x
Rice Culture		x
Hydrology		
Permanent Inland Water	x	
Non-Permanent Inland Water		x
Regularly Flooded Area		x
Geomorphology		
Shifting Sand, Dunes	x	
Security Zone for Shifting Sands 10 km		x
Salt Pans		x
Glaciers	x	
Security Zone for Glaciers		x
Land Use		
Settlement		x
Airport		x
Oil or Gas Fields		x
Mine, Quarry		x
Desalination Plant		x
Protected Area, Restricted Area		x

Table 1: Compulsive and optional criteria for the exclusion of terrain for CSP plants. Within the MED-CSP study, all criteria were applied for the site exclusion of CSP.

6.3. Site Ranking based on Levelized Electricity Cost (LEC)

Together with the solar irradiance as input, the power block simulation, the net present value and all other available country information, the LEC can be determined. This value gives an idea about the cost for each produced kWh for the defined solar thermal power station and for the investigated site. Figure 9, Figure 10 and Figure 11 show some results. The results are shown as a relative ranking with no absolute values.

Complete Area Canary Islands	7273 km ²
Non-excluded Area Canary Islands produced by STEPS	1166 km ²
Solar Electricity Potential Canary Islands	90 TWh/y
Complete Area Gran Canaria	1532 km ²
Non-excluded Area Gran Canaria produced by STEPS	302 km ²
Solar Electricity Potential Gran Canaria	25 TWh/y
Complete Area Fuerteventura	1731 km ²
Non-excluded Area Fuerteventura produced by STEPS	645 km ²
Solar Electricity Potential Fuerteventura	50 TWh/y

Table 2: Areas for Canary Islands, Gran Canaria and Fuerteventura. The values for non-excluded areas are based on the STEPS analysis. The solar electricity potentials are also given. They compare very favourably with the total annual electricity demand of the Canary Islands for 2005 that was predicted to be around 9 TWh/y, (RETELGAS, 2002)

The results of the study are particularly useful for energy planning by regional authorities, as they show the detailed localisation of the available solar electricity potentials of the analysed territory. They also can be used to quantify the overall electricity yield that can be achieved with different renewable energy technologies in a region. The specific renewable electricity yield of around 80 GWh/km²/y of concentrating solar power plants in the Canaries is about 4 times higher than the equivalent area-specific electricity yield of e.g. a wind park in this region. This may be of primary concern taking into account the valuable and scarce land resources of the islands.

For every point of the map, the satellite based assessment methodology of STEPS yields an hourly time series of the solar power capacity of a solar thermal power plant. By correlating this time series with the time series of electricity demand (load curve), the capacity credit of different renewable power technologies can be evaluated. In this context, concentrating solar power plants are especially useful, as they can be build with a thermal energy for night-time operation, and additionally can be operated on the basis of conventional fuels, always guaranteeing firm capacity. Thus, they combine very well with other, fluctuating renewable energy sources like wind or photovoltaic systems, as they can be used to compensate the power fluctuations occasioned by those technologies.

7. Conclusion

The satellite resource assessment with the given quality of the HELIOSAT-3 methodology is very useful for concentrating solar power project developers, as they can make a very reliable economic analysis of the performance of the power plants prior to the investment phase. The high accuracy of the determined radiation data is a critical criterion for using such data for project planning and power plant simulation. The more accurate the data the more accurate the future energy output and electricity yield can be determined.

Heliosat-3 helps for future project planning and power plant simulations in providing such accurate data, with a high temporal and spatial resolution.

However, although the results are very accurate, it must be taken into account that the naturally inter-annual fluctuations of solar energy can be of the order of 20-30 %. Therefore, long-term time series (> 10 years) of data are necessary to yield acceptable security for economic planning.

8. References

BMU (2003): SOKRATES (2003): Solarthermische Kraftwerkstechnologie für den Schutz des Erdklimas.

Broesamle H., H. Mannstein, C. Schillings and F. Trieb (2001): Assessment of Solar Electricity Potentials in North Africa based on Satellite Data and a Geographic Information System. *Solar Energy* 70 (1), 1-12.

Schillings C., H. Mannstein and R. Meyer (2004): Operational method for deriving high resolution direct normal irradiance from satellite data. *Solar Energy* 76, 475-484.

INDITEP (2004) European Commission, Contract ENK5-CT-2001-00540, INTEGRATION OF DSG TECHNOLOGY FOR ELECTRICITY PRODUCTION

Kronshage S., C. Schillings and F. Trieb (2002): Country analysis for solar-thermal power stations using remote sensing methods. *Proc. of World Renewable Energy Congress VII*, Cologne, Germany.

RETEL GAS (2002): PLANIFICACIÓN DE LOS SECTORES DE ELECTRICIDAD Y GAS, Ministerio de Industria, Turismo y Comercio, Madrid 2002

9. Figures and Tables

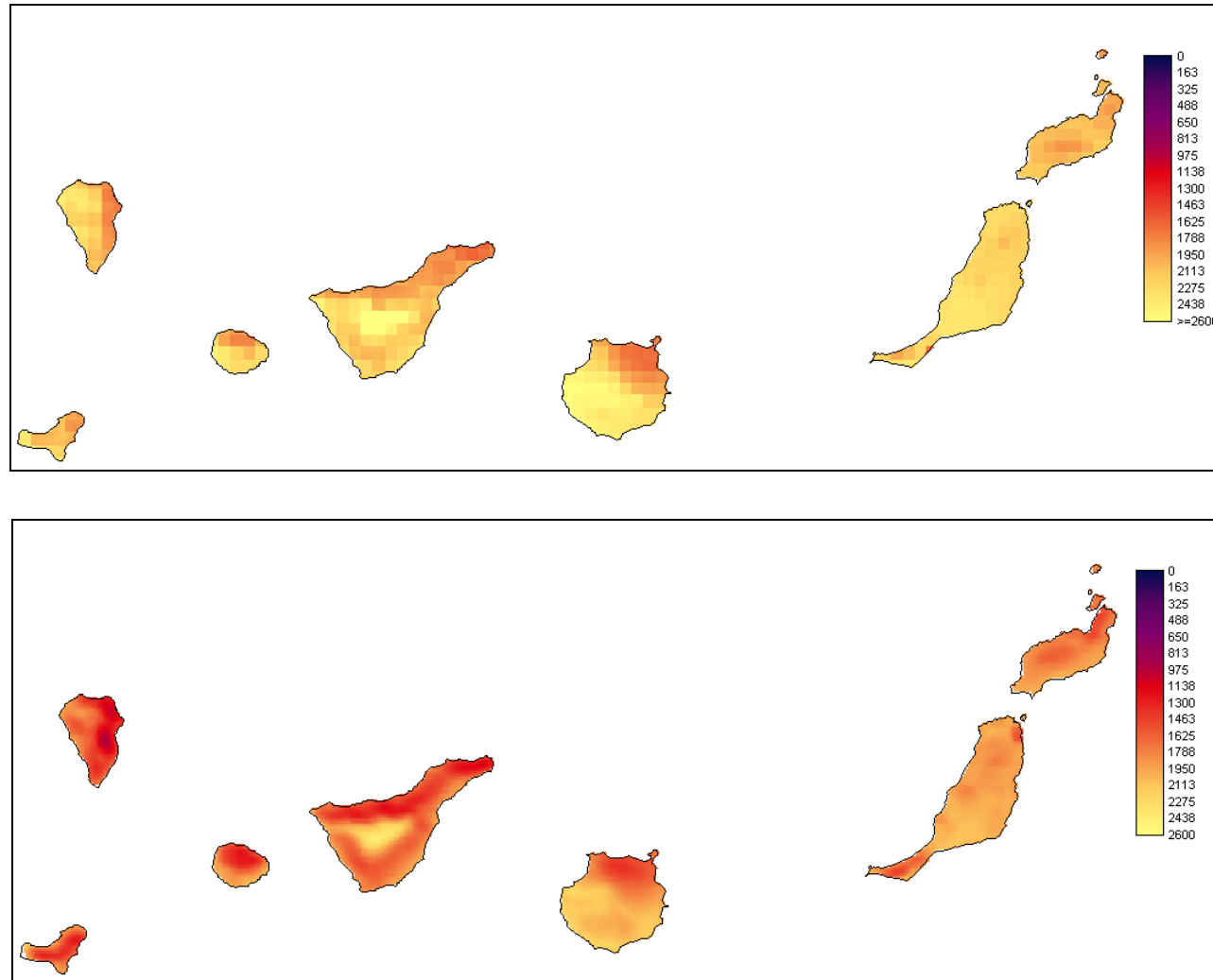


Figure 6: Top - DNI based on DLR-method for Canary Islands for the yearly sum 2001. Bottom - DNI based on Heliosat3 method for Canary Islands for the synthetically yearly sum. The values shown in the legend are in kWh/m²a.

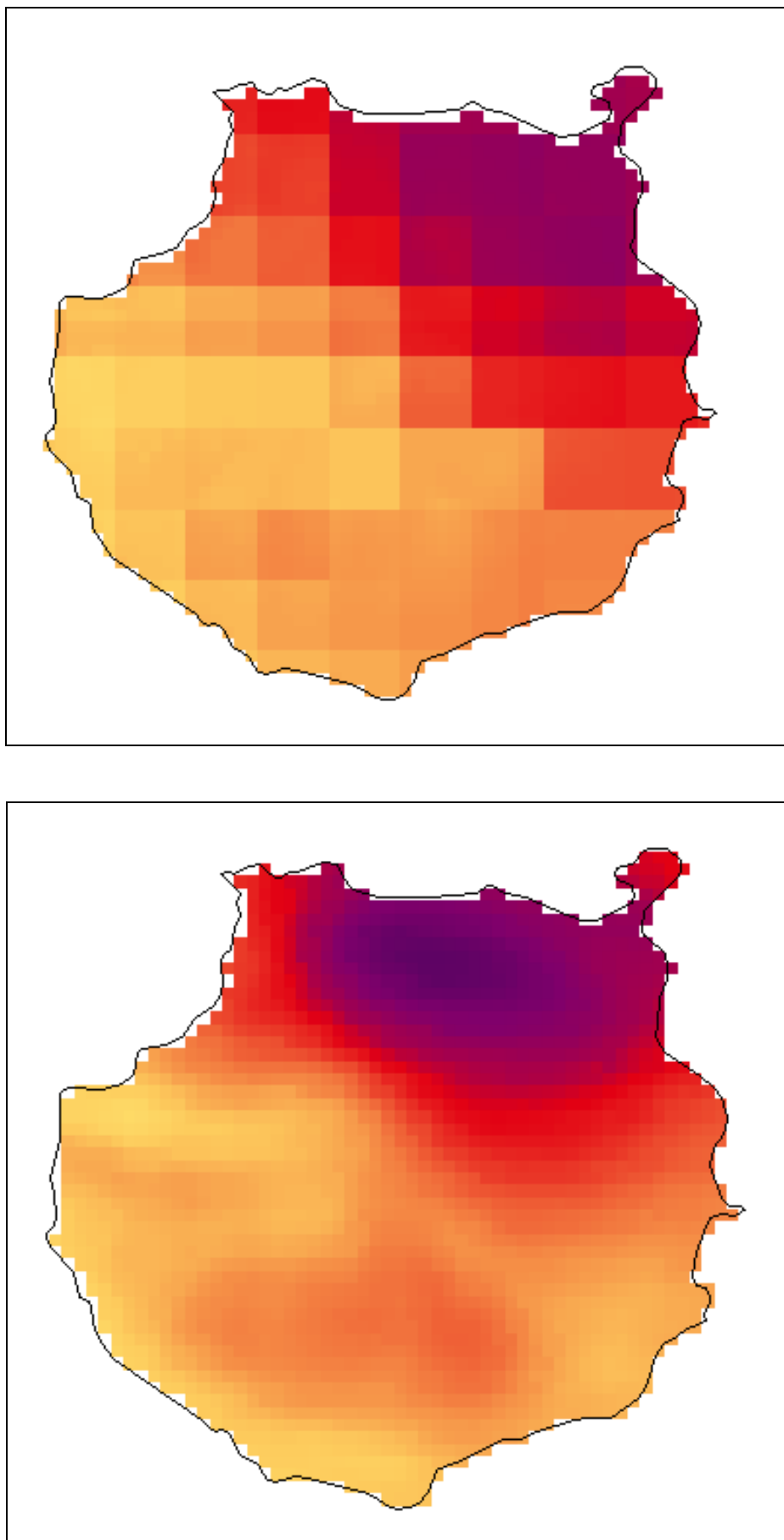


Figure 7: Top - DNI based on DLR-method for Gran Canaria the yearly sum 2001. Bottom - DNI based on Heliosat3 method for Gran Canaria for the synthetically yearly sum. No legend, colours adapted for comparison of different spatial resolutions!

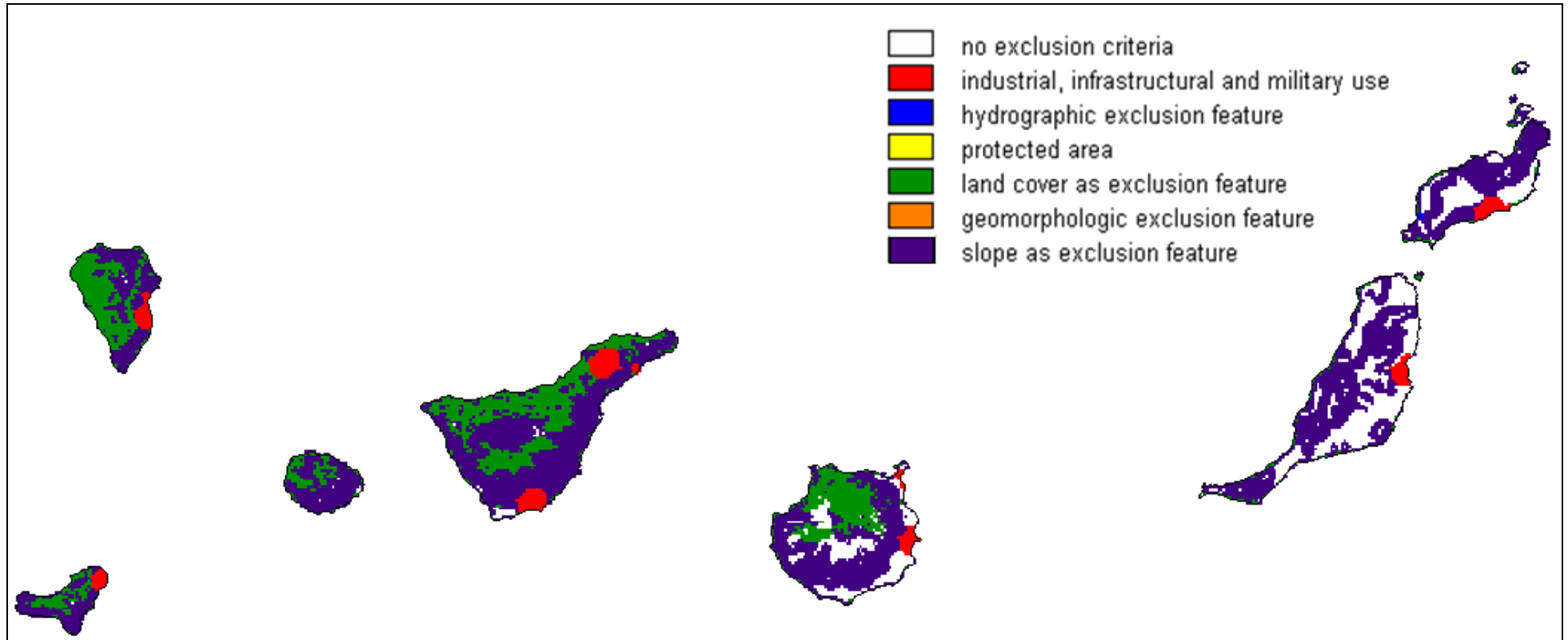


Figure 8: Exclusion map for Canary Islands for solar thermal power plants based on STEPS-calculation. White areas are suitable areas for potential power plant sites.

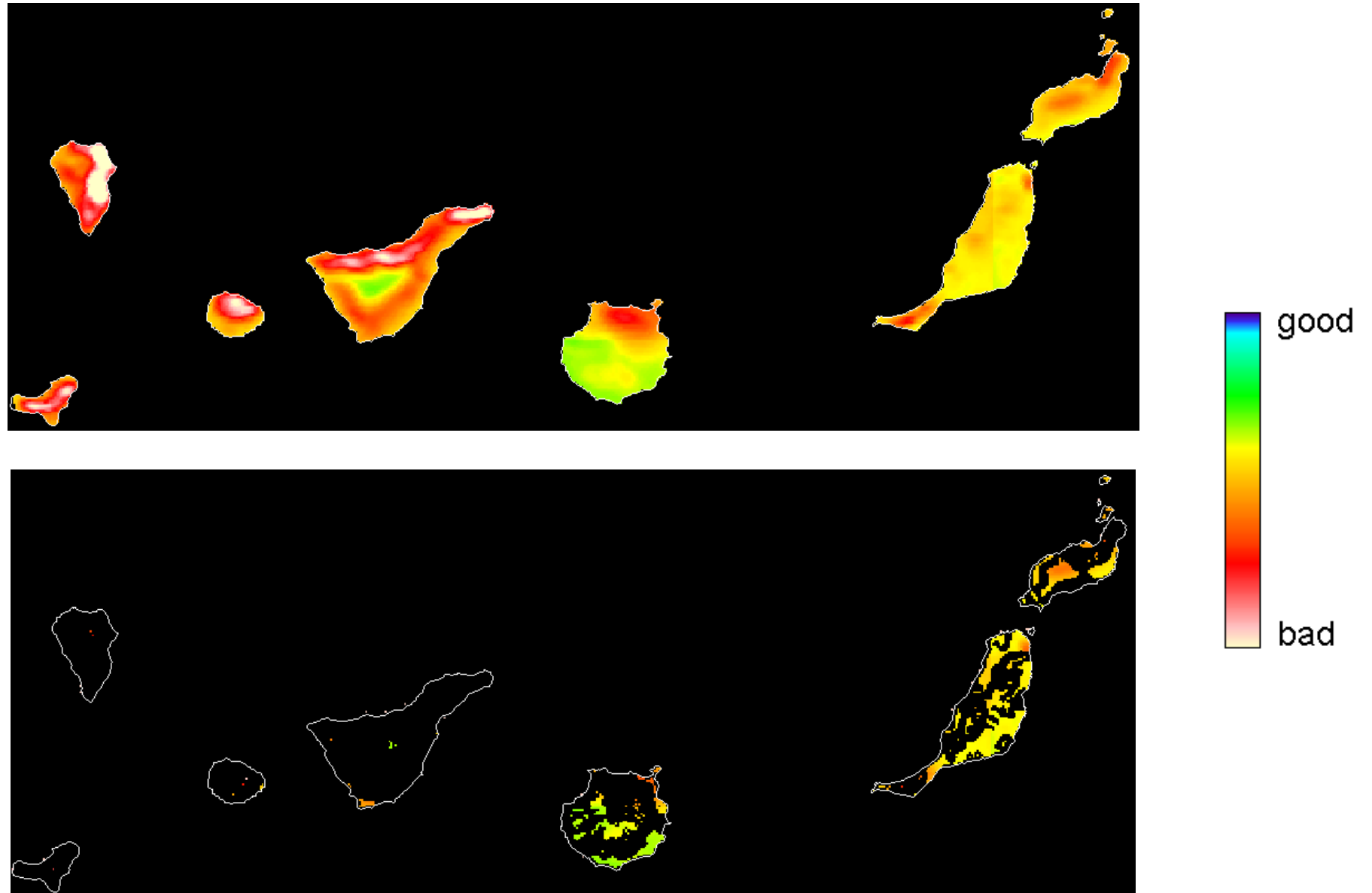


Figure 9: Site ranking based on Levelized Electricity Cost (LEC) for 50MW Direct Steam Generation (DSG) solar only, based on STEPS calculation. Top – for all sites. Bottom – suitable sites only (with exclusion mask based on Figure 8).

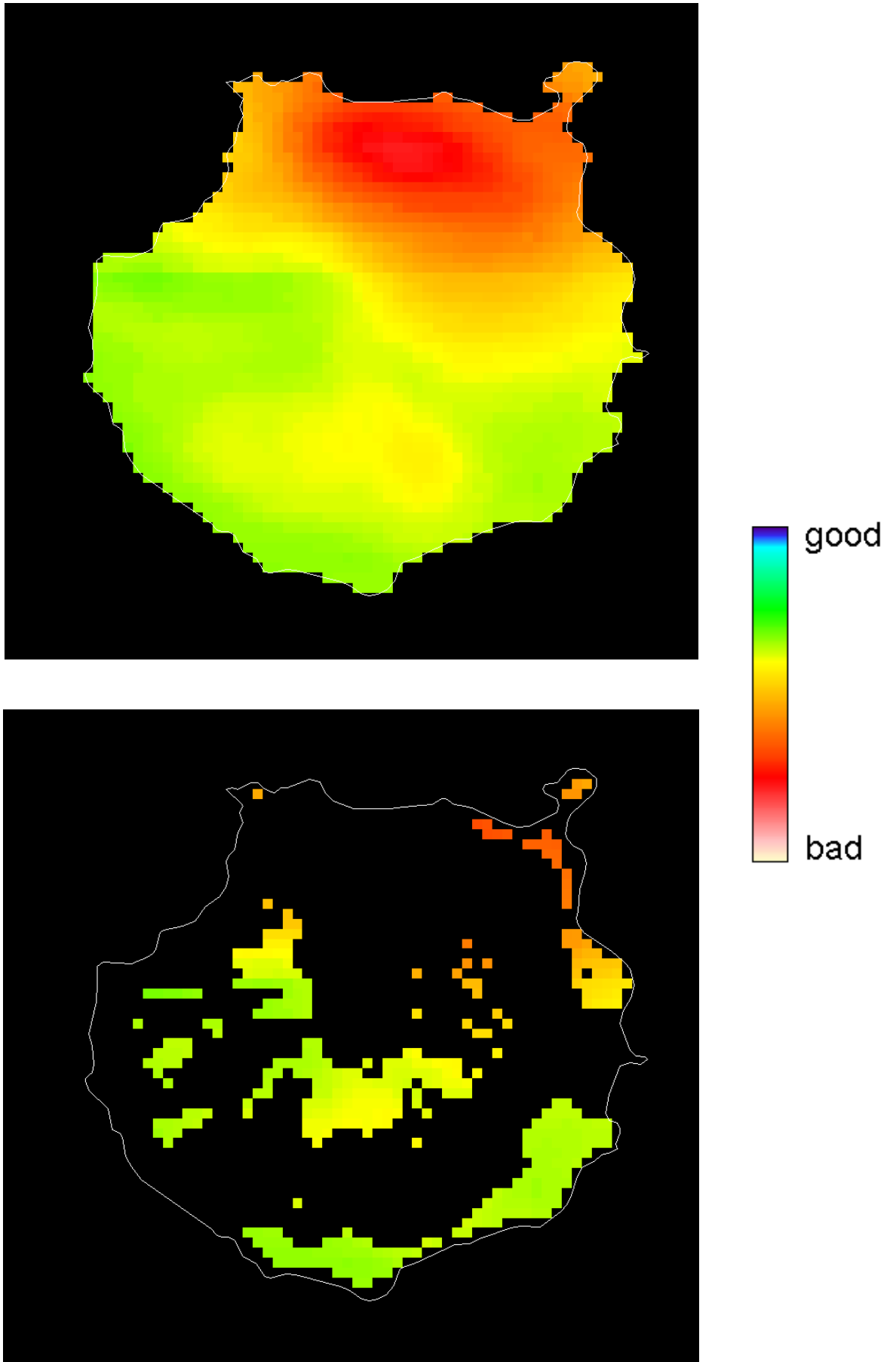


Figure 10: As Figure 9, site ranking based on Levelized Electricity Cost (LEC), zoomed into Gran Canaria.

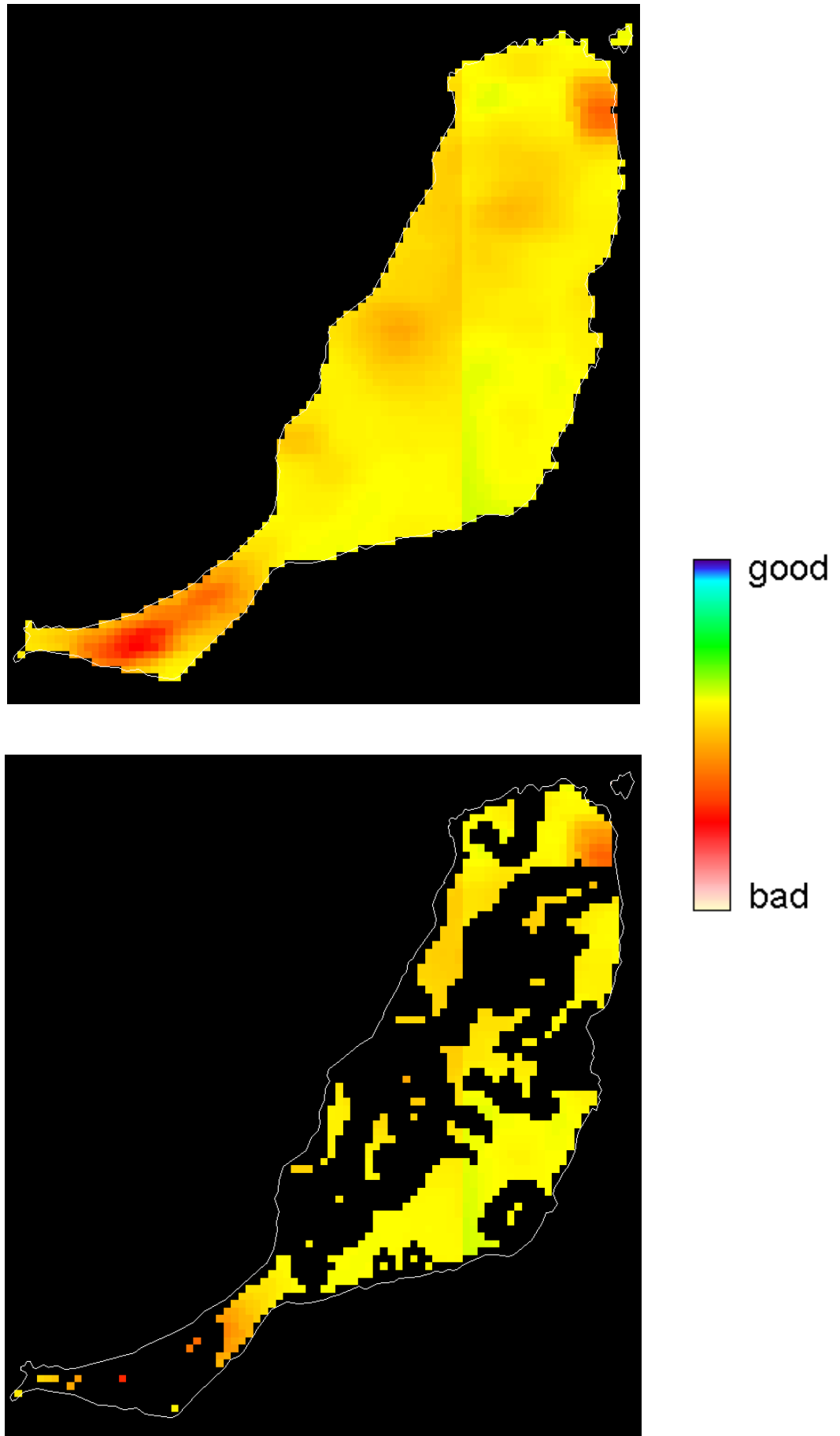


Figure 11: As Figure 9, site ranking based on Levelized Electricity Cost (LEC), zoomed into Fuerteventura.

solar field size [m ²] (depending on cooling type)	{230350, 244460, 254230}
efficiency of recovery turbine[]	0.8
efficiency of cooling pump [], fresh water cooling.	0.71
efficiency of supply pump [], fresh water cool.	0.71
efficiency of cooling fan []	0.6
efficiency of cooling pump [], evaporation cool.	71
efficiency of cooling pump [],evaporation cool.	0.71
efficiency of cooling fan []	0.6
efficiency of feed pump []	0.71
efficiency of generator []	0.965
efficiency of recovery turbine, MED []	0.85
solar zenith angle (nominal case) [°]	40.6
solar azimuth angle (nominal case) [°]	88.5
cooling water temperature [°C]	22
ambient temperature [°C]	25
ambient preassure [bar]	0.98
relative humidity []	0.5
distance to cooling resource [m]	500
life steam pressure [bar]	100
velocity at cooling pump [m/s] fresh water cooling	2.5
velocity at supply pump [m/s] fresh water cooling	1
Frischdampfperatur [°C]	90
Resistancy Factors of Cooling Pipelines	0.9
	0.9
	10
	230
	0.25
	0.011
Resistancy Factors of Supply Pipelines	0.9
	0.9
	0.25
	0.011
Temperature Increase Cooling Water [°C]	10
Pipe Friction Factor	0.018

Table 3: Selected power plant parameters for 50MW_{electric}, DSG, solar-only (data based on BMU (2003)).

Cost Calculation Parameters

Parameter	Value	Unit
-----------	-------	------

Financial Project Parameters		
Economic Life Time of the Plant	25	a
Longterm Loan Payback Period	10	a
Equity Share	30	%
Real Interest Rates		
Equity Interest Rate during Construction	18.0	% p.a.
Loan Interest Rate during Construction	9.0	% p.a.
Equity Interest Rate during Operation	12.0	% p.a.
Loan Interest Rate during Operation	6.0	% p.a.

Parameters during Operation		
Operation and Maintenance		
Wages, Personnel Non-Conv. Components	60.0	kEuro/(P*a)
Wages, Personnel Conv. Components	60.0	kEuro/(P*a)
Materials, Non-Conv. Components	1.3	%/a
Materials, Conventional Components	1.3	%/a
Spare Parts, Non-Conv. Components	0.2	%/a
Spare Parts, Conventional Components	0.2	%/a
Insurance during Operation	1.0	%/a

Country Data Source	Manual Insert ▼
---------------------	-----------------

Manual Insert of Country Data	Value	Unit
Discount Rate	2.4	% p.a.
Fuel Costs 2000		
Natural Gas	0.00	Euro/MWh _t
Fuel#2	22.00	Euro/MWh _t
Coal	10.00	Euro/MWh _t
Real Price Escalation Rates during Op.		
O&M, Labor	0.0	%/a
O&M, Materials	0.0	%/a
Spare Parts	0.0	%/a
Natural Gas	0.0	%/a
Fuel#2	1.0	%/a
Coal	1.0	%/a
Insurance during Operation	0.0	%/a
Inflation Rate	0.0	% p.a.

LEC-Calculation

Parameter	Unit	
Project Parameters		
Type		SEGS
Manufacturing in		Manual
Design		
Rated Power	MW _e	50
Collector Area	m ²	230350
Cooling Type		Sea Wat.
Fuel Type		Solar Only
Fossil Share	%	0
Annual Thermal Power Yield	GWh _t /a	250
Annual Thermal-Electric Efficiency	%	32.0
Annual Electricity Yield	GWh _e /a	80
Personnel during Operation		
Non-Conventional Components		10
Conventional Components		18
Investment Costs		
Site and Infrastructure		
Land	kEuro	691
Site Preparation	kEuro	1382
Internal Infrastructure	kEuro	1100
Total Site and Infrastructure	kEuro	3173
Solar Field	kEuro	53793
Heat Collecting	kEuro	19500
Metal Structure and Tracking	kEuro	20500
Control	kEuro	1850
Heat Transfer Fluid	kEuro	2250
Materials & Work	kEuro	8370
Freight & Transport	kEuro	1323
Heat Transfer System	kEuro	4428
HTF Heat Exchanger	kEuro	1850
Solar Field Superheater	kEuro	0
Pumps	kEuro	1750
Materials & Work	kEuro	720
Freight & Transport	kEuro	108
Total Non-conv. Components	kEuro	58221
Power Block	kEuro	20480
Turbine & Generator	kEuro	13500
Electric System	kEuro	3150
Materials & Work	kEuro	3330
Freight & Transport	kEuro	500

Balance of Plant	kEuro	10024
Cooling System	kEuro	1200
Water Treatment	kEuro	520
Steam Boiler	kEuro	0
Fuel System	kEuro	0
Flue Gas Treatment	kEuro	0
Electric System	kEuro	780
Instrumentation & Control	kEuro	1130
Connection to Grid	kEuro	2250
Materials & Work	kEuro	3968
Freight & Transport	kEuro	176
Total Conv. Components	<i>kEuro</i>	30504
Total Component Costs	<i>kEuro</i>	88725
Direct Investment	<i>kEuro</i>	91898
Services	kEuro	7098
Engineering	kEuro	2662
Project Development	kEuro	1774
Project Management	kEuro	1774
Commissioning	kEuro	887
Total EPC Investment	<i>kEuro</i>	98996
Other Costs during Construction	kEuro	24517
Insurance during Construction	kEuro	444
Contingencies	kEuro	4950
Equity Interest during Construction	kEuro	8963
Loan Interest during Construction	kEuro	10161
Total Project Investment	<i>kEuro</i>	123513
Costs during Operation		
Operation and Maintenance	kEuro	56113
O&M, Labor, Non-Conv. Components	kEuro	11182
O&M, Labor, Conv. Components	kEuro	20128
O&M, Materials, Non-Conv. Components	kEuro	14106
O&M, Materials, Conv. Components	kEuro	7390
Spare Parts, Non-Conv. Components	kEuro	2170
Spare Parts, Conv. Components	kEuro	1137
Fuel	kEuro	0
Other Costs during Operation	kEuro	84414
Insurance during Operation	kEuro	16536
Equity Interest during Operation	kEuro	50994
Loan Interest during Operation	kEuro	16885
Total Costs during Operation	<i>kEuro</i>	140527
Levelized Electricity Costs	<i>ct/kWh_e</i>	17.7

Table 4: Cost Calculation Parameters for Canary Islands / Spain.