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A novel method to calculate the solar energy potential based on cadastral data: A Canary Island case study

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Abstract. The energy consumption in buildings represents more than the 30% of the total energy demand in Europe. The new standards to minimize the energy consumed and energy construction codes are increasing their scope and rigor in all countries, highlighting the use of more efficient construction technologies and the use of renewable technologies in the rehabilitation of buildings. Although the sector needs faster changes to move towards the net zero emissions scenario by 2050 (NZE), the incorporation of renewable generation in the mode of self-consumption or net-metering has been shown to be an interesting way to explore in achieving of the NZE target.
Therefore, several initiatives have been developed during the last years to obtain information maps and tools to calculate the photovoltaic (PV) potential to be installed on the roof of buildings. The main objective of these solutions is to provide an accurate calculation of the available surfaces, taking in account shading and climatological aspects in a certain location. By means of the accessible public data, we propose a new methodology using the Spanish cadaster information and lidar layers to obtain the building geometry and a system based on EnergyPlus to calculate the PV potential and the maximum PV power to be installed.

Key words. Energy transition, PV cadaster, PV potential.

1. Introduction

The Canary Islands, as an outermost region and with a limited territorial area, suffer from a patent dependence on fossil fuels for energy production, with the contribution of renewable energy sources to supply the current island energy demand still being low [1].
Many initiatives have been proposed to take advantage of the wind and photovoltaic potential of the Canary Islands. However, the use of renewable sources has been mainly approached following a centralized model. This fact implies the renewable energy generation is carried out far away from the demand sites.
Although this approach has advantages of scale, it also comes with the limitation of requiring a large land surface area. This is particularly challenging in territories with high urban density.
In contrast to the centralized model, self-consumption or net metering systems allow for the allocation of small generation plants near consumption points. This approach leverages existing infrastructure and reduces energy transportation losses. As a result, the number of photovoltaic (PV) power plants installed on building rooftops is dramatically increasing along the world [2].
This article aims to analyze the photovoltaic potential of rooftops on the Canary Islands, these islands represent an example of an isolated electrical system with limited land availability, with the aim of create a novel solar energy potential assessment to foster the implementation of self-consumption.
This approach is based on the location of buildings, using cadastral information and LiDAR layer of the surrounding environment. It will also factor in the boundary conditions, different typologies of the built environment, diverse urban contexts, and the varying levels of irradiation across the archipelago's climatic zones.

2. Materials and methods

The buildings have been modelled using the DesignBuilder software, a tool based on EnergyPlus engine, from the DXF files available from the Spanish Cadaster.
As an initial phase, the cadastral data of the plants and buildings are obtained directly from the resources provided by the General Directorate of Cadaster (DGC), through its electronic website. The website offers downloadable compressed files containing georeferenced geometric data of the buildings. Additionally, these files include other relevant data such as the number of floors, type of use, year of construction, etc.
Regarding downloading this data from the DGC, several methods are available through its electronic website:
- Using the cartographic viewer. It allows the selection of plots and the download of associated data in the following file formats: XML, DXF, GML and U GML.

- Using the link “Dissemination of cadastral data” and “Download of vector cartography”. In this case, a digital certificate is needed, and it allows downloading by municipalities. In this approach, ShapeFile (.shp) type files are obtained.
- Using the “INSPIRE Cadastral Mapping Services”. For this option it is advisable to download using the available API (Application Programming Interface), since the direct download can be somewhat tedious.

During the work, two download methods were used based on the last option of those presented: (1) using a plugin for the QGIS tool (Inspire Cadaster Download), which uses the API, and (2) using a custom development Python script, thus performing direct download from the web. As a result of this process, Geography Markup Language (.gml) type files are obtained.

Once the files have been downloaded, the file corresponding to the buildings will be selected and incorporated into a new project in QGIS for subsequent processing.

On the other hand, to download the cadastral data corresponding to the properties, a Python script is created, which uses the web scraping technique to download the data shown in the web query in the form of a table. For each query, that is, for each cadastral reference, a table in HTML format is stored in a specific directory for later visualization using the QGIS tool. In this way, we will have a folder with as many tables as cadastral references are consulted.

Another of the data identified as necessary for the project objective are the results of the simulations with EnergyPlus. The simulation results, which are included in an .eso file, being associated with a “block” or geometry, are not associated with a cadastral reference or a georeferenced object. Therefore, it is necessary to go one step further and associate these “blocks” with the geometries of the buildings, to later georeferenced those blocks and associate a cadastral reference to them.

Therefore, after each simulation, it is necessary to generate a CAD file that relates the geometries of the buildings to the “blocks”. This CAD file is introduced into a QGIS project along with a layer that contains the same geometries of the simulated buildings (Cadastral layer). Subsequently, the vertices of the geometries of the blocks of the CAD layer are marked and they are equal to the vertices of the georeferenced geometries (Cadaster layer). Finally, a new GIS layer is generated that will include the georeferenced geometries, cadastral references, and block numbers.

EnergyPlus is a software devoted to the modelling of buildings, air conditioning systems and renewable energy. This software allows the evaluation of energy efficiency, both in existing buildings and in their design in each of their phases. With this tool, maps of the annual solar irradiation incident on the roofs of the selected blocks can be obtained.

Tekton 3D is a facility design software. Among its functions, divided into different calculation modules, the energy evaluation of buildings, as well as the calculation of renewable energy installations are available. Using this tool, the proposed installations and sensitivity studies have been carried out, regarding the variation of orientations and inclinations of the photovoltaic modules.

In addition, the results of the photovoltaic simulations are compared with the calculations carried out using the procedure established in the Technical Specifications for Grid-Connected Installations for Photovoltaic Solar Energy Installations (Institute for Energy Diversification and Saving (IDAE), [3]).

The proposed methodology has been carried out according to the next steps:

Step 1: Identification and treatment of relevant conditions.

Using the available data in the public databases, the recognition and analysis of the relevant parameters in energy production of the building have been considered.

Depending on the place, the considered parameters related to the construction characteristics of the buildings, such as the orientation, inclination and the useful surface area of its roof and the shadows projected by the surrounding structures, have been studied. Once these parameters have been identified and classified, the data set have been, recorded, and assessed specifically in each building.

To carry out the identification of the relevant conditions several databases have been used: (i) the Spanish Cadastre, [4] which has provided the shape and contours of the buildings information and Grafcan Database [5] with the adequate orthophotos and plane information of the placements.

Step 2: Classification of the parameters.

The obtained variables have been classified in two factors, related with the nature of the datasets:

(i) Meteorological factors. The influence of different meteorological variables on energy production for the PV production have been considered and evaluated, to create a PV production model. In this point three different commercial software have used to compare and analyze the feasibility of the meteorological variables.

(ii) Geometric and construction factors. It is assessed how urban development conditions the maximum photovoltaic electricity generation capacity, considering the surfaces to be occupied by the solar panels, their arrangement, as well as the influence of shadows projected from the study building itself and the adjacent buildings.

Step 3: Energy calculation model.

Based on the information from the previous step, conveniently recorded and weighted for each case, using an EnergyPlus based on models, the available PV potential have been calculated on the target roof, considering the adjacent buildings and elements. Also, shadows during different dates and hours during a year have been calculated to obtain the PV potential on the roof along the year.

Step 4: PV installation proposal.

Through Tekton 3D software and considering the previous steps, an optimized PV power plant have been proposed on two groups of blocks chosen as examples in Santa Cruz de Tenerife and Las Palmas de Gran Canaria.

To obtain the optimum installation, to maximize the use of the roof and to minimize the shadows on the proposed installation, various simulations have been carried out with different configurations and arrangement of panels on the roof of the selected building.

In addition, sensitivity studies have been carried out, using the Tekton 3D tool, to determine the best orientation and inclination of the modules, as well as the best combination for both variables. As the results of the calculations depend on the technical characteristics of the modules used as well as the inverter mode, mid-range commercial products commonly used in this type of installations have been considered. The solar module specification is shown in the table I. The parameters for the solar inverter are depicted in the table II.

Table I. – Solar module characteristics

STC Conditions	
Power	450 W
MPP Voltage	41.1 V
MPP Current	10.96 A
Open Circuit Voltage	49.1 V
Short circuit current	11.6 A
Efficiency	20.4%
NOCT Conditions	
Power	338 W
MPP Voltage	38.5 V
MPP Current	8.76 A
Open Circuit Voltage	46.4 V
Short circuit current	9.35 A
NOCT Temperature	41.0 ºC
Constructive characteristics	
Length ()	2108 mm
Width (mm)	1048 mm
Thickness (mm)	35 mm

Table II. – Solar inverter characteristics

Maximum DC power	27 kWp
Maximum voltage (Vmax)	1000 V
Minimum voltage to start power	188 V
Maximum DC current	33 A (Idc max 1) + 33 A (Idc max 2)
Voltage range MPP(T)	240-800 V
Maximum AC Power	15 kW
Nominal SC network voltage	230 / 400 V
Maximum AC current	29 A
Frequency	50 Hz
Power factor	1
Maximum performance	98,4%
European performance	98%
Dimensions	661x682x264 mm
Weight	61kg
Noise level	51dB(A)

3. Results and discussion

To carry out the study, two areas have been selected, located in the provincial capitals, made up of several building blocks. The first area, located in Santa Cruz de Tenerife, specifically in the El Toscal neighborhood, and the second, in Las Palmas de Gran Canaria, in the La Isleta neighborhood. The scope of work in Santa Cruz de Tenerife is delimited by the streets: San Francisco Javier, San Martín, Santiago, and San Juan Bautista (Figure 1). In the case of Las Palmas de Gran Canaria, the streets that frame the study area are: Veneguera, Saucillo, de Faya and Princesa Guayarmina (Figure 2).

Fig.1. Building blocks in El Toscal, Santa Cruz de Tenerife, Spain.

In the case of El Toscal, the area has been determined considering the volumetric and typological heterogeneity of the complex since it has buildings of different heights that cast shadows on each other (Figure 3).
In La Isleta, the blocks chosen to respond to the usual typology, with buildings of varying heights that give rise to roof surfaces that receive more and less solar radiation due to the projection of shadows between them (figure 4).

Fig.2. Building blocks in La Isleta, Gran Canaria, Spain.

At the same time, in the El Toscal neighborhood, a building has been selected, with an adequate orientation and roof surface, to install a photovoltaic installation that provides sufficient electrical production. The objective is to compare the results between the two simulation applications that are going to be used. With the models at the level of several blocks, both in Gran Canaria and Tenerife, solar irradiation maps will be created.
One of the aspects to be assessed in the comparison of the different design tools to be used and in the influence of meteorological factors is the annual photovoltaic production. For this purpose, the following distribution of the generation plant on the roof of the selected building is used, which is reproduced in the applications used (Tekton 3D and DesignBuilder) to compare and evaluate the results obtained (Fig. 5).

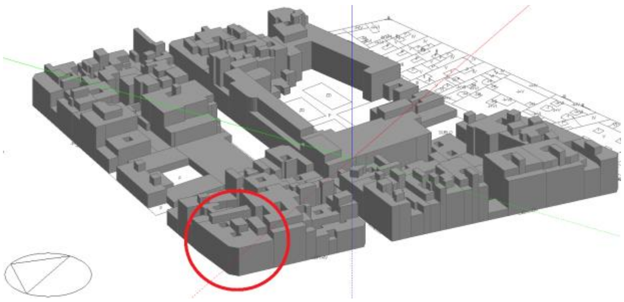

Fig.3. Set of building blocks modelled in DesignBuilder in the El Toscal neighbourhood and building selected for the simulated photovoltaic installation framed in a circle.

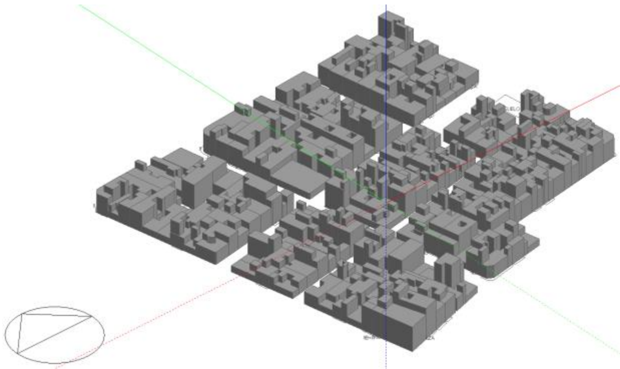

Fig.4. Set of building blocks modelled in DesignBuilder in the La Isleta neighbourhood.

Fig.5. Base photovoltaic plant for comparison of design tools and meteorological factors in Tekton 3D in El Toscal.

The spatial use of the roofs, tracing the position of the photovoltaic modules with parallel and perpendicular lines to their sides, allows achieving greater installed powers in the site facilities. However, when the building is not oriented towards solar south, these types of strategies can produce a significant reduction in energy production.

The adequate selection of the climate file is an important step to assure the accurate of the results. In this sense, three databases have been used for each study case: (i) the own climatic file incorporated in EnergyPlus (Fig. 6 and 9), the PVGIS climate file (Fig.7 and 10) and Meteonorm climate file (Fig.8 and 11).

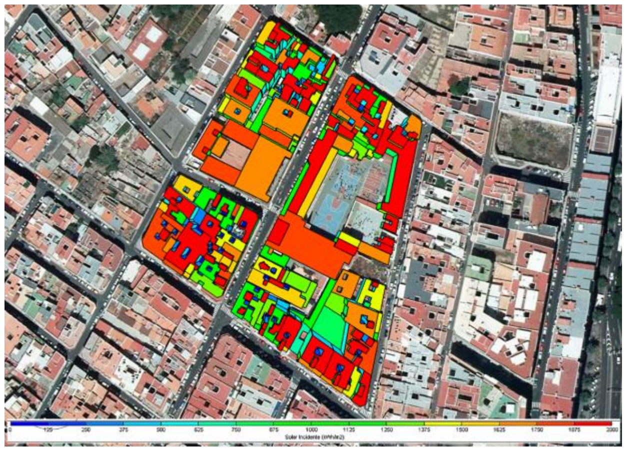

Fig.6. Aerial photo of the study area in El Toscal, with incident irradiation normalized by roof surface (kWh/m^2·year) with the EnergyPlus climate file.

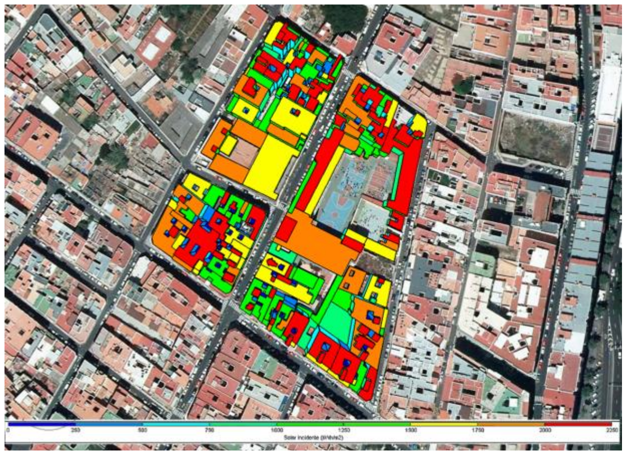

Fig.7. Aerial photo of the study area in El Toscal, with incident irradiation normalized by roof surface (kWh/m^2·year) with the PVGIS climate file.

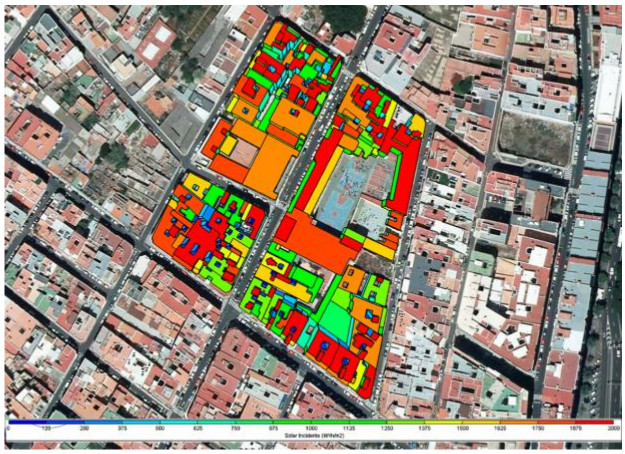

Fig.8. Aerial photo of the study area in El Toscal, with incident irradiation normalized by roof surface (kWh/m^2·year) with the Meteonorm corrected climate file.

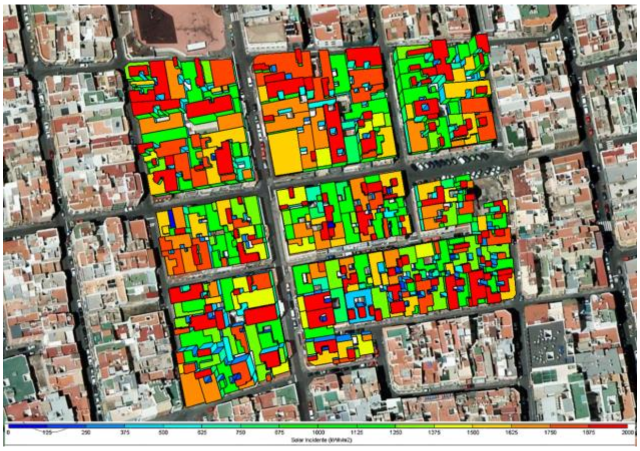

Fig.9. Aerial photo of the study area in La Isleta, with incident irradiation normalized by roof surface (kWh/m^2·year) with the EnergyPlus climate file.

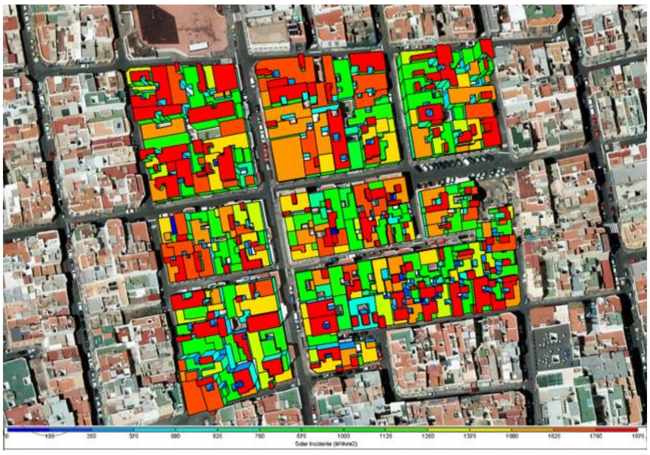

Fig.10. Aerial photo of the study area in La Isleta, with incident irradiation normalized by roof surface (kWh/m^2·year) with the PVGIS climate file.

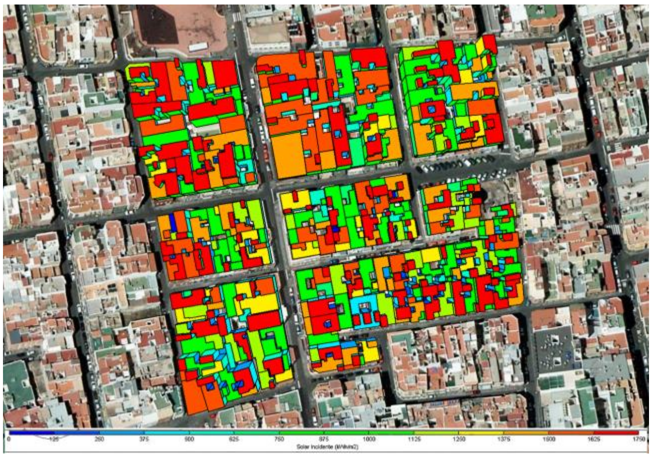

Fig.11. Aerial photo of the study area La Isleta, with incident irradiation normalized by roof surface (kWh/m^2·year) with the Meteonorm corrected climate file.

In the case of the Meteonorm climate files, a shift in the real solar noon have been detected. Therefore, in view of the result obtained, it is necessary to advance the radiation data by one hour during the winter months (October to March) and two hours in the summer months (April to September), to adjust the solar noon with the maximum radiation value. The variation in the number of hours that it is necessary to transfer the data is due to the time zone with which each of the climate files has been generated. Below are the results corresponding to each of the climate files used. In the Tekton 3D tool model, each photovoltaic module has been assigned a performance coefficient value of 100% (PR=100%) to be able to make the desired comparisons under equal conditions because, as already indicated, DesignBuilder does not allow incorporating a different value for this parameter.

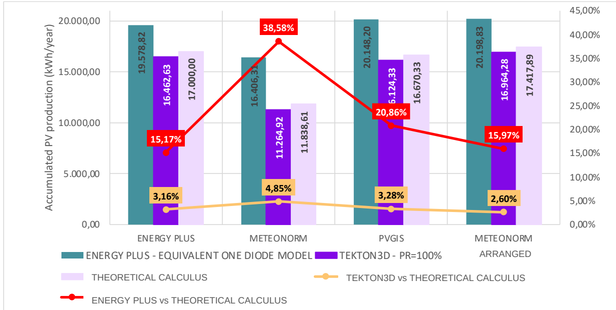

Fig.12. Photovoltaic production results with climate file processing.

In view of the results, Energy Plus obtains greater energy generations than what was achieved with the other two methods. The cause of this is the use, by its calculation engine, of the global incident irradiance, understanding it as the sum of the direct, diffuse and reflection irradiances, on the surface of the photovoltaic panels, instead of using the normal direct component.

4. Conclusions

It has been proven that, to obtain reliable results in energy simulations, the irradiance data from the climate files must be well positioned based on the time, which is why the correct conversion of the time into consideration of the time zone is essential. every season of the year. This is a consequence of the fact that .epw files work in official time and .met files work in solar time. In fact, these transformations must be corrected and verified considering solar positioning.

It is also noted that Design Builder makes use of the global radiation incident on the panel for energy generation estimates, while Tekton 3D uses the direct normal incident radiation data, which excludes Design Builder as an optimal tool for modelling photovoltaic plants.

Furthermore, because of having contrasted the results using different data sources, it is determined that the use of PVGIS represents the best source available for obtaining the climate data necessary for the studies to be carried out in the future. In the development of the following tasks, we will work with the data obtained by real weather stations.

Regarding the energy use of the roof, in a first approximation, it is concluded that the south orientation with the optimal annual inclination of the photovoltaic panels is the configuration that offers the best annual energy production per installed power. On the other hand, the 15º inclination is the one with the greatest photovoltaic potential, allowing the occupancy of the available roof to be optimized. Likewise, without considering external conditions, due to the self-disconnection in the solar

panels caused by shading between rows, horizontal placement of the modules offers better results.
Finally, in the proposed workflow and having minimized the errors in the photovoltaic simulations, it is determined that the most optimal thing is to use Design Builder to obtain incident irradiation data on the surface of buildings and the Tekton 3D tool for the design of photovoltaic plants, which will allow defining photovoltaic potential maps of the roofs of buildings in the Canary Islands.
The geographical data of the buildings provided by the OSM (Open Street Map) project for the Autonomous Community of the Canary Islands is incomplete and imprecise.
To download the geographical data of buildings from the DGC, in an automated way, the most recommended option is using the "INSPIRE Cadastral Mapping Services".
The structure of GML files is similar, but not identical to the structure of GML-INSPIRE files.
If the intention is to generate a 3D urban virtual model that acceptably represents the real dimensions of the buildings, it is necessary to use the MDT (for the terrain levels) and the MDE (for the heights of the buildings) of the area.
3D modelling of buildings can be done with tools such as QGIS and Blender, but the results are not directly compatible with the EnergyPlus calculation engine.
Obtaining EnergyPlus-compatible Green Building XML (.gbxml) files from geographic data is not straightforward using existing applications or tools.
Carrying out intermediate steps to convert between formats is not recommended, since they usually generate errors in the formats.
The generation of IDF files from the geographical data available in the Cadastre GML files seems to be the most viable option if the aim is to obtain a model for energy analysis with EnergyPlus.

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References

[1] Red Eléctrica de España SA (REE SA). Red Eléctrica de España 2019. www.ree.es (accessed March 20, 2019).
[2] Luthander R, Widén J, Nilsson D, Palm J. Photovoltaic self-consumption in buildings: A review. Appl Energy 2015;142. https://doi.org/10.1016/j.apenergy.2014.12.028.
[3] IDAE. EnerAgen. Guía IDAE 021: Guía Profesional de Tramitación del Autoconsumo 2020.
[4] Dirección General del Catastro. Portal de la DGC: Estadística del Catastro Inmobiliario Urbano 2020.
[5] GRAFCAN. Sistema de Información Territorial de Canarias. 2016. http://visor.grafcan.es/visorweb/default.php?svc=svcStatISTAC&lat=28.3&lng=-15.799999999999954&zoom=8&lang=es %0A (accessed January 16, 2016).