Towards a more sustainable campus, proposal of improvement through renewable energies implementation

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Abstract

The implementation of photovoltaic (PV) panels on building surfaces allows taking advantage of the building's energy potential through the distributed generation of electricity at the consumption point. Thus, electricity generation would be possible in remote areas, while avoiding transportation costs and electrical losses. This study analyzes the feasibility of installing PV panels in eleven buildings of the Universidad de Burgos. To achieve a correct implementation, possible shadows produced by nearby obstacles were avoided. Skelion, a plug-in incorporated in the image rendering software Sketchup, has been used. According to the results obtained, only two buildings do not offer good adequation to justify the photovoltaic installation.

Keywords: Solar Energy, Photovoltaic panels, Renewable energy, Energy performance, Simulation

1. Introduction

The relevance of renewable energies in the current energy scenario has notably increased compared to fossil fuels. At the present-day, the international entities are proposing new strategies to promote the development and implementation of technologies to promote the use of energies and ensure environmental conservation, such as the European Green Deal (European Commission, 2019). In the local context, the Spanish government is promoting multiple measures to reinforce energy savings. Regarding the regulatory framework, through the Integrated National Energy and Climate Plan 2021-2030, Spain commits to tackling climate change to get the condition of a carbon-neutral country in 2050, when the 42% of end-use energy should be came from renewable sources (INECP, 2021).

Of particular concern is the energy consumption of buildings, which are also responsible for approximately 36 % of all CO2 emissions of the European countries, a situation that is especially aggravated by the Union energy dependence (Directive (EU), 2018). In particular, public facilities are bound to have excessive or inefficient energy use, usually because of their size and age of construction (Granados-López et al, 2020).

Facing this challenge, it is of good interest to make the campus of the Universidad de Burgos (Spain) more sustainable by the renewable energy implementation. Nowadays, the market of the renewable energies is leaded by the photovoltaic technologies, that have improved to the point to reach profitable energy production (Suárez-García et al., 2017).

This work analyzes the viability of the implementation of photovoltaic (PV) panels on non-used surfaces of a set of buildings of the campus (buildings description in Fig. 1). This would make it possible to produce electricity near the consumption points and to avoid transportation cost and electrical losses. Besides, it describes the estimation process of photovoltaic production by 3-D modeling to ensure a correct implementation of the PV panels avoiding the shadows produced by the close obstacles.

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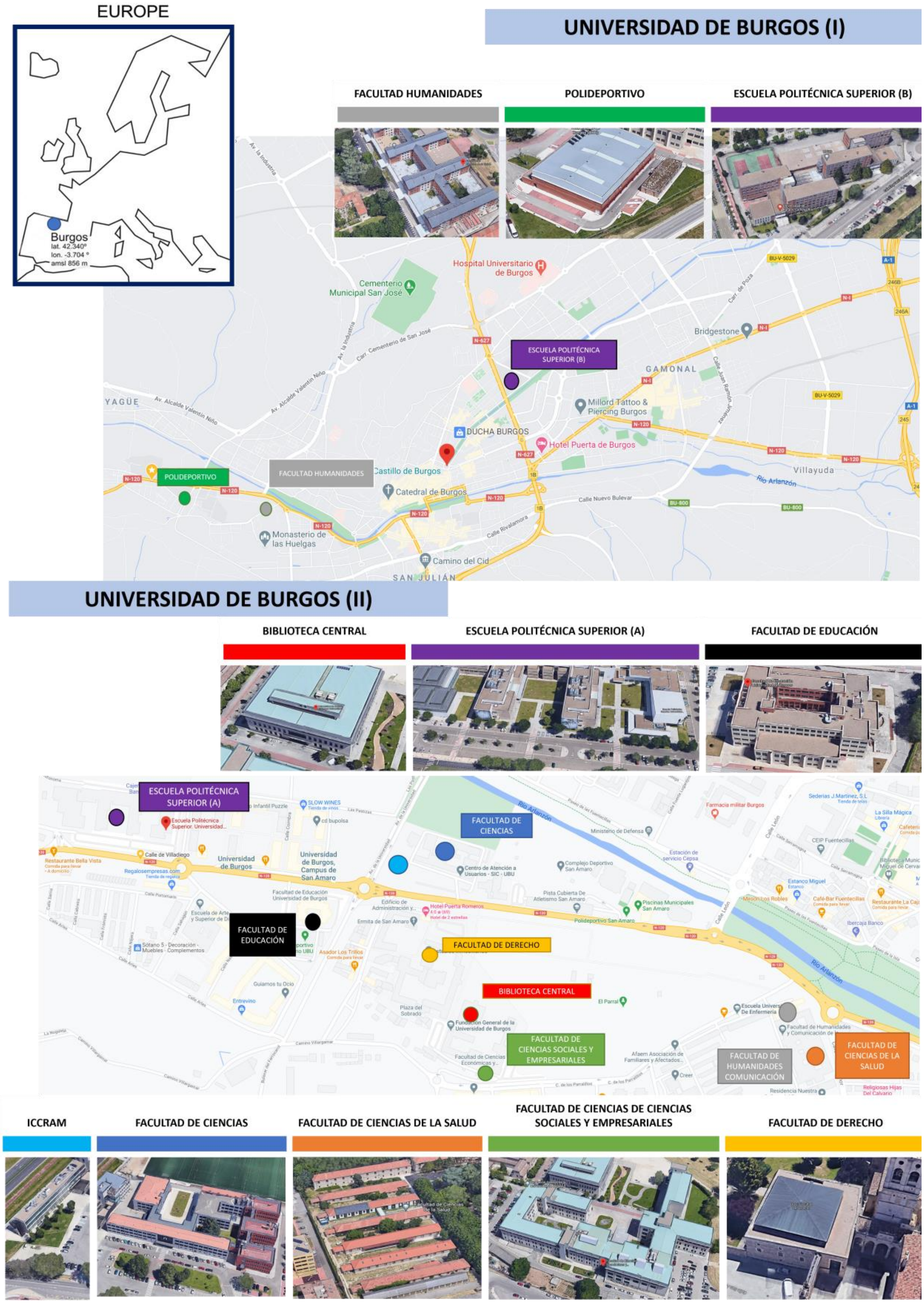

1. International Research Center in Critical Raw Materials for Advanced Industrial Technologies (ICCRAM)*

Fig. 1: Description of the Campus (II) of the Universidad de Burgos (Spain)

2. Methodology description: Campus description and PV-Simulation

The feasibility of implementing photovoltaic installations in a total of 11 buildings of the University of Burgos, was studied. As some of them are quite old, in some cases the orientation of the building may not be the adequate or are conditioned by several limiting factors. Therefore, the buildings have been divided into three groups according to the possibilities of improvement, see Tab 1: I) Installation of panels on flat roofs at 45 degrees, facing south. II) Installation of panels supported on simple auxiliary structures, on the slope of the roof, and facing the direction of the building facade (which may not be south), III) buildings that do not allow improvement, either by the obstacles of the environment, the characteristics of the building, or by legislation.

Tab. 1: Building stock description.

Group	Buildings belonging to each group
I	Facultad de Ciencias Sociales y Empresariales, Escuela Politécnica Superior (A), Escuela Politécnica Superior (B), Facultad de Educación, Biblioteca Central, and Polideportivo. **Limiting factors** -
II	Facultad de Ciencias de la Salud, Facultad de Humanidades, and Facultad de Ciencias **Limiting factors** • Facultad de Ciencias de la Salud is oriented to South - West • Facultad de Humanidades is oriented to South - West • Facultad de Ciencias is South - East.
III	ICCRAM, and Facultad de Derecho. **Limiting factors** • ICCRAM- It has all the cooling systems on the roof, and the vertical facades are glazed. • Facultad de Derecho - Placed in a historic setting, with high trees surrounding it.

This work uses the rendering technique to consider the shape of the building and its surrounding area. Therefore, all the possible obstacles are considered, and the solar irradiance that reaches the surfaces of interest can be calculated. As this first step is not limited to specific modeling programs, the Sketchup software was selected, a freeware license that has a large variety of plugins and pre-built designs (Sketchup, 2022). In the particular context of PV simulation, the Skelion plug-in (Skelion, 2022) is used due its versatility and its virtual interface. Thus, the sequence to estimate the PV production of a building is the following: First, the studied building and the surroundings are modeled by the software Sketchup. Then, the weather database Photovoltaic Geographical Information System (PVGIS) is selected (PVGIS, 2022). Finally, by the implementation of Skelion the PV production is obtained (see Fig. 2).

Fig. 2: Workflow for PV-Simulation

2.1. Building modeling - Sketchup

In urban environments, the shape and orientation of buildings can present very diverse and complex combinations, it mainly hinders the planification of energy retrofit process to fulfill the desired energy savings in each location. Currently, throughout the simulation it is possible to model the nuances with good detail level anywhere. Nonetheless, it is limited by the software and the researcher knowledge. In this work, Sketchup has served to 3D model several facilities of The Universidad de Burgos, which is a university that is located inland North of Spain (42°21′04″N; 3°41′20″O; 856 m above mean sea level), in Fig.1.

2.2. Photovoltaic simulation – Skelion

The objective of the proposed energy rehabilitation is to harvest solar radiation at the roofs. So, Skelion plug-in has been used to simulate and test the performance of the photovoltaic installation. The proposed PV-designs are shown below, Fig. 3 and 4. Panel specifications are 160 Power (W), 1.5 Length (m), 0.7 Width (m).

First, the proposal of photovoltaic installation for the Group I buildings are shown, see Tab. 1. In all of them, the roof is flat, consequently, it has been provided with panels, inclined at 45 degrees, approximately the latitude of Burgos, perfectively oriented to the South, Fig. 3.

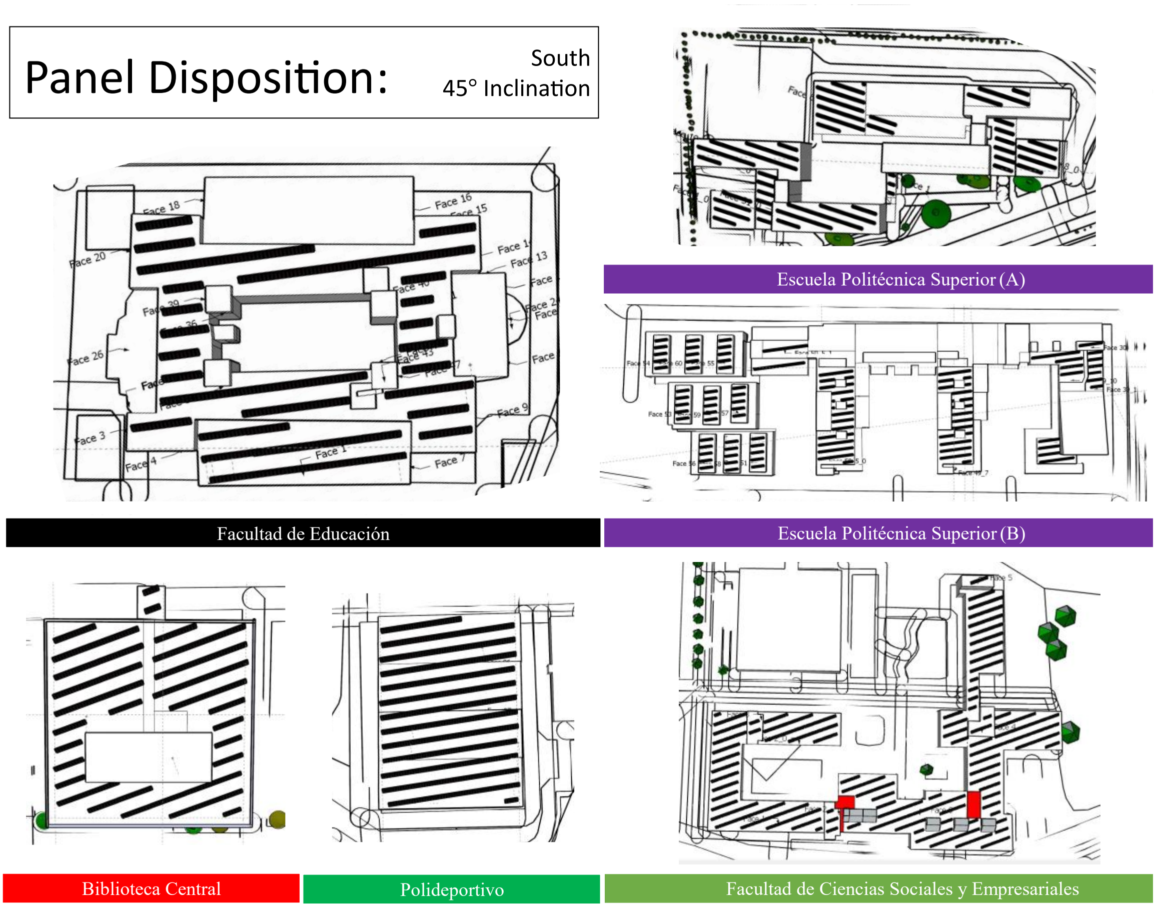

Fig. 3: PV installation on the Universidad de Burgos, Group I.

Moreover, note that in the facilities of Group II: “Facultad de Ciencias de la Salud”, “Facultad de Humanidades” and “Facultad de Ciencias”, the moderate slope of the roofs is characteristic of the building, for it, in these situations, the panels have been arranged directly on the roof, respecting the natural slope and orientation, Fig 4.

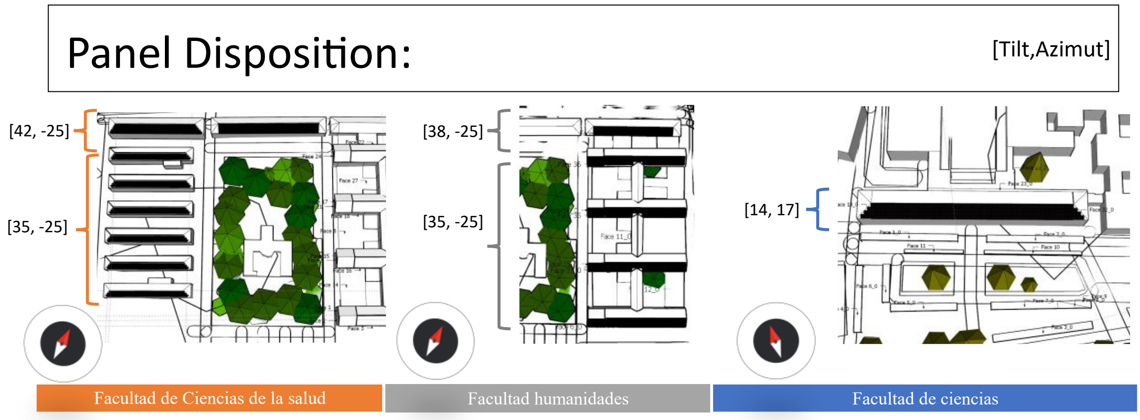

Fig. 4: PV installation on the Universidad de Burgos, Group II.

Tab.2 summarizes the basic characteristics of the proposed PV installations. In the case study, only two of eleven facilities of the Campus do not have adequate conditions to host photovoltaic installations: “Facultad de Derecho”, and “ICCRAM”.

Tab. 2: Panel distribution.

Facility	[Azimuth, Tilt]	Number of panels	Physical PV implementation
Facultad de Ciencias Sociales y Empresariales	[0,45]	1453	Yes
Escuela Politécnica Superior (A)	[0,45]	669	Yes
Escuela Politécnica Superior (B)	[0,45]	1294	Yes
Facultad de Ciencias	[17,14]	508	Yes
Facultad de Educación	[0,45]	519	Yes
Facultad de Humanidades	[-25,35] and [-25,42]	2582	Yes
Facultad de Ciencias de la Salud	[-25,31] and [-25,38]	1308	Yes
Facultad de Derecho	-	-	No
Biblioteca Central	[0,45]	474	Yes
ICCRAM	-	-	No
Polideportivo	[0,45]	655	Yes

2.3. Weather Database

Skelion Plugin provides an estimation of PV-production by using the previously 3D-model, its geographic location and shadows cast by near buildings and terrain (obstacles). Moreover, it uses the insolation dataset, that is ideally recorded near the location, in this case it has been obtained from the Photovoltaic Geographic Information System (PVGIS) database, a software tool of the European Union for the promotion of renewable energies implementation (PVGIS, 2022).

3. Results

The installed power and the annual energy production is calculated. Table 3 demonstrates that the viability of the self-sufficiency using photovoltaic energy for singular facilities depends on the building shape as well as the surroundings. In particular, the dimensions of the “Facultad de Humanidades” allows to host an installed power 5.4 times bigger than the “Biblioteca Central”, which is also transposed as larger total annual energy production, 612 versus 111 MWh.

Tab. 3: Study of viability for the facilities of the Universidad de Burgos

Facility	Power (kWp)	Energy (MWh) (yearly)
Facultad de Ciencias Sociales y Empresariales	232	340
Escuela Politécnica Superior (A)	107	144
Escuela Politécnica Superior (B)	207	305
Facultad de Ciencias	81	116
Facultad de Educación	83	121
Facultad de Humanidades	413	**612**
Facultad de Ciencias de la Salud	209	311
Facultad de Derecho	-	-
Biblioteca Central	76	**111**
ICCRAM	-	-
Polideportivo	105	154

The facilities analyzed have very different available useful areas and, consequently, host a useful power of different orders of magnitude. To facilitate the comparison of the facilities, the annual energy produced has been divided by the number of panels. Also, by using the meteorological data, Skelion estimates the percentage of solar energy that is missed due to near shadings. The analysis of the annual installed energy production per panel as well as the shading loses shows that the facility with the worst performance is “Escuela Politécnica Superior (A)”, with 215 kWh/panel), Tab 4.

Tab. 4: Study of viability for the facilities of the Universidad de Burgos,

Facility	Power (kWp)	Energy (kWh/panel) (yearly)	Shading loses (%)
Facultad de Ciencias Sociales y Empresariales	232	234	2.11
Escuela Politécnica Superior (A)	107	**215**	**9.63**
Escuela Politécnica Superior (B)	207	236	1.31
Facultad de Ciencias	81	228	0.11
Facultad de Educación	83	233	2.61
Facultad de Humanidades	413	**237**	**0.7**
Facultad de Ciencias de la Salud	209	238	0.41
Facultad de Derecho	-	-	-
Biblioteca Central	76	234	1.91
ICCRAM	-	-	-
Polideportivo	105	235	1.47

Moreover, Monthly Energy production of the highlighted facilities (“Facultad de Humanidades” (larger production), “Biblioteca Central” (lower production), “Escuela Politécnica Superior (A)” (bigger shading loses)) is shown in Fig. 4. All of them presents a maximum in the central months of the year and a minimum production in the wintertime. But The production of the “Facultad de Humanidades” is not symmetrical along the year as it is facing South-west. It should be emphasized that even if the orientation and tilt is the same in “Escuela Politécnica Superior (A)” and “Biblioteca Central”, the production of “Biblioteca Central” is always better as it has much less shading loses.

On the other hand, in the “Facultad de Humanidades”, where the panels have been placed directly on the roof respecting its inclination, several benefits have been found a) first, the production of this facility is similar to the others studied, b) since it requires a simple auxiliary structure, it is more economical, c) it allows placing the panels without separation (they will not generate shadows between them).

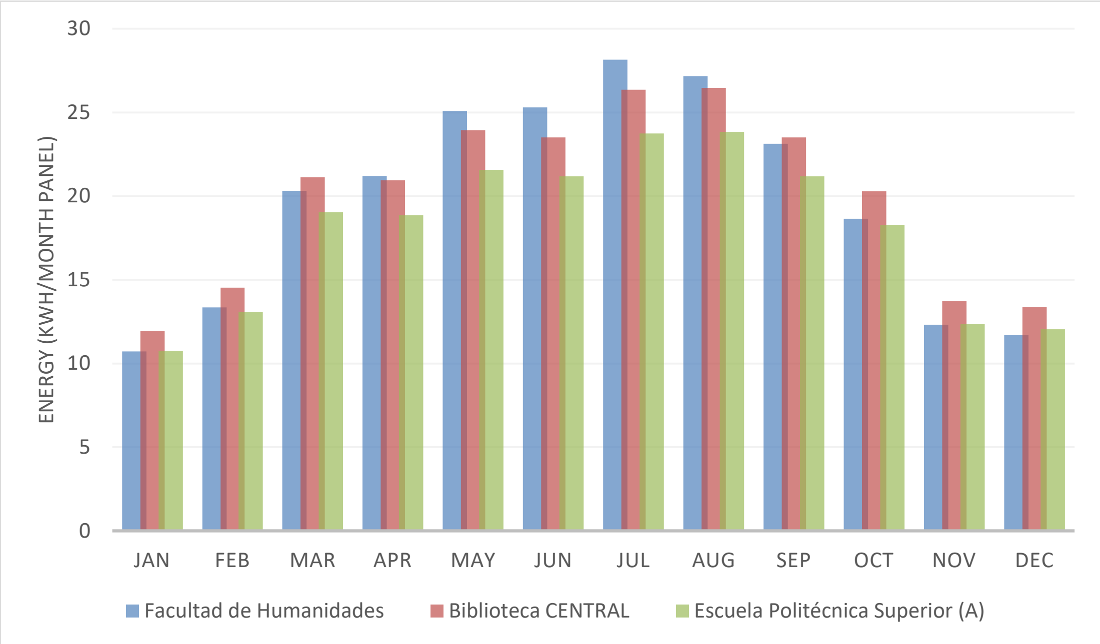

Fig. 4: Monthly Energy production

4. Conclusions

This study looks forward achieving a more sustainable campus, by proposing PV installation as renewable energies alternative to increase the sustainability and energy performance. Indeed, the implementation of photovoltaic (PV) panels on building surfaces allows taking advantage of the building's energy potential through the distributed generation of electricity at the consumption point. The following conclusions are derived:

1. Only two buildings cannot host the photovoltaic installation: “Facultad de Derecho”, and “ICCRAM”.
2. The PV installation designed of “Facultad de Humanidades” has the largest production, 612 MWh, using 2584 PV Si-monocrystalline panels wrapping the building's useful surface.
3. It can be very profitable to have the panels on sloping roofs, especially when the slope is very close to latitude, in addition to the economic benefit, it allows to host a high concentration of panels, Tab. 2.
4. Energy production per panel is very similar in all facilities, this has been achieved by avoiding nearby obstacles as well as the panels shading each other.
5. The energy saving is around 27%, this saving will be "approximately" the same in the months of January, February, March, November, and December. In the months of April, May, June, July, August, September, and October the savings can be increased (possibly to double 30-35%).

5. Acknowledgments

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