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PROMOTING SUSTAINABLE MOBILITY THROUGH THE ECODESIGN OF MULTIFUNCTIONAL URBAN INFRASTRUCTURES IN THE CONTEXT OF SMART CITIES

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ABSTRACT

Sustainable mobility is a focus of major concern for promoting environmental friendly cities. Life cycle thinking arises as an interesting alternative in the design of mobility infrastructures to effectively mitigating overall environmental impacts from transport. This paper analyzes the CO_2 savings of an eco-designed solar pergola (SP) that supports pedestrian and electric bike mobility during 10 years. Results indicate that SP can save 20,135 kg of CO_2 eq. due to its optimized design, energy self-sufficiency, and generation of surplus electricity. Surplus electricity can be used for charging e-bikes, which contributes to an extra saving of 112 kg of CO_2 eq. The design of smart mobility infrastructures plays a key role in promoting sustainable mobility at a minimum environmental cost.

INTRODUCTION

Cities are confronted with a common core set of environmental problems associated with urban mobility. In Europe, half of all road transport fuel is combusted in cities where urban traffic accounts for 40 % of greenhouse gas emissions and more than 70% of local noxious emissions (European Commission, 2007). City planning is being performed in a way that aims to rethink urban mobility towards the optimization of the use of public transportation and the consolidation of walking and cycling activities. However, greening the urban motorized vehicle fleet is a key strategic issue towards the achievement of the European 20-20-20 Climate and Energy targets (European Commission, 2010). The use of electric vehicles (EVs) is foreseen as one of the most promising technology pathways for restricting fuel consumption and CO_2 emissions on a per-kilometer basis (IEA, 2012). Within the last years, an extensive network of urban infrastructures has been implemented in cities to facilitate the shift towards sustainable mobility. However, recent literature (Mendoza et al., 2012; Oliver-Solà et al., 2011) has highlighted the relevance of incorporating life cycle environmental criteria in the planning, design and management of supporting infrastructures for sustainable mobility to reduce to effectively mitigate overall environmental impacts from urban transportation which results into an important issue in the development of smart cities. This paper addresses the environmental assessment of a multifunctional eco-designed solar pergola (SP) for promoting pedestrian and electric mobility at a minimum environmental cost.

MATERIALS AND METHODS

By applying the methodological framework presented in Gonzalez-García et al. (2011), based on the application of Design for the Environment principles, a conventional pergola (CP) that provides diurnal shadow and nocturnal light for pedestrian mobility has been environmentally characterized. Results were used as reference to rethink the CP towards an environmentally optimal design. The specifications of the product systems and case scenarios analyzed are defined in Figure 1.

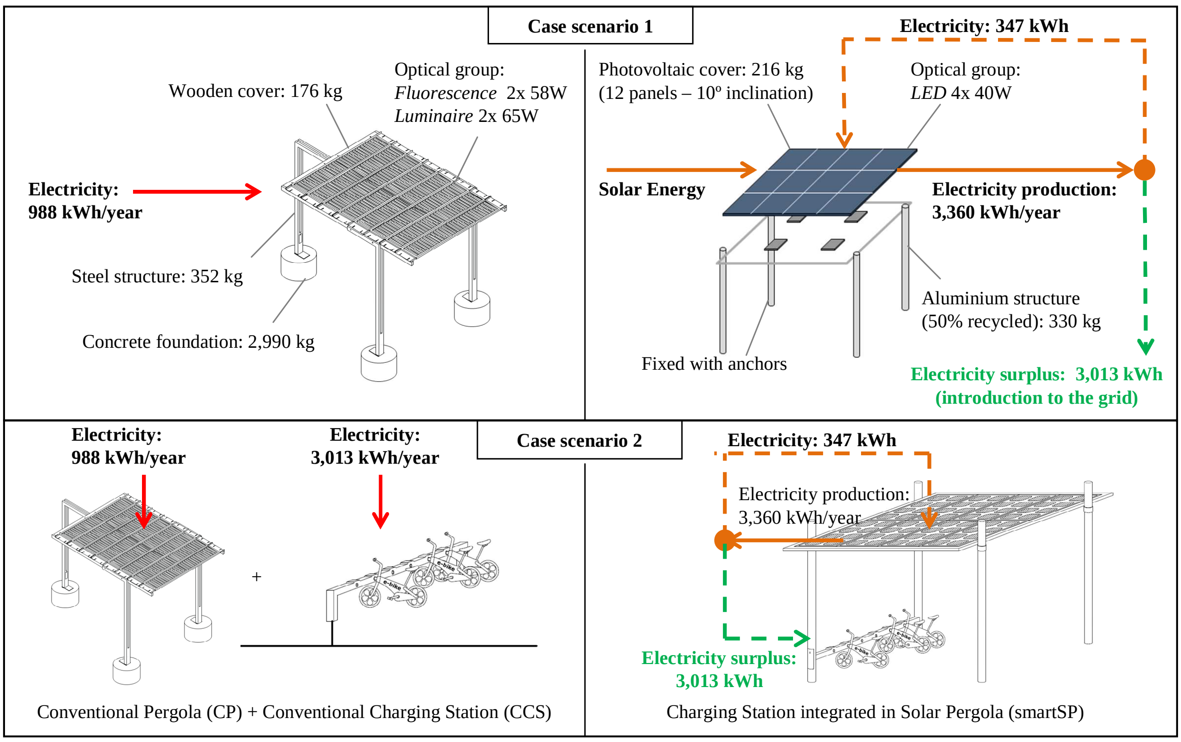

Figure 1. Basic features of the product systems compared under different case scenarios

The functional unit (FU) used was defined as the prospect of supplying shadow (45,000 h) and nocturnal light (42,600 h) over a surface of 20 m^2 for pedestrian mobility during a timeframe of 10 years in the geographical context of the city of Barcelona (Spain). The SP was eco-designed based on two strategies: optimization of the use of materials and implementation of photovoltaic panels on the cover. The photovoltaic production is 3,360 kWh per year. It has been determined by the application of PV Estimation Utility considering 10% of inclination. With only 11.5% of the photovoltaic production, the annual energy demand of the SP is satisfied and, therefore, an important electricity surplus is available. Two different case scenarios were assessed to determine the environmental benefits associated with the use of the surplus electricity generated by the SP: introduction of the surplus electricity into the grid, and use of the surplus electricity for charging electric bikes (e-bikes). In the first case, the environmental gains related to the substitution of conventional electricity from the grid is accounted and allocated to the SP. In the second case, the FU was expanded to analyze the substitution of a functionally equivalent slow-charging station implemented at the public space of the city of Barcelona for charging e-bikes.. The CML-GWP indicator expressed in terms of kg of CO_2-eq. emissions is calculated.

RESULTS AND DISCUSSION

Figure 2 shows the life cycle GWP of each of the product systems analyzed. In scenario 1, the implementation of the CP at the urban public space accounts for a total contribution to GWP higher than 8,700 kg CO_2 eq. after 10 years of operation, while the implementation of the SP will have no contribution to GWP. The SP infrastructure has 74% higher environmental burden than the CP infrastructure, which mainly comes from the photovoltaic panels and the aluminium structure. However, after the first year of operation the GWP of the SP will be lower than the related to the CP. After the third year of operation, the GWP balance of the SP will become “zero” due to the carbon credit related to the introduction of the surplus electricity into the grid. During the following seven years of operation, the SP will generate net environmental benefits. For every photovoltaic kWh introduced into the grid the emission of 0.59 kg of CO_2 eq. related to the production of a conventional kWh will be avoided, which finally provides a total saving of over 11,400 kg CO_2 eq. during the time period analyzed. The overall contribution to GWP by the SP is 231% lower than the CP. In scenario 2, a major GWP saving can be achieved by promoting the implementation of a smartSP design instead of the set CP+CCP. The integration of a charging station for e-bikes in the SP contributes to save an extra amount of 112 kg of CO_2 eq. due to the substitution of the functionally equivalent charging infrastructure. The materials requirements to implement a charging station in the SP are assumed to be around 3 times lower than the required for implementing a charging infrastructure at the public space. It makes almost negligible the increase on the life cycle GWP of the smartSP infrastructure. The GWP of the use phase of the smartSP is “zero” due to all the solar electricity produced is used for providing nocturnal lighting and e-bikes charging. The total GWP savings correspond to the substitution of the CP+CCP product system. Nowadays, e-bikes have batteries of 0.20 kWh to 0.35 kWh of capacity that can be fully recharged after 4 h. By assuming a daily electricity surplus of 8.3 kWh, from 5 to 10 e-bikes could be completed recharged under ideal conditions.

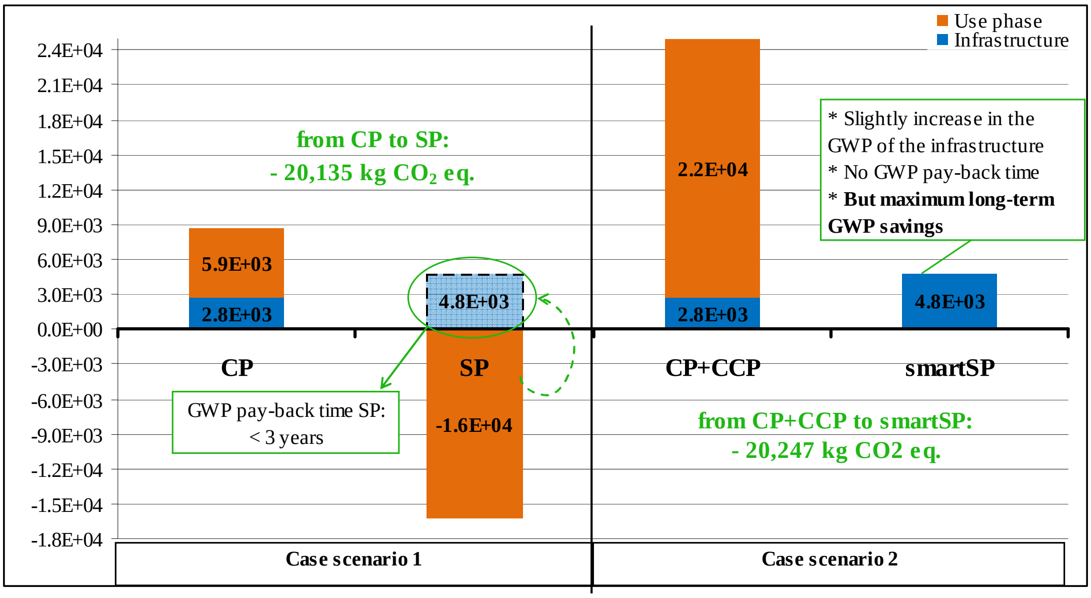

Figure 2. Life cycle GWP of the product systems analyzed

CONCLUSIONS

The promotion of eco-designed urban infrastructures has been demonstrated to play a key role in the development of sustainable mobility at a minimum environmental cost in cities. Smart pergolas can represent an active contribution to sustainability since they support pedestrian mobility and promote the use of “zero emission” e-bikes that represent an attractive alternative mode of transportation from kids to elderly people. The use of e-bikes can be also an attractive mode of transportation demanded by tourists. Smart pergolas represent therefore multi-modal urban elements that can provide different functions depending on the end-user of the green surplus electricity.

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