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Accounting for local impacts of photovoltaic farms: The application of two stated preferences approaches to a case-study in Portugal

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ABSTRACT

Renewable energy sources for electricity generation are unequivocally more environmentally friendly than the traditional sources, but are not impact-free. Given the potential for solar photovoltaic energy to contribute to the energy mix in some countries, it is timely to carefully consider the potential environmental costs of operation of photovoltaic farms, which are experienced by the local population, while the general benefits accrue to all. We apply the contingent valuation method to a sample of local residents close to three selected photovoltaic farms in Portugal. Also, we design a discrete choice experiment to elicit the valuation of specific adverse impacts of electricity generation through photovoltaic energy by national residents. Our results show that the value elicited in the vicinity of the photovoltaic farms is non-negligible. On the other hand, national residents ponder the trade-offs implied by the choice sets and value positively the different adverse local impacts. Both of these estimates, in conjunction or independently, can be used to fully account for this often neglected cost of solar energy. Furthermore, we argue that when studying the public acceptance of renewables, using stated preference methods explicitly presents the trade-offs between negative impacts and costs, contributing to more realistic portrayal of public opinion.

1. Introduction

Renewable energy sources (RES) present undeniable advantages over other energy sources ranging from national energy security to reduced environmental impacts in terms of air pollution, including greenhouse gas emissions (e.g. Borenstein, 2012; Wiser et al., 2016). Notwithstanding the many advantages of renewable energy sources, they are not entirely "environmentally benign" in that they also damage the environment and impact individuals negatively (OECD/ IEA, 1998). This occurs specifically as a consequence of the operation of the power facilities and the damages are mostly experienced locally. As a consequence, the benefits of renewable energy sources are shared by the population in general, but the negative impacts are mostly experienced by communities neighbouring the facilities. In this case study we focus on solar photovoltaic farms and how the impact of their operation is monetarily valued by the two groups of stakeholders to firstly establish how stated preference methods in economic valuation can be applied to enrich benefit-cost analysis concerning future developments, and secondly to check whether a compensation is feasible from the beneficiaries to those negatively affected.

Solar photovoltaic farms have been increasingly used to produce electricity in the last years with decreasing fixed and variable costs (Baker et al., 2013; Louwen et al., 2016). Being "one of the most promising emerging technologies", the International Energy Agency predicts that the share of photovoltaic energy will account for 16% of the global electricity production by 2050 (IEA, 2015). In general, solar energy has the potential to reduce greenhouse gas emissions and help in the transition towards a green model of growth less dependent on fossil fuels and more sustainable (OECD, 2012). As such, not only do photovoltaic developments allow countries to comply with national goals for international agreements, and increase national energy independence, but also contribute towards local economic development.

While contributing to local economic development, it is also a fact that the operation of solar photovoltaic farms causes local negative impacts. When making a decision about a new energy project, all benefits and costs need to be accounted for, so that an efficient decision from an economic perspective is made and economic welfare max-

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imized. As a consequence, in the particular case of photovoltaic energy, the costs imposed by the daily operation of the farms on the local population need to be accounted for. Furthermore, given that the stakeholders who benefit and those who incur the above mentioned costs are not the same, equity considerations also call for including and measuring the impacts on the local population.

We propose that stated preference methods can be used to assign a monetary value to the local impacts, so that they can be included in the decision-making process concerning aspects such as the location and size of the farm, as well as ultimately the efficiency of its development and operation. These issues are explored in a case-study implemented in Portugal, which is a country that has intensified solar photovoltaic electricity generation the recent years and has the potential to continue this effort in the future. This implies that it is all the more timely to consider that although RES are beneficial in comparison with fossil fuels, local environmental impacts should not be neglected.

Specifically we first apply the contingent valuation method to local residents of specific solar photovoltaic farms in Portugal, so as to value economically the impact of the operation of their neighbouring farm. We then use the discrete choice experiments method on a random sample of the national population to elicit the value of specific impacts of solar photovoltaic farms. The application of these techniques to different groups of stakeholders highlights how they can be used to inform the decision-making process. In particular, this study illustrates how the two techniques can be used either autonomously or complementarily, given that they are used to economically value local impacts of solar photovoltaic farms, which do not have a market value, but from two different perspectives. In accordance with the results from the survey by Welsch (2016) and to the best of our knowledge, this is the first stated preference study focusing specifically on the valuation of externalities from solar photovoltaic facilities, in particular using two complementary methods and perspectives.

This study also highlights that the impacts on local residents are non-negligible and that photovoltaic energy, as well as other renewable energy sources, is not entirely "environmentally benign" (Botelho et al., 2016). There is however potential for compensation *ex-post*, minimizing social equity issues. Alternatively, at least all costs should be accounted for during the *ex-ante* project evaluation, and to that end having monetary estimates of the local damage is desirable, either in terms of use values by local residents or in terms of total economic value by all national beneficiaries.

The paper is organized as follows. Section 2 reviews the evidence on local negative impacts of solar photovoltaic farms. Section 3 describes the methodology by discussing the two valuation methods used. Section 4 presents the results from the two valuation case studies as well as a comparison of results. Section 5 draws the main conclusions.

2. Local negative impacts of PVFs

Notwithstanding the many benefits of using solar power in general and solar photovoltaic farms (henceforth PVFs) in particular, there are different types of non-negligible environmental burdens. The OECD/IEA (1998) consider that potential burdens are mostly small, with the exception of visual intrusion of large-scale projects. The OECD/ IEA (1998) mostly identifies life-cycle emissions as the main environmental impact caused by renewable energy sources, namely in what concerns the development, production, and decommissioning processes, rather than the daily operation of PVFs.

The literature on the environmental effects of PVFs often focuses on one of these perspectives, either the construction and dismantling phase or on the daily operations. Taking the first perspective, Turconi et al. (2013) review studies on the life-cycle assessment of electricity generation technologies and find in the case of photovoltaic technologies, those studies address emissions from the production of the infrastructure. Dubey et al. (2013) highlight potential consequences for workers, as well as the environment, during the life-cycle of the technology. Other studies focus on the recycling stage at the end of the life of the project (Fthenakis, 2000) or on the impact of emissions during production of plant components on the environment and human health (Beylot et al., 2014). Furthermore, Guerin (2017a, 2017b) explores environmental and community risk during construction of large scale solar PV plants by comparing expected risks with observed effects. The author concludes that for the studied Australian case "with the exception of road preparation, the project did not require large-scale earthworks and all impacts to the site were reversible" (Guerin, 2017b, p. 338).

Several studies concerning the operation of PVFs have identified other types of environmental burdens, most of them inconveniencing neighbouring populations. These depend on the size of the plant and are location-specific (Tsoutsos et al., 2005).

There are important impacts in terms of land use (Lackner and Sachs, 2005; Chiabrando et al., 2009). Large areas may be required to accommodate PVF projects, which as noted by Chiabrando et al. (2009) explains recommendations to utilize photovoltaic energy on roofs before developing large-scale PVFs. On the other hand, PVFs may displace food crops and replace cultivable land (Sacchelli et al., 2016; Tsoutsos et al., 2005) which contributes to the ongoing "food vs. fuel" controversy (Srinivasan, 2009). Delfanti et al. (2016) document the regulatory effort in Italy to restrict the expansion of PVFs to greenfields. There is however the potential for co-location with use of the ground for animal grazing (Hernandez et al., 2014), food crops (Dupraz et al., 2011) or bio-fuel cultivation (Ravi et al., 2014).

Chiabrando et al. (2009, p. 2445) identify a potential for fragmentation of the countryside in that "the PV system may deplete the unitary characteristic of a specific countryside" with negative impacts on nature conservation and biodiversity. Changes have also been identified in local animal and plant species as a result of the installation and operation of PVFs (e.g. Chiabrando et al., 2009), as well as aquatic ecosystems (Grippo et al., 2015). Several studies also point to impacts on wildlife and biodiversity during construction, operations and decommissioning of solar photovoltaic plants (Gasparatos et al., 2017; Katzner et al., 2013; Lovich and Ennen, 2011; Northrup and Wittemyer, 2013).

Another potential negative impact concerns landscape alterations (Lakhani et al., 2014; Mérida-Rodríguez et al., 2015; Naspetti et al., 2016; Scognamiglio, 2016). Torres-Sibille et al. (2009) explore the visual impact on the landscape of often rural areas both objectively through expert assessments and subjectively through public perceptions, focusing on the impacts due to the visibility of the plant in relation to the total landscape area, colour, fractality (i.e., the contrast in shapes relative to the surrounding environment) and concurrent use of different types of panels in one plant. Also, Fernandez-Jimenez et al. (2015) study the potential observability of photovoltaic plants, which takes into account the number of potential observers, both local inhabitants and travellers as well as distance to the plant. Choosing locations so as to minimize observability of new plants can contribute to less visual impact on the landscape and increases local support.

Thermal pollution is as a potential effect from the impact on the thermal balance of the surrounding area (Gunerhan et al., 2008), as well as impact on the climate of the site (Chiabrando et al., 2009; Lovich and Ennen, 2011; Neff, 1981). There is also the potential discharge of pollutants (Gunerhan et al., 2008), although normal but still risky for locals and workers (Tsoutsos et al., 2005), as well as the use of toxicants that may contaminate local waterways (Gasparatos et al., 2017).

Several authors have studied the negative impacts of the glare effect due to reflection of sunlight (Chiabrando et al., 2009; Ho, 2013; Rose and Wollert, 2015) and this is potentially a major source of inconvenience given that it can directly affect the wellbeing of local residents on a daily basis, rather than indirectly as with the other impacts identified above. The perspective taken in this paper focuses on the operation of PVFs, thus excluding the impacts from the construction and dismantling phase.