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On-site renewable electricity production and self consumption for manufacturing industry in Ireland: Sensitivity to techno-economic conditions

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ABSTRACT

The technical and economic feasibility of on-site renewable energy production from solar and wind for a specific manufacturing plant in Ireland is assessed. The energy load of the plant during a typical year is identified through the analysis of gas and electricity consumption, based on internal monitoring and billing information. Solar and wind potentials are modelled for a period of 22 years using historical meteorological data. The distributed system is sized based on the physical limitations of the site and the effect on the net demand is calculated. As expected, solar and wind energy are generally decoupled. The solar energy presents a more predictable daily and seasonal trend; the wind system introduces a high variability on the net demand. Based on this real case study, a model is implemented to simulate the economic viability of the installation in different scenarios by assessing the influence that technical and economic input parameters have on the Net Present Value. Thus, it is possible to find the conditions in which the project would be viable and evaluate the needed economic policies and/or technical improvements to move in that direction. It is concluded that while a technical opportunity does exist, the economic conditions necessary (specifically, reduction in initial cost of investment, significant subsidy, and long payback period) to make on-site renewable generation a viable option in manufacturing industry in Ireland are too onerous to make it attractive.

1. Introduction

Over the last century, human activities have contributed to warm the planet by releasing into the atmosphere greenhouse gases. The main contributor, with over 60% share, is the energy sector, which includes many sub-sectors such as power generation, industry, transport and HVAC. The industrial sector accounts directly for 21% and indirectly (electricity taken from the grid) for another 11% of global greenhouse gas emissions (IPCC, 2014). The main reason for the high level of emissions produced by this sector is found to be the massive electric and thermal energy demand to manufacture consumer products. In the specific context of Ireland, given a final energy consumption of 11,339ktoe in 2015, industry has been responsible for 2,398ktoe consumption (21%) (SEAI, 2016). A partial solution for decreasing the environmental impact of the energy sector is to rely more on low-carbon electricity sources such as solar, wind and hydro.

The traditional grid based on a one-way power flow connecting centralized power plants to end users through the electricity grid has become an old paradigm and is now facing radical changes (Driesen and Katiraei, 2008). Consumers are now becoming also producers at a local level: they produce distributed energy with decentralized systems located nearby, satisfying part of their own energy needs and even producing a surplus that could be sold to the grid. As a consequence the mono-directional power flows are becoming bi-directional. The cost reduction of Renewable Energy Source (RES) technologies, driven by both technological improvements and government policies, and the impelling necessity to decrease the carbon intensity of the grid, are leading to an increasing penetration of renewable distributed generation. Mehigan et al. (2018) give an exhaustive definition of distributed generation and identify the main factors that influence the future role that it will have in the electricity systems. A review of the available tools to simulate the impact of higher penetration of distributed systems on the grid is presented. While it concludes that at the moment no tool can be used to simulate the interactions

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of all the factors with each other since they are all strongly interconnected, many studies in the literature have identified what are the main challenges that have to be faced to successfully integrate distributed RES into the energy system. Verzijlbergh et al. (2017) present an overview of the main technological and institutional barriers: one of these is the high variability and uncertainty that characterize some renewable sources (e.g. solar and wind), which makes the balance of electricity demand and supply more challenging. A possible way to address this problem is to exploit hybrid energy systems that could better provide the balance of demand and supply by integrating power systems based on different (or complementary) energy sources. Vishnupriyan and Manoharan (2018) present a stand-alone hybrid power system based on solar PV panels and diesel generators that could supply the residential energy demand for six different climate locations in India. Diab et al. (2016) discuss the design and optimization of a hybrid PV-wind-diesel system for an environmental friendly factory in Egypt, where the frequent blackouts lead to significant economic losses. Khare et al. (2016) present a comprehensive review of the main features of hybrid renewable systems, discussing pre-feasibility analysis, sizing optimization, RES modelling and reliability issues. All these studies show that the integration of different energy sources increase the overall reliability of the RES systems.

A large share of renewable capacity, which has doubled over the last decade, reaching over 2 TW (IRENA, 2017), comes from utility-scale and residential systems and many investments are flowing into new systems. In 2016, the worldwide investments for utility-scale projects dominated the renewable market with 187.1 billion USD and small-scale PV installations accounted for 39.8 billion USD (REN21, 2017). The industry sector is, at this time, a smaller contributor to new renewable power generation capacity installed. In this context, manufacturing sites represent a potential opportunity for renewable energy generation which are often based on low power density technologies. In fact, they typically occupy larger spaces in non-residential areas compared to commercial sites in urban areas since they require open spaces for production machinery, parking facilities, appropriate routes for supply and delivery, dedicated connections to national utility grid and other environmental considerations (e.g. noise pollution). While the effect of on-site generation in residential and utility-scale applications has been widely analysed from both a technical and economic point of view (La Monaca and Ryan, 2017; Ruf, 2018; Castaneda et al., 2017; O'Shaughnessy et al., 2018), it is not clear the impact that the switch to on-site generation by manufacturing facilities (industry sector) would have. Given the high energy consumption that characterizes manufacturing facilities (2.5MW$_{el}$ and 5MW$_{th}$ for the medium size manufacturing facility analysed here) compared to the average electric and thermal power demand of a house (480W$_{el}$ and 1,255W$_{th}$ (CER, 2017)), the potential impact could be significant and may bring to light new challenges for the grid and the electricity market.

In this study, the power demand of the facility will be produced on-site by a properly sized renewable distribution plant and it will be instantaneously and locally consumed reducing transmission and distribution losses. The usage of storage will not be required due to the high and almost constant electricity consumption profile which is typically found at manufacturing sites. A model is built to study the sensitivity of on-site renewable electricity generation to different economic and technological parameters in the context of the Irish manufacturing industry. The model's design and validation is based on a real case study with available electricity consumption data in half hour intervals. The use of data from a real Irish manufacturing facility allows a technical and economic assessment of the proposed scheme taking into account the interaction with the grid.

2. Methodology

In order to design a model for the assessment of on-site renewable energy production and consumption applicable to the Irish manufacturing industry, a real facility is analysed. The chosen facility is part of an international pharmaceutical company with 69,000 employees all over the world. The Irish manufacturing site counts more than 800 employees; it has an electricity and natural gas usage which is almost constant during the year and a continuous steam requirement for the production lines. It is a 24/7 batch production process with no shut-down during the year except for one short scheduled maintenance period. The required inputs for the model are shown in Fig. 1: the electricity demand is based on the real data provided by the company.

The implemented model calculates as output the technical and economic feasibility of on-site electricity generation in different scenarios. The selected renewable sources for this analysis are solar and wind, which are less site-specific and therefore are more suitable for a widespread deployment that could be applied to

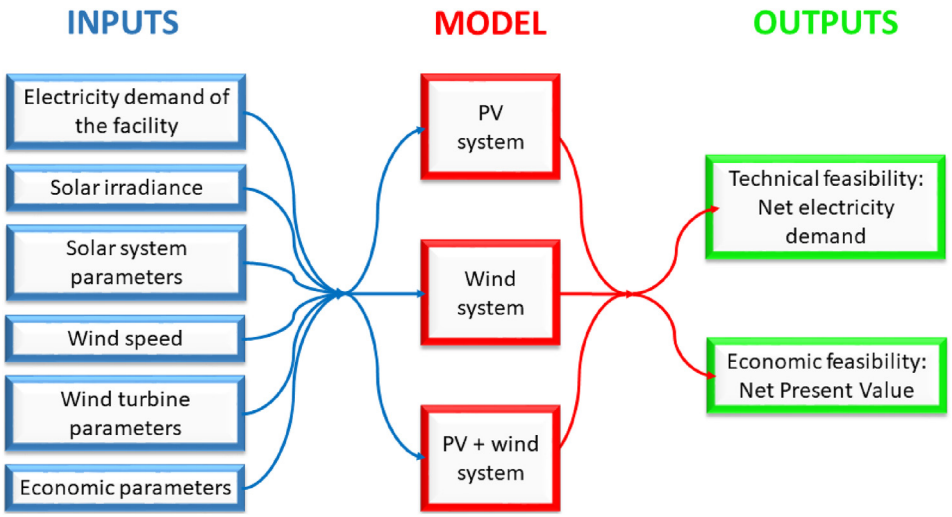

Fig. 1. Inputs and Outputs of the implemented model.