Energy Policy 102 (2017) 440–452

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Combining feed-in tariffs and net-metering schemes to balance development in adoption of photovoltaic energy: Comparative economic assessment and policy implications for European countries

F. Javier Ramírez[a,*], A. Honrubia-Escribano[b], E. Gómez-Lázaro[b], Duc T. Pham[c]

[a] School of Industrial Engineering, Department of Business Administration, Universidad de Castilla-La Mancha, Av. de España, s/n, 02071 Albacete, Spain
[b] Renewable Energy Research Institute and DIEEAC-EDII-AB, Universidad de Castilla-La Mancha, Av. de España, s/n, 02071 Albacete, Spain
[c] Department of Mechanical Engineering, College of Engineering and Physical Sciences, The University of Birmingham, B15 2TT, UK

ARTICLE INFO

Keywords:
Photovoltaic energy
Feed-in tariff
Net-metering
Profitability
Scheme combination

ABSTRACT

In the last fifteen years, Europe has been involved in the major development of photovoltaic (PV) solar energy. The Kyoto Protocol requirements and the European Union (EU) directives to promote the use of renewable energy sources (RES) together with environmental policies introduced for the development and use of alternative energies have generated a large number of market opportunities for this sector. Differences in the application of energy policies have caused significant imbalances in electricity systems and distortion of electricity prices. The main concern of governments is to define the support schemes to be used and how to combine them in the most profitable manner. The aim of this paper is to provide a comparative cost-effectiveness assessment using feed-in tariffs (FiT) and net-metering (NM) schemes in some representative EU countries. The authors have developed an economic model to evaluate the profitability of PV projects combining these support schemes. Results show not only the circumstances under which solar energy is economically profitable, but also the kind of PV systems, locations, minimum levels of tariff prices and specific combination of support schemes that should be promoted.

1. Introduction

Energy is the basis of the economic development of society and the sun is the largest source of energy that exists, as well as being a virtually inexhaustible source. In 2014, energy consumption was equal to 1777 Mtoe (Million tonnes of oil equivalent) in Europe (Enerdata, 2012; IEA, 2015a) while at global level it was around 13,737 Mtoe, 0.5% more than in 2013. This energy accounts for only 0.05% of the free solar energy that the earth receives, which comes with zero CO_2 emissions (Hosenuzzaman et al., 2015; Sahu, 2015).

Although the ratio of renewable energy (RE) use is still low by comparison to conventional energy, it is continually growing. In 2014, 58.5% of new installations worldwide used renewable energy sources (RES) (EPIA, 2015). Electricity consumption in 2014 was 3226 TW h in Europe (Enerdata, 2012). Of this, 32.7% was covered by RES. Photovoltaic (PV) energy contributes around 1.3% of the global electricity demand, 3.5% of the electricity demand in Europe (IEA, 2016b). Furthermore, Europe represents around 42.3% of the world-wide installed capacity (IEA, 2016b; EPIA, 2015).

Energy consumption is one of the most serious concerns of governments around the world, especially in the European Union (EU) countries (European Parliament, 2009, 2012). The increasing impact of the use of conventional unclean energy sources on global warming requires the identification of policies to limit the unrelenting degradation of the planet (IPCC, 2007; IEA, 2015d). The Kyoto Protocol agreements (UN, 1998) define policies to enhance energy efficiency, and also to promote the use of sustainable energy sources. Additionally, measures to reduce CO_2 emissions in different countries have been applied, and the use of penalties if these goals are not met has been implemented.

In 2015, a new record for installed solar power was reached in Europe, with the addition of 8.5 GW, representing a total installed capacity of 97.14 GW. Germany, Italy, the United Kingdom, France, Spain, Belgium and Greece have 85.7% of the total installed capacity in Europe. The share of RE is expected to increase in the future. EU authorities have decided to define new clean energy targets for 2030, when the contribution of RES to the total energy mix will be at least 27%.

* Corresponding author.
E-mail addresses: franciscoj.ramirez@uclm.es (F.J. Ramírez), andres.honrubia@uclm.es (A. Honrubia-Escribano), emilio.gomez@uclm.es (E. Gómez-Lázaro), D.T.Pham@bham.ac.uk (D.T. Pham).

http://dx.doi.org/10.1016/j.enpol.2016.12.040
Received 5 September 2016; Received in revised form 10 December 2016; Accepted 22 December 2016
0301-4215/

Nomenclature

BIPV	Building-integrated Photovoltaics
CF	Cash Flow
c-Si	Crystalline Silicon
EC	European Commission
EPIA	European Photovoltaic Industry Association
EU	European Union
Eurostat	Statistical Office of the European Union
FiT	Feed-in Tariff
FiP	Feed-in Premium
HICP	Harmonised Indices of Consumer Prices
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	The International Revewable Energy Agency
IRR	Internal Rate of Return
NM	Net-metering
NPV	Net Present Value
O& M	Operation and Maintenance
PBP	Payback Period
PV	Photovoltaic Energy
PVGIS	Photovoltaic Geographical Information System
R& D	Research and Development
RE	Renewable Energy
REN21	Renewable Energy Policy Network for the 21st Century
RES	Renewable Energy Sources
ROC	Renewable Obligation Certificate
SC	Self-consumption
U.N.	United Nations
VAT	Valued Added Tax
WACC	Weighted Average Cost of Capital

Within this framework, solar power is beginning to play an important role in power generation in many countries (Honrubia Escribano et al., 2015). However, the application of policies to promote the use of PV energy has caused significant imbalances in electricity systems and distortion of electricity prices. A well-planned policy is needed to control its impact on the electricity market and the development of PV energy must be well-controlled (Pyrgou et al., 2016; Avril et al., 2012). Thus, the main concern of governments is to define the energy support schemes to be used and how to combine them in the most profitable manner for a better-balanced electrical power generation system.

In the recent literature, some authors have focused on the economic analysis of the main support policies for solar PV. Pyrgou et al. (2016) examined the feed-in tariff (FiT) scheme in-depth to evaluate its sustainability, feasibility conditions and effect on electricity prices. Dusonchet and Telaretti, (2015); Dusonchet and Telaretti, (2010b, 2010a) and Campoccia et al. (2014) used economic indices to compare support policies and define the best profitability conditions in the different countries analysed. Mir-Artigues and delRío (2014) presented a cost-effectiveness analysis to test whether a combination of a primary instrument (FiTs) with secondary instruments (investment subsidies and soft loans) led to lower support costs compared to the use of FiTs alone. Furthermore, Fokaides and Kylili (2014) examined the conditions of accomplishing grid parity event by the analysis of different parameters, such as the manufacturing cost, the selling price of the energy and the performance of the solar panels. Some authors studied the financial benefits and performance of the main mechanisms in different countries (Avril et al., 2012), while, with a more global vision, others analysed solar energy technologies, prospects, progress and policies in relation to other energy sources (Hosenuzzaman et al., 2015; Hadjipanayi et al., 2016). Nevertheless, as yet, no research has been conducted on the potential combination of FiT and net-metering (NM) schemes. Furthermore, most publications have evaluated the results of applied policies, showing the success or failures in their implementation, but not with a view to presenting the most suitable mix of these schemes to improve future PV development.

The present paper presents a model to evaluate the profitability of PV systems with different combinations of FiT and NM support schemes. The paper makes three contributions to the literature on the topic of PV support schemes assisted by an economic model. The first and main contribution is to evaluate which combinations of FiTs and NM might be appropriate for a certain country and to define the ranges of FiT prices that best combine with NM policies as a function of the electricity prices to create a profitable development. The second contribution is to provide a comparative assessment between the seven EU countries that have experienced the fastest PV development in recent years, with the goal of helping identify their potential future PV development. The third contribution is to highlight the conditions for making efficient decisions concerning where, how and upon which requirements PV policies must be promoted.

The rest of the paper is structured as follows: Section 2 analyses the evolution of PV development in the European context with regard to both installed capacity and satisfied electricity demand covered. Section 3 focuses on the legal aspects, specifying the policies that have been implemented in the main EU countries. Section 4 defines the economic model and the main parameters to be considered in an economic analysis of PV systems. Section 5 presents comparative economic results for the selected PV systems in seven representative EU countries. Section 6 summarises the main conclusions and recommendations of the authors regarding PV energy policy.

2. PV energy in the European context

The PV market in Europe has grown rapidly over the past fifteen years. The total installed and accumulated PV electric power in 2015 reached 97.14 GW, representing a growth factor of 750 since 2000 (0.129 GW installed in 2000–97.14 GW installed in 2015). Fig. 1 shows the cumulative installed capacity in Europe by country during the last fifteen years, in percentage (IEA, 2016a, b, REN21, 2015a, b).

Regarding the rate of electricity demand covered by different energy sources, currently countries such as Italy, Greece and Germany have enough PV capacity to cover 8%, 7.4% and 7.1% of their annual electricity demand, respectively. More than twenty countries in Europe have enough PV capacity to produce at least 1% of their electricity demand from PV, which represents at least 3.5% of the electricity demand and the 7% of the peak electricity demand. In addition, 75% of the total PV installed capacity in the world from 2002 to 2011 was located in Europe (IEA, 2016b).

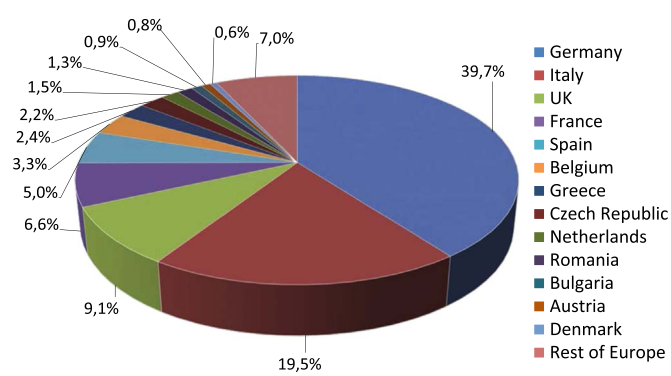

Fig. 1. European solar PV cumulative installed capacity 2000–2015 (in percentage by country).