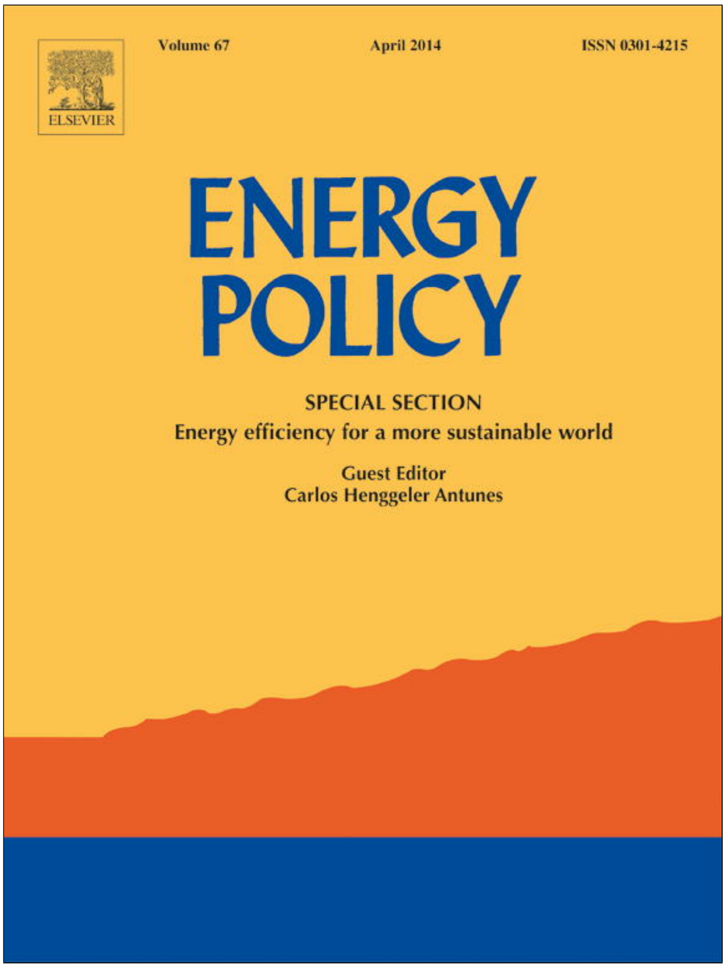
Volume 67
April 2014
ISSN 0301-4215
ELSEVIER
ENERGY POLICY
SPECIAL SECTION
Energy efficiency for a more sustainable world
Guest Editor
Carlos Henggeler Antunes

Energy Policy 67 (2014) 583–594

Contents lists available at ScienceDirect

Energy Policy

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

The doping effect of Italian feed-in tariffs on the PV market

Marco Antonelli [a], Umberto Desideri [b,*]

[a] Dipartimento di Ingegneria dell'Energia, dei Sistemi, del Territorio e delle Costruzioni, Università di Pisa, Largo Lucio Lazzarino, 56122 Pisa, Italy
[b] Dipartimento di Ingegneria – Università di Perugia, Via G. Duranti 93, 06125 Perugia, Italy

HIGHLIGHTS

- Italy has had a booming PV development due to uncapped FIT schemes for 4 years.
- The RES development has disrupted the utilization of all programmable power plants.
- The financial burden will exceed 7 billion euros for the next 20 years.
- The market prices were driven by the incentives and not viceversa.
- The installation was not based on available solar radiation.

ARTICLE INFO

Article history:
Received 1 August 2013
Received in revised form
11 December 2013
Accepted 16 December 2013
Available online 14 January 2014

Keywords:
Feed in tariff
Photovoltaic energy
Italy

ABSTRACT

In less than six years, Italy has become one of the leading markets for PV power plants and one of the countries in the world with the largest number of installations and installed peak power. Such a quick and large growth is due to a series of feed-in tariff schemes that have been uncapped until 2012. As a matter of fact, any size or any number of PV power plants could be installed during a period of three years.

Since the feed-in tariffs are not paid by national taxes but are charged on the electricity bills, Italian energy users are now due to pay each year a surcharge of 9 billion euros on their energy bills.

This paper aims at discussing this development by highlighting the benefits but also some significant drawbacks that the application of uncontrolled feed-in tariffs has produced.

1. Introduction

Three main economic mechanisms to incentivize the deployment and utilization of renewable energy sources (RES) have been applied with different success:

– Net metering
– Green certificates
– Feed-in tariffs (FIT)

Feed-in tariffs, either alone or combined with simple authorization procedures and other incentives, such as net metering or a financial contribution to plants' capital costs, are a very effective way of promoting the use of renewable energy sources (Jacobs and Sovacool, 2012; Jenner et al., 2013; Mints, 2012; Moosavian et al., 2013).

Yamamoto (2012) presented a complete comparative study among the three different mechanisms and their combinations, not only showing the economic return but also the impact on social welfare and the retail electricity rates. FITs, although with a number of drawbacks, are shown to be the best option to stimulate the deployment of RES, with better results in combination with the other mechanisms. On the contrary, the other mechanisms without FITs are not so effective.

Del Rio and Gual (2007) highlighted that FITs facilitated the development of RES offering a long-term perspective to investors. A comparison among different EU countries showed that FITs push the market to significant levels only when they are high enough (Dusonchet and Telaretti, 2010). A similar conclusion was drawn by Haas et al. (2011) who compared FIT schemes to green certificate trading and stating that FITs are stabler, easier to implement, easier to change and adapt to the market and cheaper from an administrative point of view, since it is not necessary to create and operate a market for green certificate trading.

In a study focused on several European countries and Turkey, Bortolini et al. (2013) have assessed the economic performance of the installation of PV power plants according to the national incentivization programs of each country. The differences among

* Corresponding author. Tel.: +39 0755853743; fax: +39 0755853736.
E-mail addresses: marco.antonelli@ing.unipg.it (M. Antonelli), umberto.desideri@unipg.it (U. Desideri).

0301-4215/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enpol.2013.12.025

countries are significant, and the installation of PV power plants is attractive only where national support strategies, along with the most relevant technical, environmental, economic and financial parameters, are well designed.

Sarasa-Maestro et al. (2013), presented an extensive comparative study of the incentives in the European Union by using the internal rate of return (IRR) as parameter for the quality of the investments and concluding that differences in FITs are more justified by difference in the country risks due to non economic factors than by the return of the investment.

Interesting country assessments and studies were published about:

- Germany – Erge et al. (2001) studied the effect of the first FIT scheme in 1999, Frondel et al. (2008) described the situation from 2000 to 2006 and expressed serious worries about the potential negative consequences on the economy, the society and the technology of too profitable incentivization mechanisms, and Leepa and Unfried (2013) focused on the consequences of cut-off between different FITs and incentivazion measures, which may cause excessive accelerations and deceleration of the investments near the cut-off dates.
- Greece – Papadopoulos and Karteris (2009) showed that Greek FITs were too high, and Danchev et al. (2010) highlighted the different returns of the investment in different EU regions and the difficulty to predict the cost of PV systems, since the policy of different countries are not coordinated at a global level.
- United Kingdom – Muhammad-Sukki et al. (2013) showed that the PV development in their country was quite slow and that no significant contribution was expected to the electricity generation mix.

The literature reports country studies about Spain (Schallenberg-Rodrigueza and Haas, 2012), Ontario, Canada (Yatchew and Baziliauskas, 2011; Pirnia et al. 2011), New Zealand (White et al., 2013), Australia (Zahedi, 2010), China (Rigter and Vidican, 2010). All those studies have highlighted that every country has specific economic and societal conditions and solar radiation that affect the investment of PV installation in quite different manners. A number of other studies focused on the negative aspects of applying either excessive or minimal incentives to RES.

From the analysis of risk and return of the investment in RES, Luthi (2010) concluded that the level of PV diffusion appears to be – above some minimum threshold – largely unrelated to factors determining the level of return, but there is a strong correlation between policy risk and market diffusion. As a consequence, installed PV is very sensitive to the quantity and long-term stability of the support and a feed-in tariff is an important condition for increasing PV capacity, although a really effective policy should carefully manage the risks, namely the stability with time, the eventual presence of a cap, and simple administrative processes.

In Australia, the application of different measures in different states has produced quite different results in the number of installed PV plants. This demonstrates that, with the exception of a limited number of users, who install PV panels for environmental reasons, FITs are considered a financial investment providing more stable and higher revenues than bank or bond investments (Zahedi, 2010).

If a well-balanced and stable FIT is a reason for a significant deployment of RES, there are however several drawbacks that have been pointed out in the literature. As an example, the fear of too high social costs is expressed by Falconett and Nagasaka (2010); Pirnia et al. (2011); Yamamoto (2012); Frondel et al. (2008). The latter have presented a detailed critical analysis of FITs in Germany, which is one of the largest PV markets in the world, talking about misguided political intervention and asking for the immediate and drastic reduction of the magnitude of the feed-in tariffs granted for solar-based electricity. They also calculated the cost of avoided CO_2, the negative impact on the employment, the increase in the final cost of electricity, and the loss of purchasing power for consumers and productive activities. Eventually, they also noted that very few technological advancements were due to the FITs but to R&D programs.

Falconett and Nagasaka (2010) agree with the last statement and demonstrated that feed-in tariffs fail to promote competition and efficiency, when renewable technologies have reached a certain level of maturity.

A cause of uncertainty in the investments is due to the PV purchase costs. The return of the investment strongly depends on the reduction rate of PV costs. Danchev et al. (2010) asked whether the PV supply chain and producing capacity would have been able to keep pace so that the PV prices could fall as quickly as predicted, taking advantage of the increasing economies of scale.

In the decade from 1992 to 2000, Italy has promoted combined heat and power plants with feed-in tariffs by considering the benefit of a higher efficiency comparable to the benefits of using renewable energy. Renewable energy was also incentivized by non economic measures such as guaranteeing the priority of dispatchment of electricity produced by both unprogrammable and programmable RES, and introducing easier licensing processes.

The Italian situation has been studied by several authors, but the main purpose of their papers was to analyze the economic and environmental benefits of installing PV power plants, whereas the major economic drawbacks were never investigated thoroughly.

Campoccia et al. (2009) have well described the economic benefits deriving from the first FIT scheme applied in Italy in comparison with the incentives in other EU countries. The difference in payback time, IRR and NPV as a function of the solar radiation was studied by Dusonchet and Telaretti (2010), but no conclusion was drawn about the distribution of PV power plants in Italy and the reasons behind the siting of PV plants. Cucchiella and D'Adamo (2012a, 2012b) and Cucchiella et al. (2013) have published a series of papers describing a number of economic parameters and the carbon dioxide reduction for different PV power plants. They highlighted how large power plants had a better economic return than small power plants and presented a comparative study of the location of a PV plant in three different Italian cities.

Massi Pavan and Lughi (2012) and Mazzanti et al., (2012) have pointed out that PV systems are reaching grid parity in Italy, where the cost of electricity is among the highest in Europe (Fondazione per lo sviluppo sostenibile, 2013).

A detailed comparative study of PV plants of different size installed in Italy and Germany was presented by Spertino et al. (2013), who showed that the plants with the best economic return had a larger size in Italy than in Germany. A geographically wider study involving the major countries in the EU and Turkey is presented by Bortolini et al. (2013). The analysis is limited to the economic return.

No complete assessment of the consequences of the application of the FIT schemes in Italy in the last five years has been published, highlighting the critical issues that the quick development of PV systems in Italy has produced so far and will produce in the future. The Italian case is a clear example of the consequence on the distribution and size of PV power plants, of an almost uncontrolled application of high FITs that had no cap for 5 years and will be left unchanged for a period 20 years after the plant's commissioning. This approach has transformed Italy from a country with no significant PV energy production into one of the world leading countries in terms of installed PV power and generated electricity.

This paper aims at discussing how this policy was implemented, what size of plants was privileged in different regions of the country, and if the effects are consistent with the promotion of sustainable development. In this paper, the Italian geographical, demographical and economic data are first described, in order to provide a clear picture of the regional differences, which are very important to understand the results of this study. Geographical data include solar radiation on the ground. Section 3 lists the FIT schemes introduced in the Italian legislation since 2008, and shortly describes the licensing and authorization procedures. Section 4 describes the consequences of the application of the FIT in terms of number and power output of the installations and Section 5 discusses the effect of the FIT on the plants' costs. In Section 6, the outcome is discussed and a number of problems are examined to understand the pros and cons of the policy that was implemented in Italy with some suggestions to avoid mistakes in the future. A summary of the conclusions is included in Section 7.

By looking at the data about the number, size and location of PV installations, it is quite clear that the implemented policy created a system, which cannot survive without incentives, and which produced a high societal burden to be paid by the citizens and directed to pay back the financial investments without having created a PV industry and long lasting jobs.

From the analysis of the economic data of a selected number of cases, it will be shown that PV panel final prices to customers were driven down by the reduction of the feed-in tariffs and not necessarily by the volume of installations. The system tends to adapt to lower incentives by lowering the cost of panels just before the new FIT scheme is about to replace the previous one. This demonstrates that the development was more driven by financial strategies than by providing benefits to the citizens, who will be paying huge amounts of money in the next two decades.

2. Some economic and geographical data about Italy

Italy is a country, which stretches, in the north–south direction for about 1500 km. An Alpine environment characterizes the northern regions along the borders with France, Switzerland, Austria and Slovenia. The Alps surround on three sides of the Po valley, which is the largest Italian plain and is characterized by foggy days during the winter and by hot days during the summer.

The Italian territory, on the south of the Po valley, is characterized by hills and mountains, stretching from Northwest to Southeast between the Tyrrhenian and the Adriatic seas, with small plains along the coast and the rivers. Moving from north to south, the climate is more and more temperate during the winter and hotter and hotter during the summer. In central and southern regions the fog is less frequent than in the Po valley and is concentrated in the period from sunset to sunrise.

Two main islands, Sardinia and Sicily, have quite a different climate but similar values of annual solar radiation on the ground. Sardinia is generally windier and has more extreme temperatures, Sicily has a typical North African climate.

The solar radiation is shown in Fig. 1, where a significant difference may be noted between the Po valley and the Southernmost areas. The sunniest areas have 50% higher solar radiation than those with the minimum solar radiation. Lower values of solar radiation in the eastern central regions are mainly due to a climatic difference during the winter, where snow and rainfalls are more frequent than on the western side. It is important to note those differences, since the feed-in tariff applied in Italy has the same value throughout its territory.

Italy is politically divided into 20 regions and into over 110 provinces, which have quite different size, population and regional and per capita gross domestic product (GDP). All economic and population data were provided by the Italian Institute of statistics (ISTAT, 2013a, 2013b). Table 1 lists the names and the location of all Italian regions and of their capital cities, population, area and the product of average radiation and area in GWh/year of insolation.

It can be observed that the resident population of 61,092,000 is quite unevenly distributed among the regions, In fact, one sixth of the Italian population lives in Lombardia, 20% of the population lives in 11 small regions, and the remaining 63% is almost evenly divided among 8 regions.

The regional surface is also quite different. Six regions have a surface larger than 20,000 km^2, eight between 20,000 and 10,000 km^2 and six have a surface smaller than 10,000 km^2.

The product of the regional average solar radiation, calculated with the weighted average of provincial solar radiation, provides the amount of solar energy that reaches the ground of each region, i.e. the regional solar energy potential.

Table 2 shows the 2011 regional and the per capita GDP in M€ and €/person respectively. It is quite clear, that Italy is divided in two main economic areas, one including the North and the Center where the per capita GDP ranges between 21 and 30 k€ and one including the South and the Islands where the per capita GDP ranges between 14 and 17 k€.

A more homogenous distribution, based on similar per capita GDP, social and economic conditions and solar radiation, can be made by dividing Italy into five big groups of macro regions: the Northwest, the Northeast, the Center, the South and the Islands. Fig. 2 shows the distribution of the regional GDP.

3. FIT schemes in Italy

The installed PV power in Italy was negligible until 2007. All incentivization programs before 2007 were dedicated to all kinds of renewable energy sources and the support for PV panels was not high enough to stimulate their installation. The high cost of panels and the uncertainty of the administrative (licensing procedures for the installation and duration of the measures) and political situation also contributed to prevent such investment.

In the period 2008–2010 a feed-in tariff scheme coupled with net metering was set at the level shown in Table 3 (MSE Decree, 2007).

The tariff had a different value as a function of the type of installation and the peak power output. Non-integrated plants are those located on the ground in open fields. Integrated plants are those that either lie along the slope of the roof or are not visible on the roof of the building where they are installed and those partially integrated are, for example, those tilted with the optimal angle towards the sun but placed on a horizontal roof. From the FIT scheme it was clear that the expected maximum peak power was in the order of a few tenths of kW.

Plants with a power output exceeding 20 kW could only get the incentivized tariff and sell all the produced energy at a fixed price to the national grid operator. For smaller sizes there was the option to pay only the net consumption of energy, thereby having an additional benefit of the same level of the purchase price of electricity, which is one of the highest in the EU, approx. 0.2 €/kWh.

The 2008–2010 scheme foresaw a 2% reduction of the incentivized tariff in 2009 and 2010 but no caps were put on the overall amount of installations and overall power output.

When the Italian government realized that the incentivization was becoming a success, but it also had some unexpected features, a new scheme was set for 2011 (Table 4, MSE Decree, 2010). In fact, the market had focused on MW size plants, with several

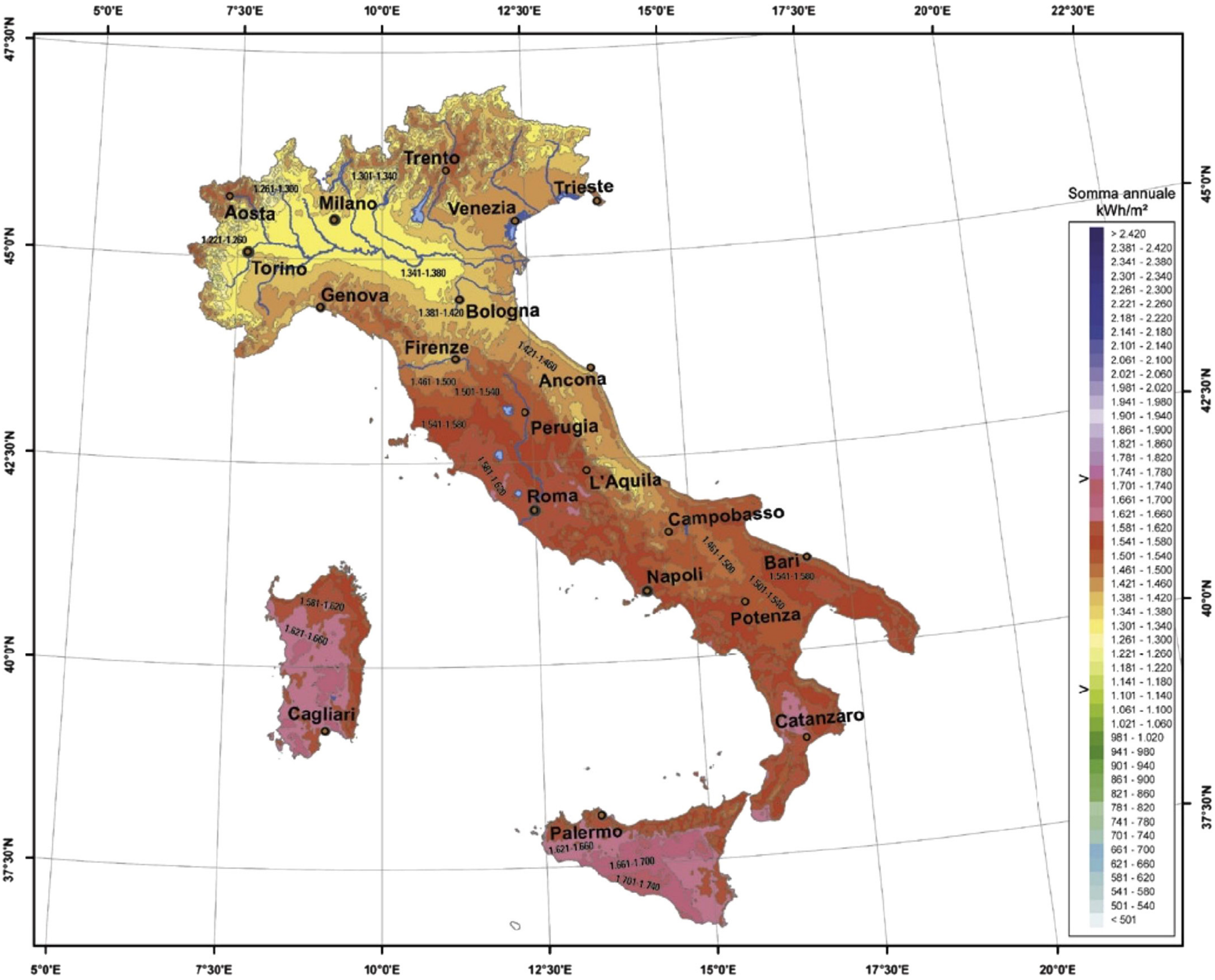

Fig. 1. Map of solar radiation in Italy.

installations on open fields, while the 2008 scheme was based on the assumption that large plants were those with a power output higher than 20 kW.

The 2011 scheme tried to reduce the advantage for plants over 200 kW, which were normally installed on the open field, but the reduction of the prices of panels was making convenient a lower tariff and the rush continued during 2011. It is only in the middle of 2011 that a cap of 23,000 MW was fixed, although too high to stop new investments. The new scheme introduced in June 2011 (MSE Decree, 2011) included a monthly reduction of the tariff, a new definition of large power plants (larger than 1 MW) for which an additional cap was set. However, the additional incentive (0.05 €/kWh) in the case of replacement of roofs containing asbestos was maintained and a new incentive (10% increase of the FIT) was introduced if PV panels and other components were made in the EU.

Table 5 shows the FIT scheme for the second half of 2011 and the first half of 2012. Only the initial and the final values of the tariff are shown, even though a constant monthly decrease was defined during the whole period.

The current scheme (MSE Decree, 2012) divides the incentives for building integrated PV systems and other installations, with a drastic reduction of tariffs, but with a premium for self consumed energy and the use of novel PV technologies.

3.1. *Licensing procedures*

The 2008–2010 FIT scheme simplified the licensing procedures considerably. The first step consists in the presentation of a preliminary project to the local distributor of electric energy, followed by the construction and commissioning, which also have simplified procedures. Once the plant is ready to be started, the owner requests the application of the FIT to the GSE (Gestore dei Servizi Energetici), which has 60 days to approve the request.

PV plants with a peak power lower than 20 kW may be authorized either to sell the electricity or to net metering.

With the procedure described above, there are no specific obstacles to the installation and operation of PV power plants and there is no preliminary authorization that is based on a cap set to limit the number of power of the plants. All plants with a peak power smaller than 1 MW have simplified procedures which are dealt with at a regional level. Larger plants, instead, have to be authorized at a national level.

Renewable power plants of any size and kind have the priority to dispatch the electricity they produce. However, it is not possible to sum different incetives such as FIT and funding more than 20% of the capital cost, or the use of green certificates.

The latest FIT scheme has created caps for the amount of incentives and the tariffs will be reduced every six months. The

Table 1
Geographical and economic data of Italian regions and the provinces of Trento and Bolzano.

Region	Macro region	Capital city	Population	Area [km^2]	Radiation × Area [GWh/year]
Abruzzo	Center	L'Aquila	1,345,037	10,753	15,970,893
Basilicata	South	Potenza	586,313	9,992	15,402,668
Calabria	South	Catanzaro	2,007,375	15,079	25,061,298
Campania	South	Napoli	6,074,882	13,595	21,216,357
Emilia Romagna	Northeast	Bologna	4,459,246	22,451	31,840,507
Friuli	Northeast	Trieste	1,236,103	7,845	10,310,291
Lazio	Center	Roma	5,800,397	17,236	26,260,770
Liguria	Northwest	Genova	1,614,841	5,420	7,730,275
Lombardia	Northwest	Milano	10,020,210	23,861	32,137,784
Marche	Center	Ancona	1,569,303	9,366	13,415,858
Molise	Center	Campobasso	313,660	4,438	6,552,707
Piemonte	Northwest	Torino	4,467,914	25,402	34,511,792
Puglia	South	Bari	4,083,971	19,358	31,169,606
Sardegna	Islands	Cagliari	1,675,411	24,090	38,884,271
Sicilia	Islands	Palermo	5,045,176	25,711	44,708,572
Toscana	Center	Firenze	3,745,786	22,994	30,719,984
Trento and Bolzano	Northeast	Trento/Bolzano	1,046,851	13,607	19,777,775
Umbria	Center	Perugia	910,285	8,456	12,438,776
Valle D'Aosta	Northwest	Aosta	128,810	3,263	4,157,062
Veneto	Northeast	Venezia	4,960,336	18,399	24,783,453
Total			61,091,907	301,316	447,050,701
Northwest			16,231,775	57,946	78,536,914
Northeast			11,702,536	62,302	86,712,026
Center			13,684,468	73,243	105,358,988
South			12,752,541	58,024	92,849,929
Islands			6,720,587	49,801	83,592,843

Table 2
Economic data about Italian regions.

Region	Regional GDP [2011 M€]	Per capita GDP [2011 €]
Abruzzo	26397.20	19625.63
Basilicata	9577.70	16335.47
Calabria	29800.70	14845.61
Campania	86583.30	14252.67
Emilia Romagna	128305.60	28772.94
Friuli	32983.00	26683.05
Lazio	154502.00	26636.45
Liguria	40241.00	24919.48
Lombardia	302184.30	30157.48
Marche	37299.40	23768.13
Molise	5600.00	17853.73
Piemonte	114453.00	25616.65
Puglia	64489.70	15790.93
Sardegna	29853.60	17818.67
Sicilia	76487.40	15160.50
Toscana	96465.90	25753.18
P.A. Trento e Bolzano	31260.00	29860.98
Umbria	19366.80	21275.53
Valle D'Aosta	4184.60	32486.61
Veneto	133607.00	26935.07
Total	1423642.20	23303.29
Northwest	461062.90	28404.96
Northeast	326155.60	27870.51
Center	339631.30	24818.74
South	190451.40	14934.39
Islands	106341.00	15823.17

caps will not be applied to PV plants smaller than 12 kW and to specific categories of installations, such as, for example, PV roof of public buildings, repowering below 12 kW, plants up to 50 kW on roof where asbestos was removed, special PV plants.

All other plants will be included into registries where priority will be given to plants located on the roofs of building of high energy class, plants built with all components produced in the EU, plants located on contaminated sites, caves, mines and landfills, plants of up to 200 kW on factories roofs and on plants located on greenhouses, parking lots, acoustic barriers and other similar surfaces.

4. Effect of the FIT schemes on PV installations

In the period from 2008 to 2012 there has been a steady and unexpected growth of the installed PV power (Fig. 3), even though the tariff was reduced more than 70% in the same period. The market was so interesting to PV panel manufacturers that panel costs decreased much more than the tariff. Only from the beginning of 2013, the market is showing a strong decrease in new installations. This is mainly due to the more complicated procedures for the authorization process of large power plants, and to some expectations that the producers will be asked to program their energy production on a weekly or daily basis.

Since the feed-in tariff scheme has been applied without any geographical difference, looking at the above data, anyone would expect to find a strong correlation between the siting of the installations and the solar radiation, or the global solar energy reaching the ground, i.e. the product of the solar radiation times the regional area.

The data concerning the siting and size of all PV power plants installed in Italy are available from the GSE (Gestore dei Servizi Energetici) in its web site atlasole.gse.it/atlasole, where it is possible to know the location and the size of each plant. It is therefore quite simple to look at the geographical distribution at regional, provincial and even municipal levels.

Examining the percent values of the regional surface, regional GDP and regional global solar radiation, and comparing those values to the percent regional installed power, we can observe that, with the exception of Puglia, where there was a strong support in terms of ease of authorization and connection to the grid, most of the northern and central regions have a larger percentage of installed power than their surface or solar radiation on the ground.

Fig. 4 shows the comparison between the installed power and the regional surface, both expressed as a percentage of the national value. Fig. 5 shows a similar comparison with the global regional solar energy. Lombardia, Emilia Romagna, Veneto and Marche have a much lower insolation than Calabria, Basilicata, Sicilia and Sardegna, but have a larger share of installed PV power.

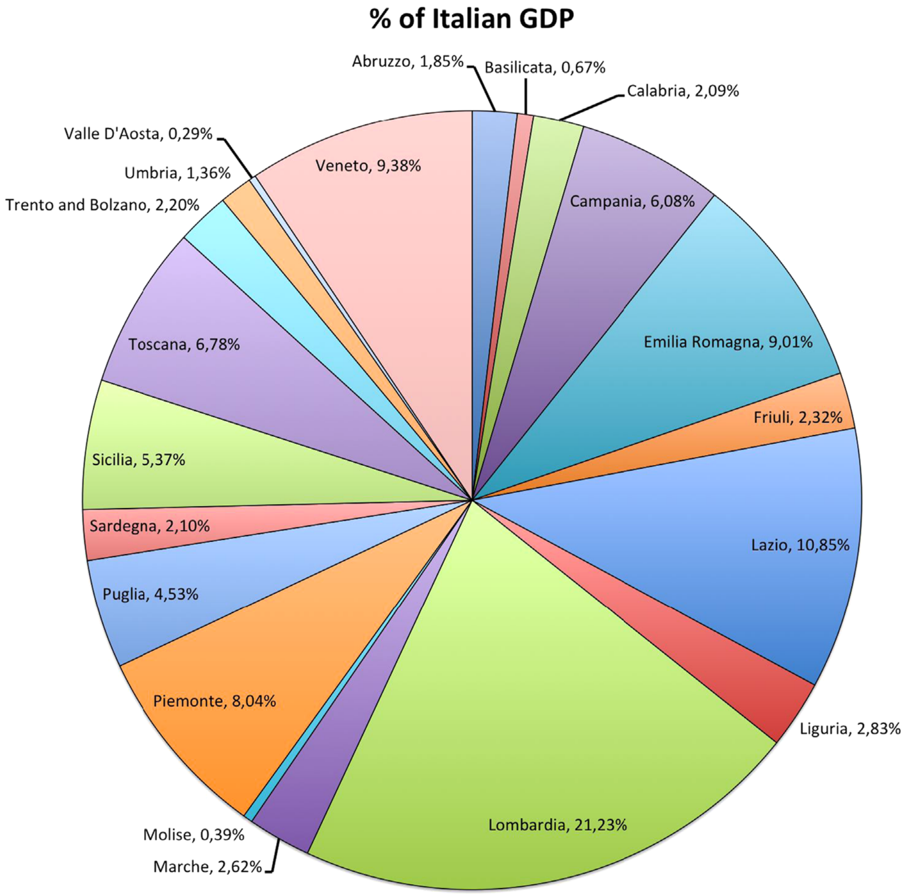

Fig. 2. Percent distribution of the regional GDP.

Table 3
2008–2010 FIT scheme (MSE Decree, 2007).

Power, P [kW]	Not integrated	Partially integrated	Integrated
	2008 FIT [€/kWh]		
$1<P<3$	0.4	0.44	0.49
$3<P<20$	0.38	0.42	0.46
$P>20$	0.36	0.4	0.44
	2009 FIT [€/kWh]		
$1<P<3$	0.392	0.4312	0.4802
$3<P<20$	0.3724	0.4116	0.4508
$P>20$	0.3528	0.392	0.4312
	2010 FIT [€/kWh]		
$1<P<3$	0.384	0.422	0.470
$3<P<20$	0.365	0.403	0.442
$P>20$	0.346	0.384	0.422

Table 4
2011 FIT Scheme (MSE Decree, 2010).

Power, P [kW]	2011 FIT [€/kWh]					
	PV plants installed before April 30, 2011		PV plants installed between May 1 and August 31, 2011		PV plants installed between September 1 and December 31, 2011	
	Roof mounted	Other plants	Roof mounted	Other plants	Roof mounted	Other plants
$1<P<3$	0.402	0.362	0.391	0.347	0.380	0.333
$3<P<20$	0.377	0.339	0.360	0.322	0.342	0.304
$20<P<200$	0.358	0.321	0.341	0.309	0.323	0.285
$200<P<1000$	0.355	0.314	0.335	0.303	0.314	0.266
$1000<P<5000$	0.351	0.313	0.327	0.289	0.302	0.264
$P>5000$	0.333	0.297	0.311	0.275	0.287	0.251

The northern and central regions have a higher population density and the available land is much smaller than in the south. Therefore, the installed power was not based on geographical criteria. This difference cannot be attributed to the difference in the geographical structure of the territory, since central and southern regions have similar orographic characteristics. Even stranger is the absence of correlation between the installed power and the global regional solar energy. This means that the distribution of the installations was not based on the availability of land or solar radiation, but on other driving factors.

If we look at the temporal evolution of the installed power in the five Italian macro regions (Fig. 6), it is quite clear that the northern and central regions and Puglia have responded to the introduction of the feed-in tariffs more promptly than the rest of the south and the islands.

This can be explained by the following reasons (ISTAT, 2013c):

(1) The north has an industrial economic structure based on small-medium enterprises (SMEs), which is more evident in the Northeast, with a larger offer of industrial buildings roofs where small and medium size plants could be installed. The Northwest has a larger number of big enterprises and the GDP, especially in the Milan area, is based on services and there is a very high population density with very high land costs. This is one of the reasons of the difference between the Northeast and the Northwest. In the Northern and Central regions there are 69.8 enterprises per 1000 inhabitants, while in the South

there are 51.4. Among the Southern regions, the largest number of enterprises per 1000 inhabitants can be found in Sardegna (ISTAT, 2013c).

(2) The population of the northern and central regions is wealthier and has a stronger propension to investing money, allowing a larger share of self financing of small and medium size plants. There is quite a significant difference in the interest rate applied in the Italian macro regions. The lowest rate is applied in the North–East and Lombardia, and the highest in the South and the Islands, with intermediate values in the Center. This is due not only to the higher risks of lending money in the South, which can be partially justified by the higher mortality of enterprises than in the North, but also to the larger number of families accessing personal credit for purchasing goods, which is characterized by a higher interest rate (ISTAT, 2013c). The larger use of personal credit from banks is also due to the larger number of families living close or under the poverty line in the South (ISTAT, 2013c). This justifies the reason why Southern families and enterprises are not borrowing money from banks for long term investments. In the Southern regions the percentage of deprived families reaches 37.5%, much higher than 15.2% in the Northwest, 12.3% in the Northeast and 18.6% in the Center.

(3) The population of northern and central regions is more sensitive to environment protection and sustainable development considerations (ISTAT, 2013c).

Table 5
2012 FIT Scheme (MSE Decree, 2011).

Power, P [kW]	2011–2012 FIT [€/kWh]					
	PV plants installed in June 2011		PV plants installed in December 2011		PV plants installed in the first semester of 2012	
	BIPV	Other plants	BIPV	Other plants	BIPV	Other plants
$1<P<3$	0.387	0.344	0.281	0.261	0.274	0.240
$3<P<20$	0.356	0.319	0.268	0.238	0.247	0.219
$20<P<200$	0.338	0.306	0.253	0.224	0.233	0.206
$200<P<1000$	0.325	0.291	0.246	0.189	0.224	0.172
$1000<P<5000$	0.314	0.277	0.212	0.181	0.182	0.156
$P>5000$	0.299	0.264	0.199	0.172	0.171	0.148

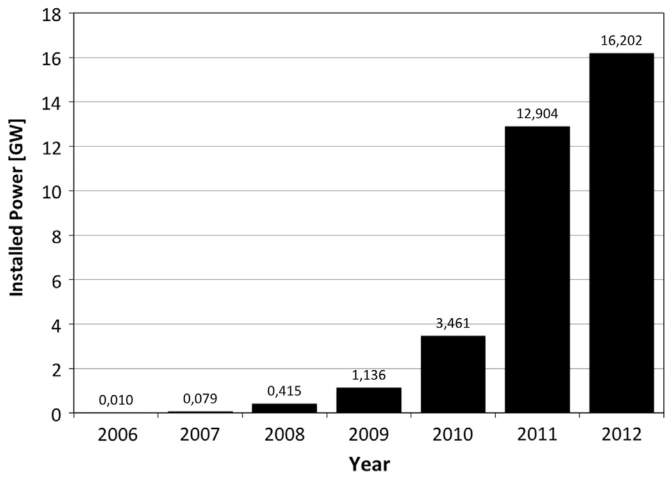

Fig. 3. Cumulated installed power in Italy from 2006 to 2012.

Those explanations are confirmed by looking at the installed PV power per 1000 inhabitants, whose highest value is found in the northeast and the lowest in the northwest and the islands (Fig. 7). The number of installations per 1000 inhabitants in the northeast is almost double than in the rest of the macro regions (Fig. 8).

This last data can be better understood if the distribution of the size of plants is examined in the different macro regions (Fig. 9). Small and medium size building integrated power plants were preferred in the northeast to large power plants on the open ground. PV plants smaller than 20 kW are typical of single houses, small residential and industrial buildings, with a share of the investment from owners of homes or small enterprises. The northern and central regions are also leading the count of plants with power output from 200 to 1000 kW, whereas the largest installations are located in the South.

In several cases, large PV plants (1 MW and above) were also installed in areas characterized by foggy weather in the winter, just a few kilometers far from the Po River. Those power plants were built neither to maximize the solar energy input nor the revenues, but simply because low-cost land was available, and

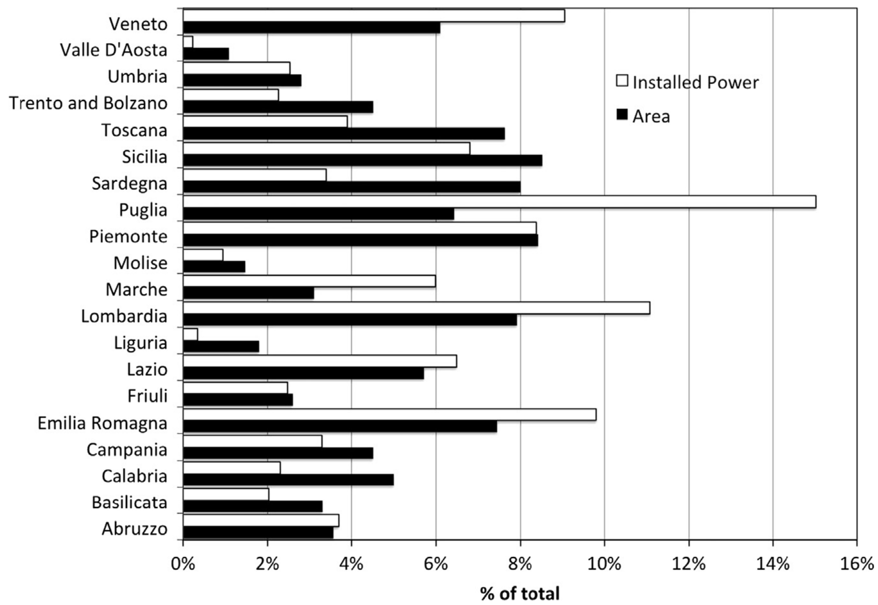

Fig. 4. Comparison between the installed power and the regional area.

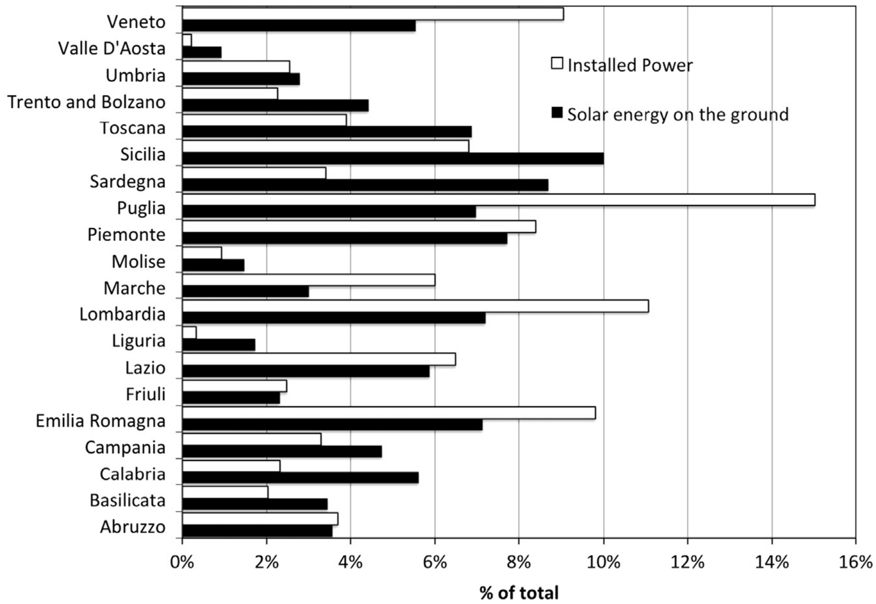

Fig. 5. Comparison between the installed power and the global regional solar radiation.

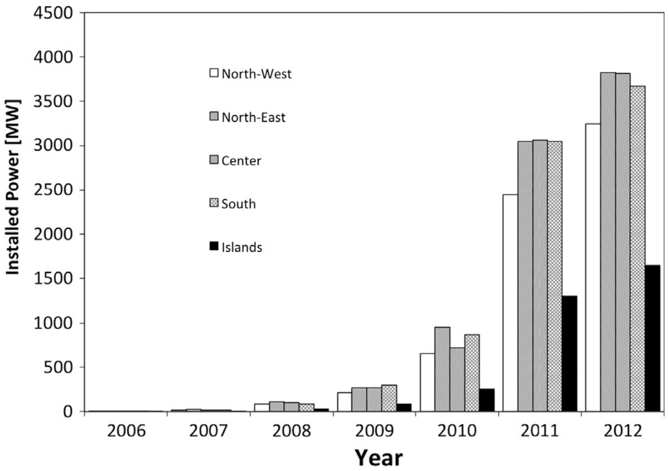

Fig. 6. Evolution of the installed power in the macro regions.

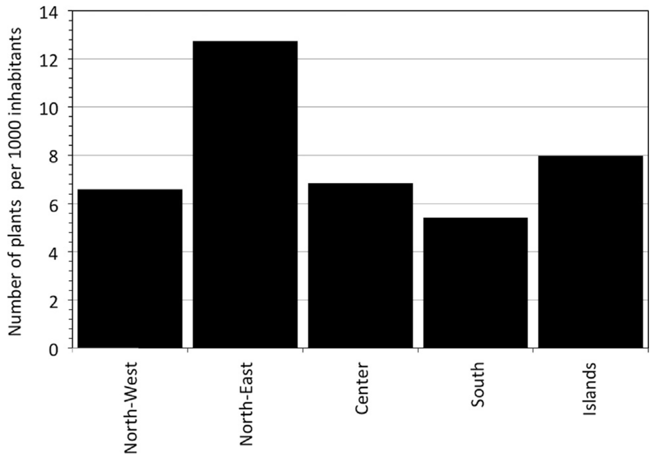

Fig. 8. Number of plants per 1000 inhabitants in the macro regions.

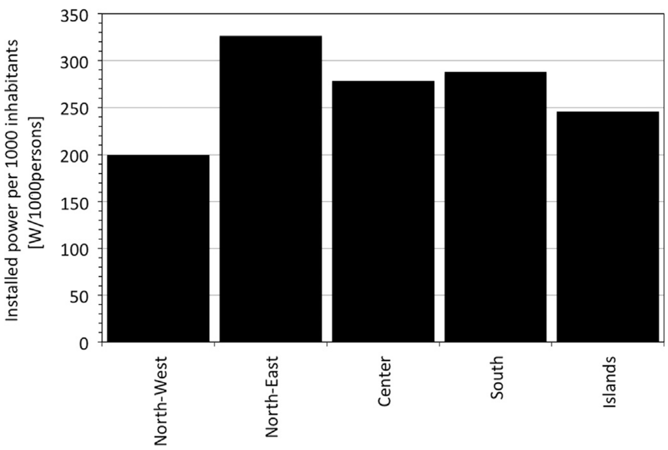

Fig. 7. Installed power per 1000 inhabitants in the macro regions.

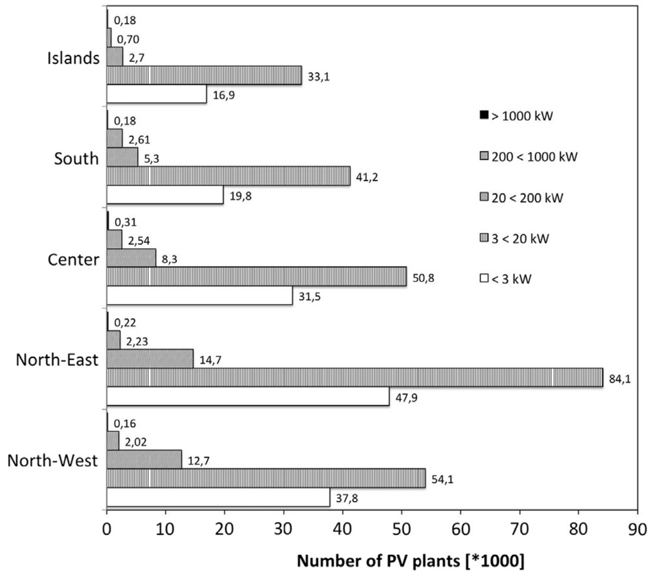

Fig. 9. Distribution of the peak power per plant in the macro regions.

authorization procedures or grid connection were easier and less expensive. The same plants in other areas located in the South could have produced twice as many revenues with the same investment cost. Therefore, the FIT schemes were high enough to make a PV plant economically feasible even in the least insolated areas of northern Italy.

Almost all cases of power plants with a peak power of 1 MW and larger were built on the open ground in rural areas. This was made possible by three additional incentives:

(1) Rural companies have a lower taxation than industrial ones.
(2) Rental of land for agricultural use was very low for investors due to the competition with revenues from agriculture.
(3) The EU agriculture policy, which is based on promoting different products every year, depending on the decisions of the EU commission, can make the land more or less profitable in different years. Having a guaranteed rental from the investors for as long as 20 years has often been considered more interesting and safer for landowners.

Big investors such as investment funds, banks and big companies, differently from small investors, have preferred maximizing the revenues by following the sun insolation, choosing locations with the maximum solar radiation.

Even though the global installed power per 1000 inhabitants is larger in the islands and smaller in the Northwest (Fig. 10), the installed power per global solar radiation is minimum in the islands and practically the same in the rest of Italy (Fig. 11).

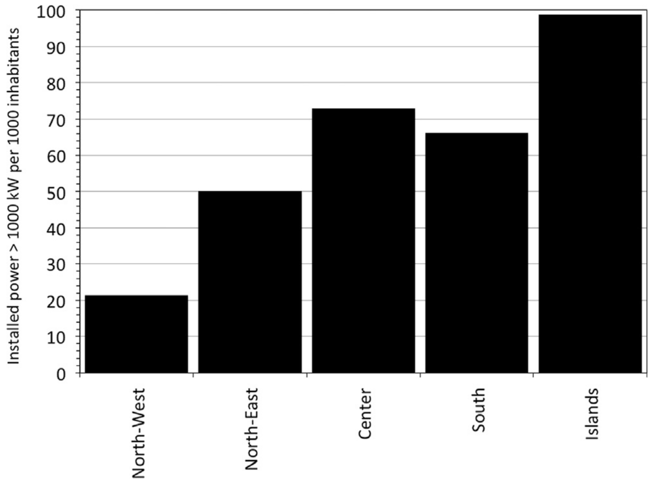

Fig. 10. Installed power of power plants larger than 1000 kW per 1000 inhabitants in the macro regions.

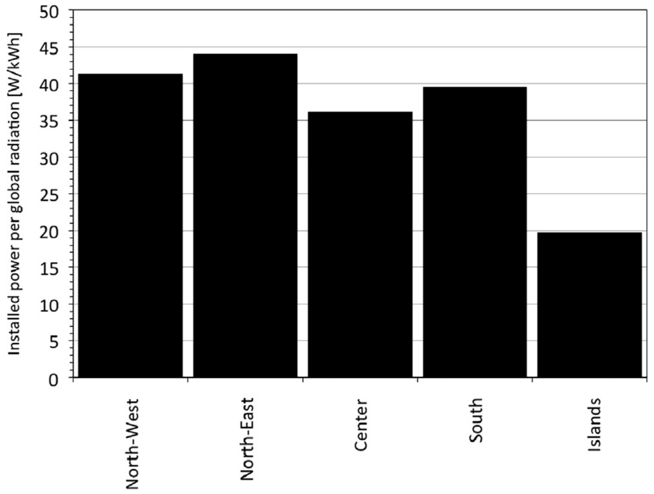

Fig. 11. Installed power of power plants larger than 1000 kW per global solar radiation in the macro regions.

Fig. 10 shows that larger installed power per 1000 inhabitants means bigger investments from other areas of Italy or abroad, since the per capita GDP in the south and the islands is much lower than in the rest of Italy.

Fig. 11 shows that the islands still have a great potential for the installation of PV power plants, which was actually unexploited because the investments started there later than in the rest of Italy.

5. Effect of FIT schemes on the plant costs

The market that was created in Italy by the above described FIT schemes caused a significant change in PV plant costs. In fact, a cost decrease was expected due to the large volume of the market, with a continuous decline in the cost of PV panels.

In the years 2010 and 2011 it was feared that the manufacturers could not provide enough panels to keep up with the demand and the major market movers were only interested in large power plants.

The economic data provided by a company which is active in the installation of small to medium size PV plants, shows the simultaneous decrease of the costs of PV plants and the FIT. Since the government fixed the FIT by decreasing of a fixed percentage the initial values, instead of adapting the value to the cost of the panels, it was the cost to be changed to keep the investment convenient. Therefore, the PV plants costs were steeply reduced

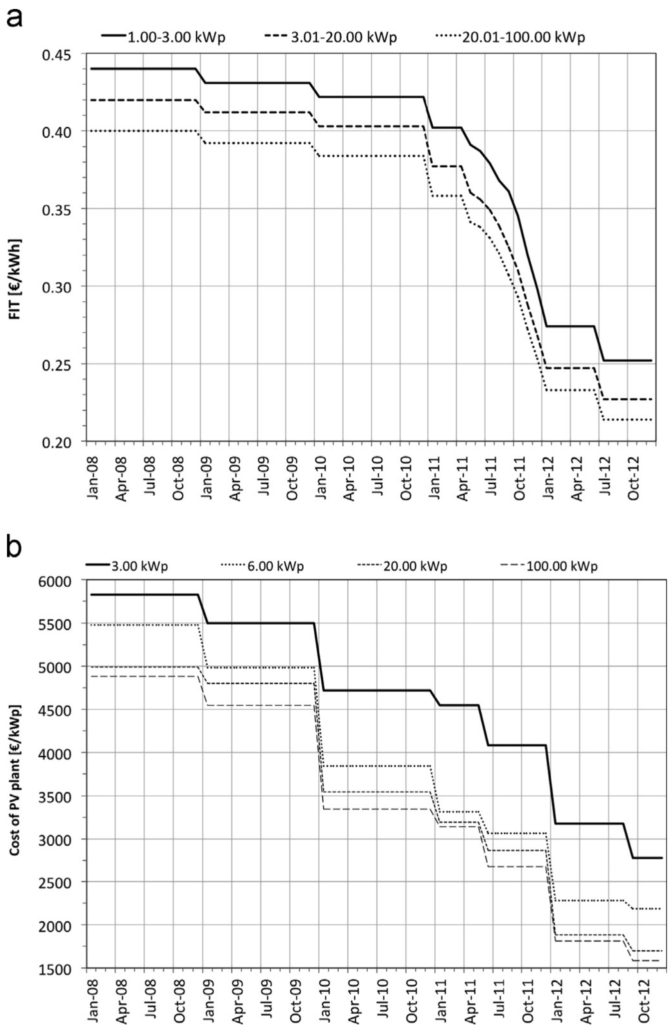

Fig. 12. FIT (a) and PV plants cost (b) changes with FIT scheme.

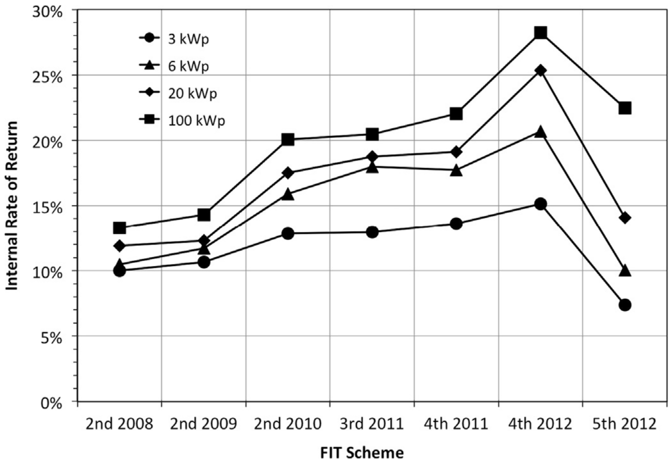

Fig. 13. Trend of the IRR of the investment for different sizes of PV power plant.

every time the FIT was decreased. Fig. 12 shows how the market price was fixed by the FIT schemes and not viceversa.

In fact, even when FIT decreased, the internal rate of return of the investments continued to rise until 2012. The IRR still remains significantly high for large power plants, whereas it is lower for small installations (Fig. 13).

This is actually the opposite of what the FITs should stimulate: i.e. helping home owners to install their systems instead of financing big investments in large power plants, which are located on the open ground.

This increase was significant also for larger plants, but is heading toward a constant percentage of the overall costs, as the cost of the inverter.

Therefore the benefit caused by the exponential decrease of the costs of the PV panels will be partially absorbed by the linear decrease of the inverter and the rising other costs. It is expected that other costs will definitely prevail in small residential systems, where energy service companies are now offering installations without costs and with a future benefit after 12–14 years to homeowners.

6. Technical and economic issues

This paper has shown that the FIT schemes that were applied in Italy in the last five years have made Italy one of the countries with the largest stock of PV plants in the world. The growth was so abrupt and uncontrolled until the end of 2012 that some important issues have to be considered:

(1) The burden for Italian citizens and enterprises which will be distributed in electricity bills will be bigger that 8 billion € in the next 20 years. The government is currently thinking of prolonging the 20 years to 30 in order to reduce the annual payback of the tariffs setting a cap at 9 billion €. To understand what this may mean in the Italian economy, it may be worth mentioning that the overall government financing of the Italian higher education system (all the government funded Universities) was 6.83 billion € and is expected to be reduced in the future. Pew Charitable Trust report, (2012) reports 28 billion € investment in Italy in 2011 mostly to finance the installation of PV plants. This means that a quarter of the investments will be paid back in the electricity bills, but the largest share will be transferred abroad to buy the PV cells. Moreover, the incentives currently represent 16–17% of the electricity bill and they have caused an increase of 30% of the cost of the kWh for residential users (Fondazione per lo Sviluppo Sostenibile, 2013). If the cost of the kWh for residential users is only 13% higher than the EU average, the cost of the kWh for industrial users is 40% higher than the EU average. This will reduce the purchase power of individuals and enterprises by 7 billion € per year and will not contribute to the competitiveness of the country for energy consuming companies, such as steel factories, which will continue to move abroad or shut down their activities in Italy.(Fig. 14)

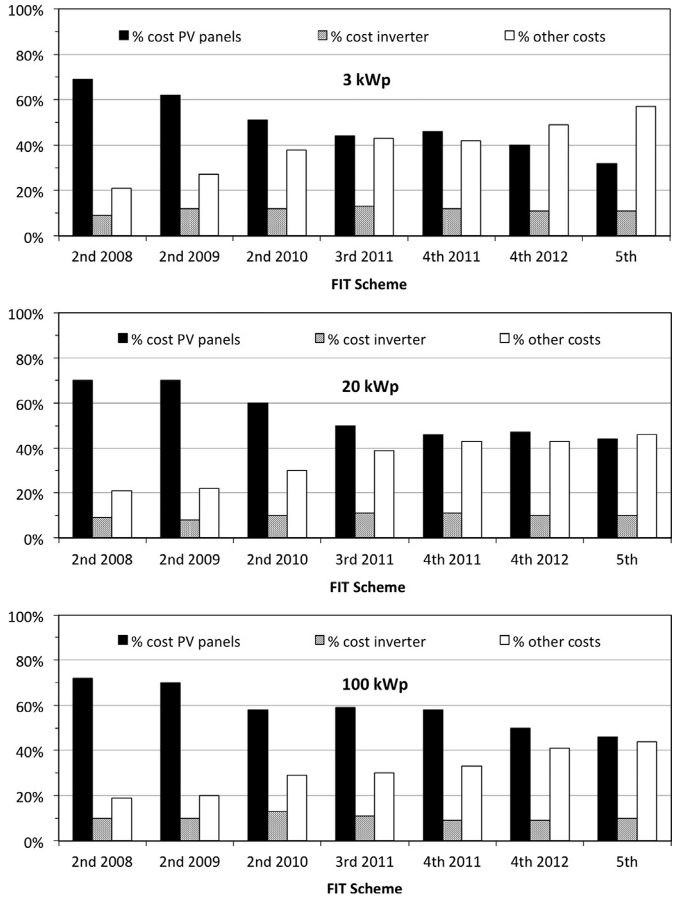

Fig. 14. Distribution of percent cost of PV panels, inverters and other costs for 3, 20 and 100 kW.

(2) Most of the costs were transferred abroad, since no producer of PV cells has established its production in Italy. Only companies assembling cells to make panels and companies providing services for the installation of the plants have started their operation in Italy in the last 5 years. A number of companies specialized in inverters have also developed their business in Italy, but there are many foreign companies too offering their products in Italy. Even the introduction of a premium tariff, since 2012, for the installation of panels manufactured in the EU has not provided significant benefits to the Italian industry and a marginal benefit to the EU industry. The decrease of the cost of panels from Asia was so high to outperform any FIT premium.

(3) There is a risk of technological bubble. In fact the 28 billions € investment in 2011 (Pew Charitable Trust, 2012) has now dropped to 1.3 billion €. Any sector with such large decrease in investment is ready to collapse. Even though the most organized and capitalized companies are looking abroad and some excellent companies are being bought by foreign companies or investors, such a decrease may mean the end of significant number of businesses. Now that the installations are capped, and procedures are much more stringent for the

authorization and the startup, the market has strongly slowed down and most companies in this field must reduce their growth expectations or just reduce their revenues and profit. Maintenance and final disposal of panels are still too far in time to justify a significant share of replacements to support such a big market.

(4) No significant benefits were obtained in terms of performance of panels. No new technology has been offered commercially in Italy at a large scale and such large growths are normally sustained with state of the art technologies (Frondel et al., 2008). Manufacturing is more important than improving products. No adequate technological premium was offered for high performance or innovative systems.

(5) A peak power of 16 GW is approximately one fifth of the available power from fossil fired and large hydroelectric plants. The peak demand in Italy is seldom higher than 50 GW. Considering that over 15% of the electricity in Italy is imported during the night and that there are 18 GW hydro power, almost 8 GW wind power and 4 GW from biomass available, one third of the electricity demand is covered by imports and renewable energy sources. More than 10 GW CHP power provide a significant share of the energy demand, so that the Italian grid hardly needs any electricity from fossil fired thermoelectric plant during most of the year. This has caused several problems since several plants have to be kept on standby or operated at part load with low efficiencies to supply the demand when renewables are not producing. Large PV plants in remote areas of the national grid were forced to shut down in summer 2012, because of excessive production with respect to the demand.

(6) Among the renewable energy sources used in Italy in 2012, it may be noted that PV energy is the one with the smallest utilization factor in terms of equivalent number of hours of peak power operation. Only 20% of the renewable energy produced in Italy is generated by PV panels, whereas more than 34% of the peak power is to be accounted to that source (GSE, 2013).

(7) If we consider the avoided CO_2, the overall PV energy is equivalent to a 2400 MW fossil fired power plant operating for approximately 8000 h. Therefore the avoided CO_2 is approximately 1.3 Mt. The overall burden divided by the avoided CO_2 gives over 5000 € per ton of CO_2.

Therefore, the benefits of renewable energy sources have to be clearly compared to other solutions, which could be more effective and profitable for the society. Not only technological costs are very high, but also social costs may become unbearable in the future.

One possible proposal to reduce all the above drawbacks in future applicatons of FITs or in other countries who have not yet actively promoted PV plants, is to control the tariff so that locations with higher insolation have a smaller benefit. Installations with tens of MW on the ground, even though they will use sustainable practices, are limiting the land utilization for two decades and probably more with a very small specific energy in terms of power per square meter.

The Italian situation shows however, that even the minimum tariff was fixed at too high a level, since PV plants were installed in the least insolated areas of the country. It should also be evaluated by the government, that the return of the investment be similar to bonds and much smaller than either industrial or highly remunerative investments, since FITs are guaranteed by the government. Capping the overall amount of installations after defined intervals of time may be a good way to control the social costs. Acting well ahead of the end of each period may guarantee a smooth transition before and after a cap is reached, and may control the cost of power plants and a well balanced investment in the years.

7. Conclusions

The introduction of a strong incentivization policy in the PV sector has lead to unexpected growth of the number of installations of all sizes with a distribution on the Italian territory that is quite uniform and does not depend much on the insolation of the site.

The investment in the wealthiest regions is much higher than in the south of Italy, even though the insolation is smaller.

From the examination of the results the following conclusions can be drawn:

- The application of a single FIT scheme in a country with more than 50% different in solar radiation between the most and the least insolated areas has not produced a concentration of the PV plants in the sunniest regions.
- Large power plants were installed where the available solar radiation was higher, small power plants where the wealth of the population is higher.
- The burden on the Italian society is and will be big for the coming 20 years and has significant drawbacks on the energy production mix, the cost of avoided CO_2, and the creation of jobs and companies on a long term basis.

The lessons that can be learnt from this experience are the following:

- Uncapped FIT schemes may provide unexpected and excessive growth and too high a social burden.
- When solar radiation has too large differences in the same country, the FIT scheme should be different for different macro regions.
- It should be avoided to create an incentive that is not distributed between peers (citizens, enterprises, etc.) but and where money is transferred from productive sectors and private citizens to banks and investment funds.
- Some mechanisms for the creation of a domestic industrial sector and long term jobs should be foreseen.
- A balanced incentivization among renewable energy sources should be promoted to avoid privileging too much one solution among all the possible ones.

References

Bortolini, M., Gamberi, M., Graziani, A., Mora, C., Regattieri, A., 2013. Multi-parameter analysis for the technical and economic assessment of photovoltaic systems in the main European Union countries. Energy Convers. Manag. 74, 117–128, http://dx.doi.org/10.1016/j.enconman.2013.04.035.

Campoccia, A., Dusonchet, L., Telaretti, E., Zizzo, G., 2009. Comparative analysis of different supporting measures for the production of electrical energy by solar PV and Wind systems: four representative European cases. Sol. Energy 83, 287–297, http://dx.doi.org/10.1016/j.solener.2008.08.001.

Cucchiella, F., D'Adamo, I., 2012a. Feasibility study of developing photovoltaic power projects in Italy: an integrated approach. Renew. Sustain. Energy Rev. 16, 1562–1576, http://dx.doi.org/10.1016/j.rser.2011.11.020.

Cucchiella, F., D'Adamo, I., 2012b. Estimation of the energetic and environmental impacts of a roof-mounted building-integrated photovoltaic systems. Renew. Sustain. Energy Rev. 16, 5245–5259, http://dx.doi.org/10.1016/j.rser.2012.04.034.

Cucchiella, F., D'Adamo, I., Lenny Koh, S.C., 2013. Environmental and economic analysis of building integrated photovoltaic systems in Italian regions. J. Clean. Prod., 1–12, http://dx.doi.org/10.1016/j.jclepro.2013.10.043. (In Press).

Danchev, S., Maniatis, G., Tsakanikas, A., 2010. Returns on investment in electricity producing photovoltaic systems under de-escalating feed-in tariffs: the case of Greece. Renew. Sustain. Energy Rev. 14, 500–505, http://dx.doi.org/10.1016/j.rser.2009.08.008.

del Rio, P., Gual, M.A., 2007. An integrated assessment of the feed-in tariff system in Spain. Energy Policy 35, 994–1012, http://dx.doi.org/10.1016/j.enpol.2006.01.014.
Dusonchet, L., Telaretti, E., 2010. Economic analysis of different supporting policies for the production of electrical energy by solar photovoltaics in western European Union countries. Energy Policy 38, 3297–3308, http://dx.doi.org/10.1016/j.enpol.2010.01.053.
Erge, T., Hoffmann, V.U., Kiefer, K., 2001. The German experience with grid-connected PV-systems. Sol. Energy 70 (6), 479–487.
Falconett, I., Nagasaka, K., 2010. Comparative analysis of support mechanisms for renewable energy technologies using probability distributions. Renew. Energy 35, 1135–1144, http://dx.doi.org/10.1016/j.renene.2009.11.019.
Fondazione per lo Sviluppo Sostenibile, 2013. I costi dell'energia in Italia. In: Ronchi, E., Barbabella, A., Refrigeri, L., (Eds.). Printed in Rome, Italy by Fondazione per lo Sviluppo Sostenibile. Downloaded from ⟨www.fondazionesvilupposostenibile.org⟩ on November 20, 2013. (In Italian).
Frondel, M., Ritter, N., Schmidt, C.M., 2008. Germany's solar cell promotion: dark clouds on the horizon. Energy Policy 36, 4198–4204, http://dx.doi.org/10.1016/j.enpol.2008.07.026.
GSE (Gestore dei Servizi Energetici), 2013. Rapporto statistico 2012 solare fotovoltaico. Downloaded from ⟨www.gse.it⟩ on November 20, 2013. (In Italian).
Haas, R., Resch, G., Panzer, C., Busch, S., Ragwitz, M., Held, A., 2011. Efficiency and effectiveness of promotion systems for electricity generation from renewable energy sources e lessons from EU countries. Energy 36, 2186–2193, http://dx.doi.org/10.1016/j.energy.2010.06.028.
ISTAT (Istituto Nazionale di Statistica), 2013a. Statistiche demografiche. Downloaded from ⟨demo.istat.it/bil20111009/index02.html⟩ on July 20, 2013.
ISTAT (Istituto Nazionale di Statistica), 2013b. Sistema Indicatori Territoriali. Downloaded from ⟨sitis.istat.it/sitis/html/⟩ on July 20, 2013.
ISTAT (Istituto Nazionale di Statistica), 2013c. Noi Italia, 100 statistiche per capire il paese in cui viviamo. Printed in Viterbo, Italy. ISBN:978-88-458-1738-0 (in Italian).
Jacobs, D., Sovacool, B.K., 2012. Feed-in tariffs and other support mechanisms for solar PV promotion. Compr. Renew. Energy 1, 73–109, http://dx.doi.org/10.1016/B978-0-08-087872-0.00104-9.
Jenner, S., Groba, F., Indvik, J., 2013. Assessing the strength and effectiveness of renewable electricity feed-in tariffs in European Union countries. Energy Policy 52, 385–401, http://dx.doi.org/10.1016/j.enpol.2012.09.046.
Leepa, C., Unfried, M., 2013. Effects of a cut-off in feed-in tariffs on photovoltaic capacity: Evidence from Germany. Energy Policy 56, 536–542, http://dx.doi.org/10.1016/j.enpol.2013.01.018.
Lüthi, S., 2010. Effective deployment of photovoltaics in the Mediterranean countries: balancing policy risk and return. Sol. Energy 84, 1059–1071, http://dx.doi.org/10.1016/j.solener.2010.03.014.
Massi Pavan, A., Lughi, V., 2012. Photovoltaics in Italy: toward grid parity in the residential electricity market. In: Proceedings of the 24th International Conference on Microelectronics (ICM), 16–20 December. Algiers, Algeria, pp. 1–4. ISBN:978-1-4673-5289-5. http://dx.doi.org/10.1109/ICM.2012.6471415.
Mazzanti, G., Santini, E., Zaccagnini Romito, D., 2012. Towards grid parity of solar energy in Italy: the payback time trend of photovoltaic plants during the last years. In: Proceedings of IEEE Power and Energy Society General Meeting, 22–26 July. San Diego, CA, pp. 1–8. ISBN:978-1-4673-2728-2, http://dx.doi.org/10.1109/PESGM.2012.6345426.
Mints, P., 2012. The history and future of incentives and the photovoltaic industry and how demand is driven. Prog. Photovolt.: Res. Appl. 20, 711–716, http://dx.doi.org/10.1002/pip.
Moosavian, S.M., Rahim, N.A., Selvaraj, J., Solangi, K.H., 2013. Energy policy to promote photovoltaic generation. Renew. Sustain. Energy Rev. 25, 44–58, http://dx.doi.org/10.1016/j.rser.2013.03.030.
MSE (Ministero dello Sviluppo Economico) Decree, February 19, 2007. Criteri e modalita' per incentivare la produzione di energia elettrica mediante conversione fotovoltaica della fonte solare. In attuazione dell'articolo 7 del decreto legislativo 29 dicembre 2003. n. 387 (in Italian).
MSE (Ministero dello Sviluppo Economico) Decree, August 6, 2010. Incentivazione della produzione di energia elettrica mediante conversione fotovoltaica della fonte solare (in Italian).
MSE (Ministero dello Sviluppo Economico) Decree, May 5, 2011. Incentivazione della produzione di energia elettrica da impianti solari fotovoltaici (in Italian).
MSE (Ministero dello Sviluppo Economico) Decree, July 5, 2012. Attuazione dell'art. 25 del decreto legislativo 3 marzo 2011. n. 28, recante incentivazione della produzione di energia elettrica da impianti solari fotovoltaici (in Italian).
Muhammad-Sukki, F., Ramirez-Iniguez, R., Munir, A.B., Mohd Yasin, S.H., Abu-Bakar, S.H., McMeekin, S.G., Stewart, B.G., 2013. Revised feed-in tariff for solar photovoltaic in the United Kingdom: a cloudy future ahead? Energy Policy 52, 832–838, http://dx.doi.org/10.1016/j.enpol.2012.09.062.
Papadopoulos, A.M., Karteris, M.M., 2009. An assessment of the Greek incentives scheme for photovoltaics. Energy Policy 37, 1945–1952, http://dx.doi.org/10.1016/j.enpol.2008.12.040.
Pew Charitable Trusts, 2012. Who's Winning the Clean Energy Race? 2011 Edition. Report compiled for the Pew Environment Group by Bloomberg New Energy Finance. Printed in the USA. Downloaded from ⟨www.PewTrusts.org/CleanEnergy⟩ on November 20, 2013.
Pirnia, M., Nathwani, J., Fuller, D., 2011. Ontario feed-in-tariffs: system planning implications and impacts on social welfare. Electr. J. 24 (8), 18–28, http://dx.doi.org/10.1016/j.tej.2011.09.009.
Rigter, J., Vidican, G., 2010. Cost and optimal feed-in tariff for small scale photovoltaic systems in China. Energy Policy 38, 6989–7000, http://dx.doi.org/10.1016/j.enpol.2010.07.014.
Sarasa-Maestro, C.J., Dufo-Lopez, R., Bernal-Agustin, J.L., 2013. Photovoltaic remuneration policies in the European Union. Energy Policy 55, 317–328, http://dx.doi.org/10.1016/j.enpol.2012.12.011.
Schallenberg-Rodrigueza, J., Haas, R., 2012. Fixed feed-in tariff versus premium: a review of the current Spanish system. Renew. Sustain. Energy Rev. 16, 293–305, http://dx.doi.org/10.1016/j.rser.2011.07.155.
Spertino, F., Di Leo, P., Cocina, V., 2013. Economic analysis of investment in the rooftop photovoltaic systems: A long-term research in the two main markets. Renew. Sustain. Energy Rev. 28, 531–540, http://dx.doi.org/10.1016/j.rser.2013.08.024.
White, L.V., Lloyd, B., Wakes, S.J., 2013. Are feed-in tariffs suitable for promoting solar PV in New Zealand cities? Energy Policy 60, 167–178, http://dx.doi.org/10.1016/j.enpol.2013.04.079.
Yamamoto, Y., 2012. Pricing electricity from residential photovoltaic systems: A comparison of feed-in tariffs, net metering, and net purchase and sale. Solar Energy 86, 2678–2685, http://dx.doi.org/10.1016/j.solener.2012.06.001.
Yatchew, A., Baziliauskas, A., 2011. Ontario feed-in-tariff programs. Energy Policy 39, 3885–3893, http://dx.doi.org/10.1016/j.enpol.2011.01.033.
Zahedi, A., 2010. A review on feed-in tariff in Australia, what it is now and what it should be. Renew. Sustain. Energy Rev. 14, 3252–3255, http://dx.doi.org/10.1016/j.rser.2010.07.033.