

The impact of the electricity tariff reform on renewable energies and energy efficiency investments: The case of the Italian residential market

Davide Chiaroni, Vittorio Chiesa, Simone Franzò, Federico Frattini & Vito Manfredi Latilla

To cite this article: Davide Chiaroni, Vittorio Chiesa, Simone Franzò, Federico Frattini & Vito Manfredi Latilla (2017): The impact of the electricity tariff reform on renewable energies and energy efficiency investments: The case of the Italian residential market, International Journal of Green Energy, DOI: [10.1080/15435075.2017.1336715](https://doi.org/10.1080/15435075.2017.1336715)

To link to this article: <http://dx.doi.org/10.1080/15435075.2017.1336715>



Accepted author version posted online: 08 Jun 2017.
Published online: 08 Jun 2017.



Submit your article to this journal [↗](#)



Article views: 24



View related articles [↗](#)



View Crossmark data [↗](#)



The impact of the electricity tariff reform on renewable energies and energy efficiency investments: The case of the Italian residential market

Davide Chiaroni, Vittorio Chiesa, Simone Franzò, Federico Frattini, and Vito Manfredi Latilla

Politecnico di Milano, Dipartimento di Ingegneria Gestionale, Milano, Italy

ABSTRACT

This article investigates the impact that the electricity tariff reform is likely to have on investments in renewable energies (i.e., photovoltaics) and the adoption of energy efficiency measures (i.e., installation of heat pumps and efficient home appliances) in the residential market in Italy. The study develops detailed cost comparisons and simulations considering two different investment scenarios (before and after the reform) to conclude that the reform will: (i) have a negative impact on investments in photovoltaic systems; (ii) favor the adoption of energy efficiency measures, such as efficient home appliances.

KEYWORDS

Electricity tariff; energy efficiency; energy policy; heat pump; home appliances; photovoltaic; renewable energy

Introduction

The electricity sector is going through a transformation driven by technological changes and, most importantly, national and supranational policies aimed at tackling three major challenges, i.e., environmental sustainability, energy supply security, and sustainable economic development (European Commission 2007). Technological advancements have led to significant cost and performance improvements for some renewable energy sources (RES), such as onshore wind and photovoltaics (PV) (Hirth 2013). The combination of technological advances, innovative financing, deal structuring, and business model configurations, have led to the increasing cost competitiveness of RES (Stark et al. 2015). Furthermore, recent policies foresee more stringent targets in terms of CO₂ emission, increased penetration of RES, and higher levels of energy efficiency (Manzano-Agugliaro et al. 2013), thereby bestowing a strategic role to electricity and heat generation from RES and to the adoption of energy efficiency measures (EEM) (Pantaleo, Camporeale, and Shah 2013; Viola et al. 2014).

At the European level, the European Commission's strategy to deal with climate change (European Commission 2015) focuses on the need to reduce emissions by 40% and increase the electricity produced from RES to 27% by 2030 (COM (2012) 663 final (2012); COM (2012) 271 (2012); European Directive 28 2009). RES generated electricity accounts for 27.5% of EU-28 gross electricity consumption (Eurostat 2016). In terms of total investments in new RES plants in Europe, wind power accounts for 38%, photovoltaics for around 36%, and hydroelectric power plants for around 14% (Figure 1) (Energy&Strategy 2016a).

The high penetration of RES in the electricity generation mix significantly affects the price dynamics and network

congestion, and as a result, the performance of the electricity market (Cucchiella, D'Adamo, and Gastaldi 2012). This is particularly relevant in the Italian market, one of the most developed in Europe in terms of renewable energy penetration, and plays a major role in terms of EEM investments (ACEEE 2016; ENEA 2015). In Italy, new investments in PV systems in 2015 totalled €558 million, equal to 290 MW of new installed capacity. Investments in the residential market segment (including systems with a power rate of up to 20 kW) accounted for 51% of total investments, equal to 55% of total new power installed capacity (Figure 2) (Energy&Strategy 2016a). Overall, 23,788 MW of RES plants were installed in Italy between 2010–2015 (Table 1). In the first quarter of 2016, new installed PV systems amounted to 195 MW, up 46% compared with the same period in 2015. Nevertheless, in the first quarter of 2016, the aggregate value of new PV, wind and hydroelectric installations was 19% less than the installed capacity in the same quarter in 2015 (ANIE 2016). Moreover, in the first 9 months of 2016, the RES energy produced covered 30.8% of total energy demand in Italy, down 3.8% compared with the same period in 2015 and 4.2% compared to the same period in 2014 (Gestore Servizi Energetici 2016; TERNA 2016).

Energy efficiency in conjunction with RES constitutes another pillar of the European strategy to reduce carbon emissions, since EEM can contribute significantly to the reduction of energy consumption (Blok et al. 2015; Chiaroni et al. 2016b; Gestlberger et al. 2016; Ponsa et al. 2013). In recent years, energy efficiency has become part of national and international policy discussions and is recognized as a relevant factor of sustainable environmental and economic growth (Geller et al. 2006; Karimu and Brännlund 2015). Specifically, implementing EEM is of paramount importance

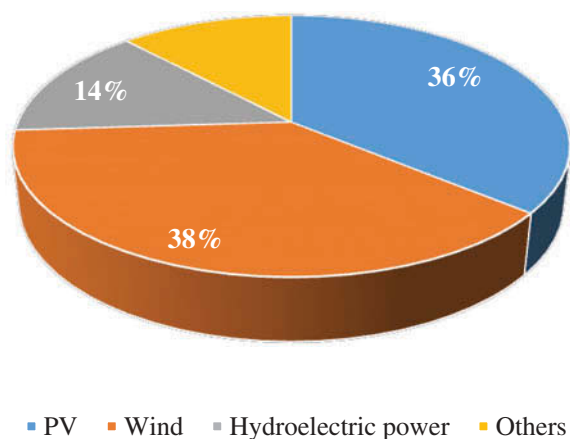


Figure 1. Share of investments in new RES plants at the EU level in 2015 (Energy&Strategy 2016a).

at the EU level where electricity prices tend to be higher compared to other geographic areas (Astrov et al. 2015). Hence, the EU has established a set of binding measures to help EU countries reach the 20% energy efficiency target by 2020, requiring member states to use energy more efficiently at all stages of the energy chain, from production to final consumption (European Directive 27 2012). In the last 4 years, EEM investments showed a Compound Annual Growth Rate (CAGR) of over 10% at the European level (Energy&Strategy 2015b). In this regard, Italy has adopted a national energy strategy that prioritizes energy efficiency as

the cornerstone of energy supply security, reducing energy costs for citizens and businesses, and ensuring environmental protection through greenhouse gas reductions (Ministero Dello Sviluppo Economico 2013). Thanks to proactive legislation, Italy is ranked second worldwide among the most energy-efficient countries (ACEEE 2016), and investments in EEM continue to increase, up to over €7.9 billion in 2015 (Energy&Strategy 2015b). The residential sector in 2015 was responsible for the majority of total EEM investments, followed by the industrial sector (ENEA 2016). Specifically, energy-efficient home appliances (with a market value of more than 2 billion €) constituted the most adopted EEM in the residential sector in 2015, followed by heat pumps, which accounted for more than 1 billion € (Figure 3) (Energy&Strategy 2016b).

In this scenario, the electricity tariff reform for the residential market in Italy (hereinafter, “reform”) entered into force on 1 January 2016 following Deliberation 582/2015/R/EEL of the Italian Regulatory Authority for Electricity, Gas and Water (AEEGSI) (AEEGSI, 2015a), in line with the national implementation of the EU Energy Efficiency Directive (European Directive 27 2012). The goal of the reform is to increase the electrification of residential energy consumption to fully exploit the use of electricity generated from RES, moving beyond the progressive structure of the network services and system charges tariffs introduced after the oil price shock of 1973 to discourage high electricity consumption among residential customers.

The reform is expected to have an impact on RES and EEM investments (Chiaroni et al., 2016a), since the new

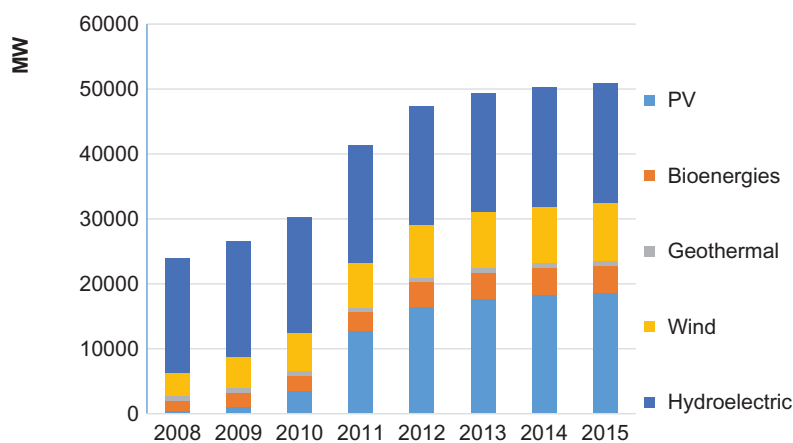


Figure 2. Cumulative RES installed capacity in Italy over the period 2008–2015 (Energy&Strategy 2016a).

Table 1. New RES installation in Italy in MW and € divided by production source for 2010–2015 (Energy&Strategy 2016a)

RES		2010	2011	2012	2013	2014	2015	Cumulative 2010–2015
Wind	MW	1,100	900	1,350	400	107	420	4,277
	Mln €	1,850	1,800	2,000	700	151	670	7,171
PV	MW	2,323	9,370	3,328	1,736	385	290	17,432
	Mln €	7,600	20,135	6,215	2,508	658	558	37,516
Hydroelectric power	MW	155	216	140	69	73	110	763
	Mln €	621	850	580	309	327	510	3,197
Bioenergies	MW	140	362	574	90	80	70	1,316
	Mln €	517	1,295	2,070	388	347	308	4,925
Total	MW	3,718	10,848	5,392	2,295	645	890	23,788
	Mln €	10,588	24,080	10,865	3,905	1,483	2,046	52,967

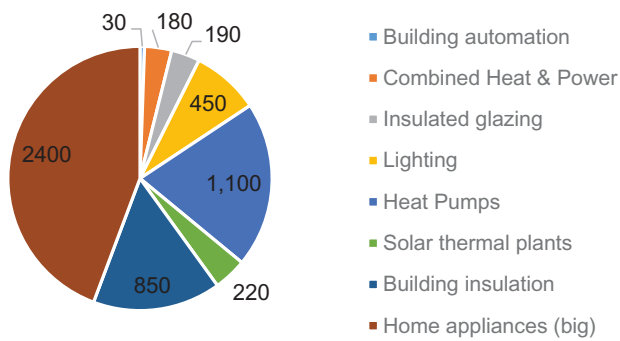


Figure 3. Investment breakdown in EEM for the residential sector in Italy in 2015 (million €) (Energy&Strategy 2016b).

tariff structure of electricity bills will affect the profitability of such investments. Electricity generation is a sector, where investments are determined by several factors, such as public policies, country generation mix, wholesale energy prices, availability of resources, administrative procedures, and social acceptance of new technology systems (Bechberger and Reiche 2004). Furthermore, economic policies (such as investment subsidies) and regulatory policies (such as the enforcement of new tariffs) play a key role in defining the electricity market regulatory framework, affecting the amount of money that will flow to new RES projects and develop further EEM (Mignon and Bergek 2016). This is particularly relevant in the electricity generation sector where the still-comparatively higher cost of electricity produced from RES, its dispatchability and impact on the grid structure have made it virtually impossible for RES to grow without the support of regulatory intervention (Das, Bhattacharya, and Cañizares 2014; Longo et al. 2014; Menanteau, Dominique, and Lamy 2003; Painuly 2001).

Aims and Structure of the Article

Although the role of regulatory policies in the electricity market has been widely investigated with a particular focus on their effects on the diffusion of distributed generation and the deployment of new RES investments (Badcock and Lenzen 2010; Battle, Pérez-Arriaga, and Zambrano-Barragán 2012; Cossent, Gómez, and Frías 2009; Del Río and Linares 2014; Jäger-Waldau et al. 2011; Kalkuhl, Edenhofer, and Lessmanna 2013), the relationship between changes in electricity tariffs and investments in RES and EEM is still under-researched in academic literature.

This article attempts to analyze how changes in the electricity tariff for the residential market in Italy may directly affect the rate of new investments in RES and EEM. In recent years, several European countries besides Italy (i.e., Spain, Portugal, Greece, and Germany) have reformed their electricity tariff systems to adjust the fixed part of the tariff components to meet the corresponding costs borne by energy companies, since such costs are increasing due to the high penetration of RES in the energy mix (European Commission 2014). In particular, Spain, Portugal, and Greece have invested massively in PV systems in the last decade, while Germany has invested in both PV

systems and wind farms. The analysis, research, and practical implications presented in this article are therefore particularly timely. For researchers, this is a first attempt to fill a gap in academic literature on the analysis of the extent to which electricity tariff reforms affect RES and EEM investments. For practitioners and policy makers, this study offers some useful insights to help align rate-making practices with the growing demand for energy production from RES and EEM at the residential level.

To achieve the objectives, the article develops and comments on detailed cost comparisons and simulations by considering two different RES and EEM investment scenarios (i.e., before and after the reform in Italy) and modelling different consumption patterns.

Regarding RES, the paper focuses on PV systems, since these have received the largest share of investments in recent years (Figure 2), and the Italian market is now characterized by the absence of incentives and other supporting mechanisms for photovoltaic installations. Therefore, changes in the market dynamics, as introduced by the reform, may negatively affect the profitability of the PV industry (Chiaroni et al. 2014). Regarding EEM, the article focuses on heat pumps and efficient home appliances, since these technologies are attracting a large part of EEM investments at the residential level (Figure 3) (Energy&Strategy 2016b).

The article is structured as follows. Section 2 illustrates the most relevant characteristics of the reform; Section 3 describes the empirical approach and the data analysis, and paves the way for the discussion on the impact of the reform on RES and EEM investments presented in Section 4. Lastly, Section 5 offers the main conclusions of the study.

The electricity tariff reform for the residential market in Italy

The reform affects two of the four electricity bill cost components: the network services tariff and system charges tariff. The other two cost components are unaffected by the reform, i.e., selling service (the cost of electricity delivered to the customer) and taxes on the electric bill (including 10% VAT and other minor fiscal duties, such as excise tax).

Network services represent the tariff for metering, marketing, and distributing electricity, and mainly reflect the cost incurred to cover network transport and the system service. As the RES penetration level increases, this cost becomes relevant, since the effect of non-dispatchable energy sources on network operations is bound to increase. The system charges tariff reflects the costs of covering general services to maintain and operate the electricity system. In 2015, the most relevant components of the system charges tariff were: (i) RES incentives equal to 82.02% of the total system charges tariff; (ii) fiscal burden of financing the decommissioning of Italian nuclear plants equal to 7.03% of the total system charges tariff; (iii) actions to promote the adoption of energy efficiency measures equal to 4.13% of the total system charges tariff.

According to the tariff system in place before the reform entered into force, 99% of the electricity price related to variable components, with a progressive structure of the

network and the system charges tariffs, i.e., with a kWh unit cost that increased for bands with greater off-take and thus discouraging higher levels of electricity consumption. The pre-reform system had four consumption bands: (i) below 1,800 kWh/year; (ii) between 1,800 and 2,640 kWh/year; (iii) between 2,640 and 4,400 kWh/year; (iv) over 4,440 kWh/year. Two different tariffs applied to each of these bands: (i) tariff “D2” for resident customers with a rated power of 3 kW; (ii) tariff “D3” for either non-resident customers or for resident customers with a rated power above 3 kWh¹ (Figure 4). In 2015, the network services and system charges tariffs accounted respectively for 17.39% and 25.28% of the total average electricity price (Figure 5).

The reform introduces two major changes:

- Regarding the network services tariff, the previous variable and progressive structure of the tariff with a kWh unit cost that increased for bands with greater off-take (€/kWh) has been replaced by a non-progressive tariff structure as detailed below:
 - (1) Fixed amount (€/year) for metering and marketing costs
 - (2) Power amount (€/kW/year) for the distribution cost, which becomes a fixed amount, although it depends on the installed rate-power
 - (3) Energy amount (c€/kWh) for transmission costs, which is now the only variable cost.
- Regarding the system charges tariff, the reform has completely replaced the progressive structure. 75% of the electricity bill now depends on the kWh used, with a tariff expressed in c€/kWh. The remaining 25% is a fixed component related to the distribution cost. A differentiation is still made between resident customers

(to whom an energy amount is applied, i.e., in c€ per kWh used) and non-resident customers (to whom the tariff is applied in both the fixed amount and energy amount).

The gradual replacement of the progressive structure of the network services and system charges tariffs will be implemented in three phases over a 3 year period (1 January 2016; 1 January 2017; 1 January 2018). This will generate a more linear relationship between electricity consumption (kWh) and price paid by costumers (€) (Figure 6) (Energy&Strategy 2016a).

Since 1 January 2016, network service tariffs are subject to a first intervention aimed at “mitigating” the progressive effect of consumption (c€/kWh) and increasing the fixed quotas. Table 2 reports the Δ price of kWh (referring to the two cost components affected by the reform, i.e., the network services and system charges tariffs) segmented by consumption bands. To be noted is that, following the reform, the higher the kWh consumption, the higher the saving compared to the previous scenario.

From 1 January 2017, with the full application of the non-progressive tariff for network services for resident customers, only two consumption bands remain. Finally, from 1 January 2018, the reform will be fully in force, applying the non-progressive structure also to the general system cost tariff.

Methodology

This section illustrates the methodological approach followed to evaluate the effects of the reform on new RES and EEM investments. First, the effects on the electricity bill of both resident and non-resident customers are estimated,



Figure 4. Electricity tariff breakdown (variable part) before the reform for a resident and non-resident customer (Energy&Strategy 2016a).

¹For clarity, according to Italian legislation, the residential electricity market is constituted of resident and non-resident customers. The former reside permanently in the apartment/house, the latter use the apartment/house typically for weekends, vacations, and/or short-term periods (generally, second homes), and different tariffs apply, as will be explained in the remainder of the article.

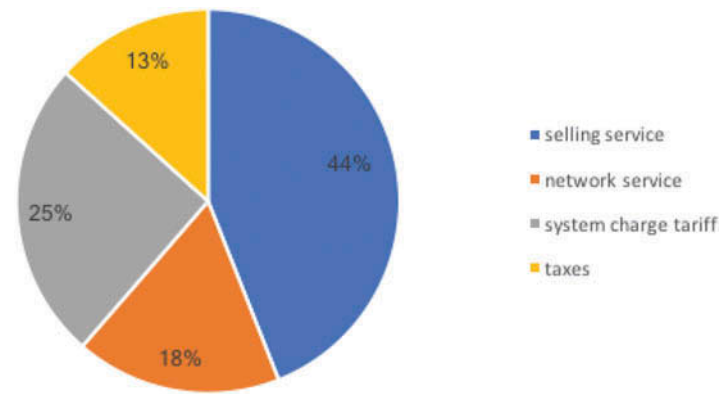


Figure 5. Electricity tariff breakdown in 2015 (Energy&Strategy 2016a).

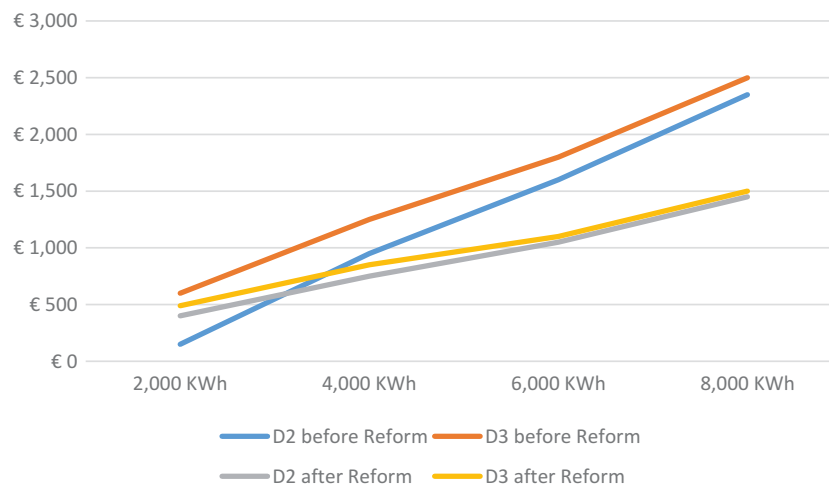


Figure 6. Yearly changes in electricity bills before and after the reform for a resident (D2) and non-resident (D3) customer (Energy&Strategy 2016a).

focusing on three different consumption bands, i.e., customers with a yearly consumption of 1,800 kWh, 2,700 kWh, and 4,000 kWh. These represent the annual consumption of three different customer clusters in Italy (respectively, a single person, a couple with two children, and a larger family) and are the same bands that AEEGSI uses in its simulations to test the impact of new policies on end customers (AEEGSI 2015b, 2015c).

Regarding the analysis of the effects of the reform on the economic viability of RES and EEM investments, simulations were run on the same consumption bands. The financial indicators adopted to analyze the economic viability of RES and EEM investments are Net Present Value (NPV), Pay-Back Time (PBT), and Internal Rate of Return (IRR).

Table 2. Δ price of kWh (referring only to the network services and system charges tariffs) segmented by consumption bands (Energy&Strategy 2016b)

Consumption Bands (kWh)	Price per kWh before the reform	Price per kWh after the reform	Δ 2015–2016
0–1,880	0.00539	0.00517	–0.00022
1,801–2,640	0.04236	0.03067	–0.01169
2,641–4,400	0.08218	0.06709	–0.01509
> 4,400	0.12485	0.06709	–0.05776

The NPV uses the discounted differential cash flows generated by the investment during its operation (set at 20 years in the present analysis), applying a discount rate that measures the risk level of the investment (Tudisca et al. 2013). In other words, the NPV compares the present values of the forecasted net cash inflow with the initial capex investment to determine the profitability of the investment or project (Samba Sowe, Thanarak, and Suriwong 2014).

The NPV is calculated as follows:

$$NPV = \sum_{t=0}^T \frac{CF_t}{(1+i)^t}$$

where:

T = project duration in years

i = discount rate, set at 4% in this analysis

CF (Cash Flow) = expected net benefit at the end of each year.

The Pay-Back Time (PBT) of an investment is a measure of the time required to reach the point at which the sum of the differential cash inflows (discounted or non-discounted) is equal to the sum of the differential cash outflows (again, discounted or non-discounted). Both cash inflows and outflows are the same as those mentioned above for the NPV

calculation. Differently from the NPV, the PBT is more subjective in its application, as the decision-maker must define a maximum acceptable time (cut-off time) to define the economic feasibility of an investment. In the Italian residential sector, a typical acceptable payback threshold is approximately 6 years (Energy&Strategy 2015a).

The PBT is calculated as follows:

$$\sum_{\text{PBT}}^{t=1} \text{CF}(t)/(1+i)^t = 0$$

where:

PBT = Pay-Back Time

i = discount rate

CF (Cash Flow) = expected net benefit at the end of each year (i.e., differential cash inflows minus the differential cash outflows).

Finally, the Internal Rate of Return (IRR) is a measure of the average profitability of an investment (i.e., the discount rate that adjusts future cash flows so that they are equal to the investment outlay). Both cash inflows and outflows are the same as those for the NPV calculation. The IRR is a relative indicator, therefore a subjective threshold has to be defined for the investment's economic evaluation (Tudisca et al. 2013), such as the cost of capital.

The IRR is calculated as follows:

$$\sum_T^{t=0} \frac{\text{CF}_t}{(1 + \text{IRR})^t} = 0$$

Tables 3 and 4 show the assumptions at the base of the different simulations to evaluate the impact of the reform on RES investments, i.e., a rooftop PV system. Each customer referred to in Table 3 adopts a 3 kW rooftop PV system, with the characteristics detailed in Table 4, and shows a 30% natural self-consumption rate (Chiaroni et al. 2014). Two residential customer types are analyzed (resident and non-resident) and the profitability of investments is estimated in a pre-reform and post-reform scenario, i.e., with the new tariff scheme.

To empirically test the impact of the reform on the adoption of EEM, a first simulation is run on a customer who intends to replace old home appliances (i.e., a fridge, washing machine and dishwasher) in energy efficiency class A with new and more efficient appliances in energy efficiency class A ++, as summarized in Table 8.

Second, a simulation is run on the replacement of a low-efficient heat pump with a new more efficient one. Table 10 shows the technical specifications of the two heat pumps (old/new), together with the savings obtained by both a resident and non-resident customer through the adoption of a new heat pump, before and after the reform. Since the adoption of a heat pump determines a significant increase in electricity consumption, in this simulation, the electricity prices considered (c€/kWh) are those applied to the highest consumption band (i.e., 4,000 kWh/year) as referred to in Table 3 for customer #3.

The technical and economic data on RES and EEM were collected through a review of product data sheets, corroborated by direct interviews with a sample of manufacturers operating in the Italian market.

The impact of the reform on the profitability of RES and EEM investments

The analysis of the effects of the reform on electricity bills shows that customers with a lower annual consumption are penalized by the reform, while customers with a higher annual consumption benefit from the reform. In particular, a resident customer using 1,800 kWh/year incurs a cost of 108 €/year more than before, which represents a 36% increase in the electricity bill. A resident customer using 4,000 kWh/year saves 164€, which represents a 19.5% decrease in the electricity bill. Lastly, the reform does not have a relevant impact on customers using 2,700 kWh/year. Figure 7 shows the results of the simulations for a resident customer, while Figure 8 shows the results for a non-resident customer.

Regarding the impact of the reform on RES investments, Table 5 shows the result of the simulation for both a resident and a non-resident customer, with a yearly consumption of 1,800 kWh, installing a rooftop PV system with the characteristics detailed in Table 4. For a resident customer, the increase in the electricity tariff is counterbalanced by a lower value for net metering (so-called scambio sul posto), which leads to a PBT of 16 years, 2 years longer than previously, an IRR above 6%, and a NPV equal to €1,543. Comparing such values with those before the reform entered into force shows that the reform penalizes the investment in a rooftop PV system for a resident customer. For a non-resident customer, the scenario is even worse, since this customer has difficulty in self-consuming the electricity produced by the PV system due to the typical use of secondary homes for vacations or weekends.

Table 3. Electricity price for a resident and non-resident customer.

Customer type	Annual energy consumption (kWh/year)	Rate power (kW)	Resident customer		Non-resident customer	
			Energy price for the end customer before the reform (c€/kWh)	Energy price for the end customer after the reform (c€/kWh)	Energy price for the end customer before the reform [c€/kWh]	Energy price for the end customer after the reform (c€/kWh)
Customer #1	1,800	3	16.5	22.5	20	33
Customer #2	2,700	3	19.3	19.4	23.8	25.5
Customer #3	4,000	3	21	17	25.2	21

Table 4. Investment characteristics of the rooftop PV system.

Characteristics	Value
Installed capacity (kW)	3
CapEx (€/kW)	2,200
Operating hours (h)	1,200
Natural self-consumption rate (%)	30
Administrative costs (€)	250
Tax deduction (%)	50 (of the Capex)
Net metering ('Scambio sul posto')	Yes
Decrease of PV performance (%/year)	1
Yearly electricity consumption (kWh)	1,800–2,700–4,000
Discount rate (%)	4
Expected life of PV system (years)	20

Table 5. Financial indicators related to the adoption a PV system by a customer with a yearly consumption of 1,800 kWh.

Financial indicator	Before the reform		After the reform	
	Resident	Non-resident	Resident	Non-resident
NPV (€)	2,254	2,530	1,543	1,748
IRR (%)	6.9	8	6.1	6.2
PBT (years)	14	12	16	15

The increase in the electricity tariff is therefore not set-off by any real opportunity to self-consume the electricity produced by the rooftop PV system.

Table 6 shows the results of the simulation for both a resident and a non-resident customer with a yearly consumption of 2,700 kWh and installing a rooftop PV system. This

scenario is particularly interesting because a yearly consumption of 2,700 kWh represents a real case for a resident family with two children who paid €521 before the reform and is expected to pay €523.8 after the reform, thus a negligible difference (Figure 7). However, the IRR associated with this investment decreases from 7.9% to 5.8% after the reform. Such reduction is due to the worsening of net metering, since the amount reimbursed as a variable cost for services and network charges is now lower than before the reform. The IRR and NPV show similar results, bringing to light the remarkable negative effect that the reform has on an investment in a rooftop PV system for this type of customer. The same consideration can be made for a non-resident customer, with a higher PBT associated with the investment in the post-reform scenario, as well a deterioration of the other two financial indicators. The worsening of the financial indicators for this customer is somewhat mitigated by the higher electricity price this customer has to pay after the reform, equal to 25.5 c€/kWh compared to 19.4 c€/kWh for a resident customer (Table 3), making any small amount of self-consumption a valid opportunity to save on the electricity bill.

Finally, Table 7 shows the results of the simulation for both a resident and non-resident customer with a yearly consumption of 4,000 kWh. Also emerging in this case is a worsening of the IRR and other financial indicators mainly due to the decreasing structure of the electricity tariff, which incentivizes

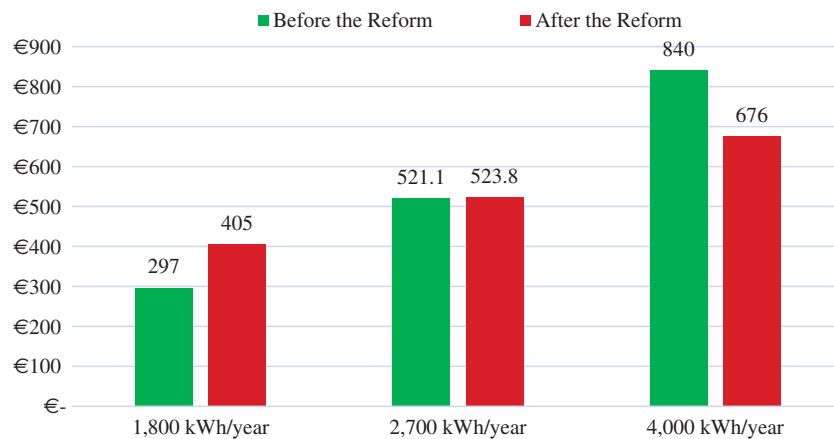
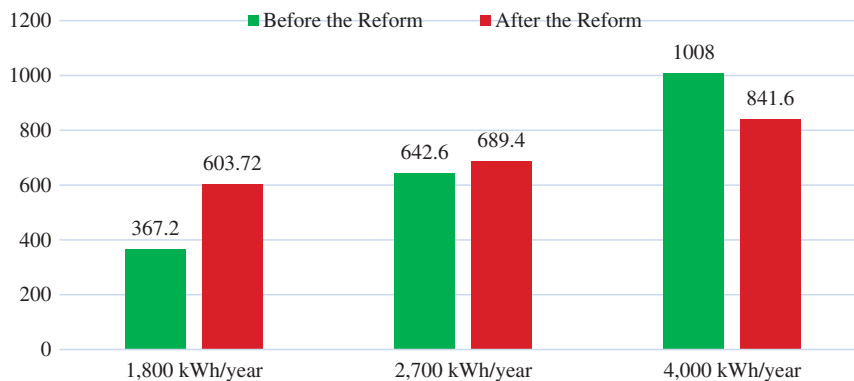
**Figure 7.** Comparison between electricity bills for a resident customer before and after the reform (Energy&Strategy 2016a).**Figure 8.** Comparison between electric bill for a non-resident customer before and after the reform (Energy&Strategy 2016a).

Table 6. Financial indicators related to the adoption a PV system by a customer with a yearly consumption of 2,700 kWh.

Financial indicator	Before the reform		After the reform	
	Resident	Non-resident	Resident	Non-resident
NPV (€)	3,713	4,580	1,433	3,058
IRR (%)	7.9	11	5.8	7.1
PBT (years)	10	10	16	12

Table 7. Financial indicators related to the adoption a PV system by a customer with a yearly consumption of 4,000 kWh.

Financial indicator	Before the reform		After the reform	
	Resident	Non-resident	Resident	Non-resident
NPV (€)	5,553	6,920	1,652	3,524
IRR (%)	8.6	13	6.2	8.3
PBT (years)	9	8	16	11

a higher level of electricity consumption, hence reducing the economic value of the energy saving generated by the self-consumption of electricity produced by a PV system. Furthermore, the non-resident customer sees a less severe worsening of the financial indicators associated with the investment in a rooftop PV system.

On the energy efficiency side, the reform provides a decisively better scenario in the case of a customer with low electricity consumption (i.e., 1,800 kWh/year) willing to replace less efficient home appliances with new efficient ones, since the PBT of such investment decreases from over 20 years to around 9 years for a resident customer compared to the pre-reform scenario, as detailed in Tables 8 and 9. As

Table 8. Investment characteristics related to the adoption of new home appliances (i.e., fridge, washing machine and dishwasher) in energy efficiency Class A++.

Characteristic	Value		
Capex [€] (purchase of dishwasher, fridge and washing machine)	1,800		
Tax deduction (%)	50 (of the Capex) over ten years		
Yearly consumption bands (kWh/year)	1,800	2,700	4,000
Consumption rate of home appliances on overall yearly consumption (%)	70		
Yearly energy saving related to the adoption of new home appliances (kWh/year)	378	567	840
Yearly energy savings before the reform for a resident customer (€/year)	62.37	109.43	176.4
Yearly energy savings before the reform for a non-resident customer (€/year)	75.6	134.9	211.68
Yearly energy savings after the reform for a resident customer (€/year)	85	110	142.8
Yearly energy savings after the reform for a non-resident customer (€/year)	124.7	141.7	176.4

Table 9. Financial indicators related to the adoption of new home appliances in energy efficiency Class A++.

Financial indicator	Before the Reform			After the Reform		
	1,800	2,700	4,000	1,800	2,700	4,000
Yearly consumption bands (kWh/year)	1,800	2,700	4,000	1,800	2,700	4,000
Resident customer						
NPV (€)	-160	505	1,452	160.5	513	977
IRR (%)	2.5	8.1	14.9	5.4	8.2	11.6
PBT (years)	> 20	8	6	9	7	6
Non-resident customer						
NPV (€)	27.7	867	1,951	721.6	961	1,452
IRR (%)	4.2	10.8	18.2	9.7	11.5	14.9
PBT (years)	10	7	4	7	6	5

Table 10. Investment characteristics of two different heat pumps.

Characteristic	Old heat pump	New heat pump
	Rate Power (kW)	16
Coefficient of Performance	3	4.9
Capex (€)	-	7,000
Tax deduction (%)		50 (of the Capex) over ten years
Yearly consumption (kWh)	7,467	4,571
Electricity price before the reform for a resident customer (c€/kWh)	21	
Electricity price after the reform for a resident customer (c€/kWh)	17	
Electricity price before the reform for a non-resident customer (c€/kWh)	25.2	
Electricity price after the reform for a non-resident customer (c€/kWh)	21	
Yearly Electric bill before the reform, for a resident customer (€/year)	1,568	960
Yearly electricity bill after the reform for a resident customer (€/year)	1,269.4	777
Yearly electricity bill before the reform for a non-resident customer (€/year)	1,881.68	1,151.9
Yearly electricity bill after the reform for a non-resident customer (€/year)	1,568	960

Table 11. Financial indicator related to an investment in a new heat pump.

Financial indicator		Before the reform	After the reform
Resident customer	NPV (€)	4,545	2,911
	IRR (%)	12.9	9.9
	PBT (years)	6	7
Non-resident customer	NPV (€)	6,267	4,545.8
	IRR (%)	15.93	12.9
	PBT (years)	7	8

for the improvement of the other financial indicators, this is due to the higher electricity price (+36%) that this customer will pay compared to before the reform.

The same investment related to the other two customer types (i.e., with an electricity consumption equal to 2,700 kWh/year and 4,000 kWh/year) shows a marginal improvement of the financial indicators compared to the pre-reform scenario. Also in the case of non-resident customers, the impact of the reform is positive in relation to replacing less efficient home appliances with new more efficient ones, especially for customers with low electricity consumption (i.e., 1,800 kWh/year).

Table 11 shows the financial indicators associated with the investment in a new heat pump for a resident and a non-resident customer, before and after the reform. The PBT is almost the same in the two scenarios for both customer types, while the IRR and NPV show better values in the pre-reform scenario for both. Specifically, the non-resident customer who enjoyed better financial indicators before the reform continues to benefit from replacing an old heat pump with a new one, even though the reform worsens the actual financial benefit.

Conclusions

The goal of the reform in Italy is not to promote a general increase in energy consumption, which would be in contrast with European policies and regulations, but rather to favor the

electrification of domestic consumption, incentivizing the adoption of electric appliances for residential needs. Indeed, electricity consumption is seen as a substitute for other primary energy sources that are much less renewable, making a significant contribution to environmental sustainability. Moreover, as highlighted in Section 1.1, in recent years, several European countries have reformed their electricity tariff systems to rebalance the domestic tariff scheme taking into account the huge contribution of distributed energy generation from RES on the overall energy mix.

Concerning Italy, the simulations show that the reform penalizes customers with low electricity consumption, while favoring customers with high energy consumption (i.e., 4,000 kWh). For a customer consuming 1,800 kWh/year, the additional cost determined by the reform is around €108/year (+36% compared to the pre-reform electricity bill), while the cost saving for a customer consuming 4,000 kWh/year is approximately €164 (−19.5% on the pre-reform electricity bill). Lastly, the reform has almost no impact on customers with an electricity consumption of approximately 2,700 kWh/year.

This gradual replacement of the progressive structure of network tariffs and general system costs with a non-progressive tariff for network services for all domestic customers represents a new and somewhat unforeseen scenario for those willing to invest in a domestic PV system, since the marginal cost of each kWh decreases with the increase in off-take, thus discouraging higher levels of self-consumption. The evidence from the present analysis leads to the conclusion that the reform will have a negative impact on the PV sector, with a general reduction in profitability of new investments at the residential level. In the current market scenario, exogenous factors such as the economic crisis, the trend toward a reduction in installed power, and the reduction in incentive tariffs, already undermine the growth of the PV sector in Italy.

Regarding EEM, it can be concluded that the reform introduces some opportunities for the residential market. On the one hand, reducing the progressive structure of the network services tariffs and the general system costs, the reform promotes switching to more efficient electric home appliances (in Class A++), given that the associated investment provides interesting financial indicators. On the other hand, for other EEMs such as electric heat pumps, customers with low-efficient heat pumps will be unwilling to voluntarily replace their systems with new more efficient ones, since the expected PBT is now longer than before the reform.

The present study leaves room for further comparative studies focused on other European countries where policymakers are experiencing the same issues discussed here for Italy. Moreover, it highlights the importance for policymakers to carefully consider the impact on the diffusion of RES and EEM when designing electricity tariff reforms, since these constitute the cornerstone of achieving the targets set by energy policies at the European level.

References

ACEEE. 2016. *The 2016 International Energy Efficiency Scorecard*. <http://aceee.org/research-report/e1602> (Accessed December 10, 2016)

- AEEGSI. 2015a. *582/2015/R/EEL*. <http://www.autorita.energia.it/allegati/docs/15/582-15.pdf> (Accessed July 20, 2016)
- AEEGSI. 2015b. *Annual Report on the state of services and on regulatory activities*. Roma. http://www.autorita.energia.it/allegati/relaz_ann/15/ReportBortoni_2015.pdf (Accessed July 15, 2016)
- AEEGSI. 2015c. *Electricity reform of network tariffs in the bill to kick off from 2016 for 30 million customers*. Roma. Accessed July 15, 2016. http://www.autorita.energia.it/it/inglese/press_releases/15/151202.htm
- ANIE. 2016. *Osservatorio ANIE Rinnovabili primo semestre 2016*. <http://anie.it/osservatorio-anie-rinnovabili-primo-semester-2016/?contesto-articolo=/sala-stampa/comunicati-stampa/#.V905dpiLQ2w> (Accessed September 17, 2016)
- Astrov, V., D. Hanzl-Weiss, S. M. Leitner, O. Pindyuk, J. Poschl, and R. Stehrer. 2015. *Energy Efficiency and EU Industrial competitiveness: Energy Costs and their Impact on Manufacturing Activity*. Research Report no. 405, The Vienna Institute for International Economic Studies, Wien.
- Badcock, J., and M. Lenzen. 2010. Subsidies for electricity-generating technologies: A review. *Energy Policy* 38 (9):5038–47. doi:10.1016/j.enpol.2010.04.031.
- Battle, C., I. Pérez-Arriaga, and P. Zambrano-Barragán. 2012. Regulatory design for RES-E support mechanisms: Learning curves, market structure, and burden-sharing. *Energy Policy* 41:212–20. doi:10.1016/j.enpol.2011.10.039.
- Bechberger, M., and D. Reiche. 2004. Policy differences in the promotion of renewable energies in the EU member states. *Energy Policy* 32 (7):843–49. doi:10.1016/S0301-4215(02)00343-9.
- Blok, V., T. B. Long, A. I. Gaziulusoy, N. Ciliz, R. Lozano, D. Huisingh, M. Csutora, and C. Boks. 2015. From best practices to bridges for a more sustainable future: Advances and challenges in the transition to global sustainable production and consumption. *Journal of Cleaner Production* 108:19–30. doi:10.1016/j.jclepro.2015.04.119.
- Chiaroni, D., M. Chiesa, V. Chiesa, S. Franzò, F. Frattini, and G. Toletti. 2016a. Introducing a new perspective for the economic evaluation of industrial energy efficiency technologies: An empirical analysis in Italy. *Sustainable Energy Technologies and Assessments* 15:1–10. doi:10.1016/j.seta.2016.02.004.
- Chiaroni, D., V. Chiesa, L. Colasanti, F. Cucchiella, I. D'Adamo, and F. Frattini. 2014. Evaluating solar energy profitability: A focus on the role of self-consumption. *Energy Conversion and Management* 88:317–31. doi:10.1016/j.enconman.2014.08.044.
- Chiaroni, D., V. Chiesa, S. Franzò, F. Frattini, and V. Manfredi Latilla. 2016b. Overcoming internal barriers to energy efficiency through energy audit: A case study of a large manufacturing company in the home appliances industry. *Clean Technologies and Environmental Policy*, 19 (4):1031–1046
- COM(2012) 271. 2012. *Renewable Energy: A major player in the European energy market*. <http://ec.europa.eu/transparency/regdoc/rep/1/2012/EN/1-2012-271-EN-F1-1.Pdf>
- COM(2012) 663 final. 2012. Making the internal energy market work. https://ec.europa.eu/energy/sites/ener/files/documents/20121115_iem_0663_en.pdf
- Cossent, R., T. Gómez, and P. Frías. 2009. Towards a future with large penetration of distributed generation: Is the current regulation of electricity distribution ready? Regulatory recommendations under a European perspective. *Energy Policy* 37 (3):1145–55. doi:10.1016/j.enpol.2008.11.011.
- Cucchiella, F., I. D'Adamo, and M. Gastaldi. 2012. Modeling optimal investments with portfolio analysis in electricity markets. *Energy Educ Sci Technol Part A: Energy Sci Res* 30:673–92.
- Das, I., K. Bhattacharya, and C. Cañizares. 2014. Optimal incentive design for targeted penetration of renewable energy sources. *IEEE Transactions on Sustainable Energy* 5 (4). doi:10.1109/TSTE.2014.2339172.
- Del Río, P., and P. Linares. 2014. Back to the future? Rethinking auctions for renewable electricity support. *Renewable and Sustainable Energy Reviews* 35:42–56. doi:10.1016/j.rser.2014.03.039.
- ENEA. 2015. *Energy Efficiency trends and policies in Italy*. ENEA. <http://www.odyssee-mure.eu/publications/national-reports/energy-efficiency-italy.pdf> (Accessed October 20, 2016)

- ENEA. 2016. *Rapporto annuale efficienza energetica*. ENEA. <http://www.enea.it/it/publicazioni/pdf-volumi/raee-executive-summary-2016.pdf> (Accessed October 5, 2016)
- Energy&Strategy. 2015a. *Intelligent building report*. Politecnico di Milano, Dipartimento di Ingegneria Gestionale, Milan, Italy.
- Energy&Strategy. 2015b. *Energy efficiency report*. Politecnico di Milano, Dipartimento di Ingegneria Gestionale, Milan, Italy.
- Energy&Strategy. 2016a. *Renewable energy report*. Milano: Politecnico Di Milano, Dipartimento di Ingegneria Gestionale, Milan, Italy.
- Energy&Strategy. 2016b. *Energy efficiency report*. Milano: Politecnico Di Milano, Dipartimento di Ingegneria Gestionale, Milan, Italy.
- European Commission. 2007. *An Energy Policy for Europe*. <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV%3A127067>
- European Commission. 2014. *Electricity Tariff Deficit: Temporary or Permanent Problem in the EU?* http://ec.europa.eu/economy_finance/publications/economic_paper/2014/pdf/ecp534_en.pdf
- European Commission. 2015. *Investment Perspectives in the Electricity Market*. http://ec.europa.eu/economy_finance/publications/eeip/pdf/ip003_en.pdf
- European Directive 27. 2012. Energy Efficiency Directive. <https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive>
- European Directive 28. 2009. Promotion of the use of energy from renewable sources. <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=EN>
- Eurostat. 2016. *Renewable energy statistics*. http://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics#Electricity (Accessed July 25, 2016)
- Geller, H., P. Harrington, M. Levine, A. Rosenfeld, and S. Tanishima. 2006. Policies for increasing energy efficiency: Thirty years of experience in OECD. *Energy Policy* 34 (5):556–73. doi:10.1016/j.enpol.2005.11.010.
- Gestlberger, W., B. Dachs, M. Knudsen, and M. Schroter. 2016. Closing the energy-efficiency technology gap in European firms? Innovation and adoption of energy efficiency technologies. *Journal of Engineering and Technology Management* 40:87–100. doi:10.1016/j.jengtecman.2016.04.004.
- Gestore Servizi Energetici. 2016. *Energia da Fonti Rinnovabili in Italia_Dati preliminari 2015*. http://www.gse.it/it/Dati%20e%20Bilanci/GSE_Documenti/osservatorio%20statistico/Stime%20preliminari%202015.pdf
- Hirth, L. 2013. The market value of variable renewables: The effect of solar wind power variability on their relative price. *Energy Economy* 38:218–36. doi:10.1016/j.eneco.2013.02.004.
- Jäger-Waldau, A., M. Szabó, N. Scarlat, and F. Monforti-Ferrario. 2011. Renewable electricity in Europe. *Renewable and Sustainable Energy Reviews* 15 (8):3703–16. doi:10.1016/j.rser.2011.07.015.
- Kalkuhl, M., O. Edenhofer, and K. Lessmanna. 2013. Renewable energy subsidies: Second-best policy or fatal aberration for mitigation? *Resource and Energy Economics* 35 (3):217–34. doi:10.1016/j.reseneeco.2013.01.002.
- Karimu, A., and R. Brännlund. 2015. Energy efficient R&D investment and Aggregate Energy Demand: Evidence from OECD countries. *CERE Working Paper* 14:1–29.
- Longo, M., M. Roscia, G. Lazaroiu, and M. Pagano. 2014. Analysis of sustainable and competitive energy system. In *3rd International Conference on Renewable Energy Research and Applications (ICRERA)*, 80–86.
- Manzano-Agugliaro, F., A. Alcaide, F. Montoya, A. Zapata-Sierra, and C. Gil. 2013. Scientific production of renewable energies worldwide: An overview. *Renewable Sustainability Energy Review* 18:134–143. doi:10.1016/j.rser.2012.10.020.
- Menanteau, P., D. Dominique, and M. Lamy. 2003. Prices versus quantities: Choosing policies for promoting the development of renewable energy. *Energy Policy* 31:799–812. doi:10.1016/S0301-4215(02)00133-7.
- Mignon, I., and A. Bergek. 2016. Investments in renewable electricity production: The importance of policy revised. *Renewable Energy* 86:307–316. doi:10.1016/j.renene.2015.11.045.
- Ministero Dello Sviluppo Economico. 2013. *Strategia Energetica Nazionale: per un'energia più competitiva e sostenibile*. http://www.sviluppoeconomico.gov.it/images/stories/normativa/20130314_Strategia_Energetica_Nazionale.pdf
- Painuly, J. 2001. Barriers to renewable energy penetration; a framework for analysis. *Renewable Energy* 24:73–89. doi:10.1016/S0960-1481(00)00186-5.
- Pantaleo, A., S. Camporeale, and N. Shah. 2013. Thermo-economic assessment of externally fired micro-gas turbine fired by natural gas and biomass: Applications in Italy. *Energy Conversion Management* 75:202–213. doi:10.1016/j.enconman.2013.06.017.
- Ponsa, M., A. Bikfalvia, J. Llacha, and I. Palcicb. 2013. Exploring the impact of energy efficiency technologies on manufacturing firm performance. *Journal of Cleaner Production* 52:134–44. doi:10.1016/j.jclepro.2013.03.011.
- Samba Sowe, K., P. Thanarak, and T. Suriwong. 2014. Technical and economic viability assessment of PV power plants for rural electrification in the Gambia. *Energy Procedia* 52:389–98. doi:10.1016/j.egypro.2014.07.091.
- Stark, C., J. Pless, J. Logan, E. Zhou, and D. Arent. 2015. *Renewable Electricity: Insights from the coming decade*. Joint Institute for Strategic Energy Analysis, Denver (USA). <http://www.nrel.gov/docs/fy15osti/63604.pdf> (Accessed October 21, 2016)
- TERNA. 2016. *Rapporto Mensile sul Sistema Elettrico*. TERNA. http://www.qualenergia.it/sites/default/files/articolo-doc/Rapporto-Terna_settembre_2016_0.pdf (Accessed October 25, 2016)
- Tudisca, S., A. Di Trapani, F. Sgroi, R. Testa, and R. Squatrito. 2013. Economic analysis of PV systems on buildings in Sicilian farms. *Renewable and Sustainable Energy Review* 28:691–701. doi:10.1016/j.rser.2013.08.035.
- Viola, F., P. Romano, R. Miceli, D. La Cascia, M. Longo, and G. Sauba. 2014. Economical evaluation of ecological benefits of the demand side management. In *3rd International Conference on Renewable Energy Research and Applications (ICRERA)*, 995–1000.