Photovoltaic energy diffusion through net-metering and feed- in tariff policies:

Learning from Germany, California, Japan and Brazil

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Overview

Mitigating climate changes and guaranteeing the security of electricity supply are two of the most important drivers behind the adoption of renewable sources support policies. In the last few years, photovoltaic generation has proven growing dynamism and potential through its decreasing costs and accelerated adoption across many countries. Studies indicate that 96.3% of the gloval PV market depends on support schemes. In this context, the most widespread policies supporting photovoltaic generation are net metering and feed-in tariffs. Regarding net metering, California is an outstanding case, which over the past 20 years has played a leading role in photovoltaic energy policies nationally and internationally. Germany, in turn, has also been an early adopter of feed-in tariffs, and has often been signalled for its success in catapulting the country to the forefront of global photovoltaic installed capacity. Additionally, and following this characterization, the study looks at two "later comers": Japan and Brazil. Although dissimilar countries, both choose to adopt one of the two policy instruments during the same time period. While Japan, in 2011, chose to implement a feed- in tariff scheme, Brazil in 2012 introduced a net-metering solution. Consequently, we evaluate the policies implemented in these two countries, identifying how they differ, and, consequently, if and how they have incorporated the lessons learned from the pioneering regions. Finally, taking into consideration the different trajectories of photovoltaic energy diffusion in the different cases, this study makes an exploratory assessment of the success of the two incentive schemes and their advantages and disadvantages. There exists an indisputable challenge in comparing the performance of policies across different countries, due their heterogeneity, particularly in regards to their socio-economic configuration. Thus, these limitations are taken into consideration when appraising the success of these incentive policies in the different countries. This demonstrates the importance of having a suitable support structure, which goes beyond individual policy tools.

1. Introduction

Growing concerns over climate change and energy security have been some of the major motivations behind the adoption of renewable energy technologies. Consequently, today, we witness some controversy over the important role that these energy sources will play in the near future. Already, the rate of deployment of these technologies has been intense over the past 5 to 15 years. In particular, solar photovoltaic generation has, in recent years, displayed strong dynamism and potential through its accelerated adoption across many countries. Its attractiveness can be partly explained through its increased potential in incorporating technological progress and gains in production and its great possibilities for application. This became evident during the photovoltaic boom that occurred in many countries starting in 2010.

Yet, the underlying driver behind the success of photovoltaic technologies (and most renewable energy technologies for that matter) has been the set of public policy initiatives that have acted to support and incentivize investment in these new energy

sources. Two of the most widespread policy instruments employed for this purpose have been “net-metering” and “feed-in tariffs”, both being strategies towards supporting renewable energy generation. Looking across the globe, it quickly becomes clear that these two policies became to represent a crucial pillar in many countries strategy to foster greater and faster photovoltaic energy diffusion.
The following study seeks to analyse the implementation and evolution of the feed-in tariff in Germany, and the net metering policy in California, in order to identify some of its main characteristics and trajectory. In addition, and following this characterization, the study looks at two “later adopters” of each policy: in the form of Japan and Brazil. Both countries chose to adopt one of the two policy instruments during the same time period. While Japan, in 2011, chose to implement a feed- in tariff scheme, Brazil in 2012 introduced a net-metering solution, in order to incentivize the adoption of photovoltaic technologies. Consequently, we evaluate the policies implemented in these two countries, identifying how they differ, and, consequently, if and how they have incorporated the lessons learned from the pioneering regions.
Finally, taking into consideration the different trajectories of photovoltaic energy diffusion in the different cases, this study makes an exploratory assessment of the success of the two incentive schemes and their advantages and disadvantages.
The following composition is divided into three parts, besides this introduction: the first part will focus on net-metering, offering a brief theoretical introduction of the policy, followed by a description and discussion of California’s and Brazil’s policy trajectory. The subsequent section will do the same, but this time looking at the case of feed-in tariffs and Germany and japan. Finally, the differences between policies adopted are discussed. As a consequence, this paper seeks to enrich the discussion on the advantages and disadvantages of certain incentive policies.

2. Net-metering

2.1. Theoretical approach

Net-metering supporting policies emerged during the eighties, in order to address the need of a simple standardized scheme for the exchange of the electricity produced by renewable energy systems installed by residential consumers (Campoccia et al., 2009).
Under net-metering, the energy produced in distributed systems and injected into the grid is usually valued according to the electricity retail rate. Additionally, in this system the grid works like a battery, as it is used as a backup system for the prosumers’ excess power production (European Commission, 2015). In this sense, during the whole billing period, which can vary from periods of just one hour to some years, depending on the regulatory framework, the customer can produce and consume electricity in different moments. It is possible because if the production and consumption do not occur simultaneously, so the production surplus can be injected into the grid, generating credits that can be compensated afterwards. In general, net-metering policies include eligibility criteria, such as limitations on systems’ size, kind of renewable source, and also consumer class.
Net-metering schemes have been effective in promoting the diffusion of photovoltaic distributed generation, being adopted in many European countries, US states (43), Australian states, and many others (European Commission, 2015). Net energy metering is a customer friendly scheme, as it just requires the installation of a smart meter, and can be easily understood. From a system level perspective, however, some challenges must be addressed. One of them is related to the fact that the utilities purchase the excess production from photovoltaic distributed systems by the retail rate, which usually exceeds electricity wholesale price, and in most cases is also higher than the real value of this energy to the system (EEI, 2016; European Commission, 2015). Other key challenges are: increased retail rates and cost-shifting, lower utility shareholder return on equity, reduced utility earnings opportunities and inefficient allocation of resources (Heeter, Gelman, & Bird, 2014).

2.2. Net-metering case studies

2.2.1. The case of California

One of the main photovoltaic distributed generation supporting policies in effect in California is the Net Energy Metering (NEM), which was adopted in 1995, when Senate Bill 656 was amended. According to NEM, additionally to the self-consumption, when exporting electricity to the grid, prosumers receive energy credits, valued by the full electricity retail rate, which are deducted from monthly gross consumption, so the prosumer is just charged for its net consumption. At the end of the 12-month period, if there was a net excess generation, the utility purchased the credits at the avoided costs. Otherwise, the prosumer was billed for the net energy supplied at the prosumers “standard rate” (Alquist, 1995). It was also established that residential photovoltaic systems with no more than 10 kW of installed capacity could benefit from the scheme. This size limitation was in accordance with the policy focus on residential installations. A restriction in terms of total photovoltaic capacity was also defined, so that it could only reach a maximum of 0.1% of each utility peak demand, as projected to 1996[1]. This scale limitation reflected the need that the policy had a low impact on utilities' revenue losses, in order to avoid a strong resistance against the NEM. Otherwise, the 0,1% would represent an amount of 50 MW, a great success considering the stage of photovoltaic market in the period (Stokes, 2015).

The regulation was modified in 1998, through AB 1755, when the policy was extended to small commercial customers and small wind turbines. Additionally, the utilities peak demand cap was maintained at 0,1%, but the restriction regarding the demand projected to 1996 was eliminated. In 2000, Assembly Bill 918, was approved, and the main change was regarding the method of charging prosumers' net consumption at the end of each 12-month period. While the previous law required that the compensation owed to the utility was based on the average retail price per kWh for the prosumer's rate class, AB 918 introduced a scheme of "baseline" and "overbaseline" tariffs, and also created the possibility of charging net consumption according to time-of-use tariffs, in cases in which consumers migrated to this kind of rate (Keeley, 1999).

In 2001, the law was subject of another review, through AB 29. This bill raised installed capacity cap to 1 MW, and commercial, industrial and agricultural customers also became eligible to the scheme. Another important point was the elimination of utilities territory caps. AB 29, however, had a sunset date at 2012.Thus, in 2002, AB 58 was approved (effective from January 1, 2003), maintaining the 1 MW cap, and establishing a new ceiling of 0.5% per investor-owned utility (IOU) (approximately 270 MW total for the three IOUs) for total net-metered capacity (California Solar Center, 2016).

Although NEM was subject of many revisions during its first years, it can be said it was not able to drastically accelerate photovoltaic development. By mid-2002, only 2,200 (amounting 9 MW) systems were connected under net-metering scheme. This capacity represented only 0.02% of utilities peak load, against the defined cap of 0.1% (Stokes, 2015).

In 2009, an important bill (AB 920), regarding the treatment of net excess generation, came into effect. According to the previous legislation, at the end of the 12 months billing period, also known as the true-up period, no compensation was owed to the eligible customer in case of net excess generation, unless the utility decided to enter into a purchase agreement with the customer for purchasing this electricity. According to AB 920, however, at the end the true-up period, if the consumer has had exported to the grid more electricity than he demanded from the grid, so he can choose to receive a payment proportional to the net excess generation. This payment is also known as net surplus compensation (NSC), and it is based on a 12 months electricity retail rate moving average (Huffman, 2009). The customers also have the option to roll the credits for that generation over into the next true-up period (CPUC, 2010). Currently, the NSC can vary from US$ 0.04 to US$ 0.05 per kWh, according to the utility (CPUC, 2016a).

A new revision came into effect in 2013, when AB 327 was signed, redefining the system level capacity cap to 5% of the investor owned utilities peak demand (Perea, 2013). The bill also allowed utilities to charge a monthly fixed charge of $10 for all residential customers, except low income ones, who are charged a $5 fee. The fixed charge was supposed to enable utilities to recover fixed costs that are not covered by prosumers, in order to mitigate the cost shifting issue (Gibson, 2015). Table 1 presents the cap by utility and also the remaining capacity, as of March 2016.

Table 1: NEM Cap by utility and remaining capacity (MW), as of March 2016

Utility	5% NEM Cap (MW)	Remaining Capacity (MW)
PG&E	2,409	435.4
SCE	2,24	643.7
SDG&E	607	34.1

Source: CPUC (2016a)

Finally, in June 2016, considering the prevision that the NEM cap would be reached in the same year, the CPUC voted a revision of the program, approving the NEM 2.0. It's important to highlight that the NEM 2.0 enrolment for the three main investor-owned utilities' customers starts after each of them reaches its original net metering cap (presented in Table 1), or by July1, 2017 (Energy Sage, 2016). The new rules were thought to align the costs of NEM 2.0 customers to those of customers who don't have photovoltaic systems. In this sense, the following adjustments were approved (CPUC, 2016b; Alta energy, 2016):

[1] The net metering capacity cap to the three main investor-owned utilities, defined by the regulation was as following: Pacific Gas and Electric Company (17 MW); Southern California Edison (20 MW); San Diego Gas and Electric Company (3.6 MW) (Alquist, 1995).

i. Interconnection fee: customers who install photovoltaic systems will have to pay a pre-approved interconnection fee, proposed by the utilities, based on the historical interconnection costs. It is likely to be around $75-$150;
ii. Non-bypassable charges: prosumers will have to pay non-bypassable charges, of approximately 3 cents, per kWh consumed from the grid, independently of how much electricity was exported to the grid;
iii. Time-of-use tariffs: prosumers will have to adopt time-of-use tariffs, as soon as they are available, in order to promote the electricity consumption rationalization, as ToU tariffs better reflect generation costs along the day.
iv. Elimination of the 1 MW maximum system size.

Table 2 summarizes the main changes to the NEM policy since its implementation.

Table 2: NEM policy evolution from 1995 to 2016

	1995 (SB 656)	1998 (AB1755)	2001 (AB 29)	2002 (AB 58)	2013 (AB 327)	2016 (NEM 2.0)
System capacity cap	10 kW	10 kW	1MW	1 MW	1MW	N/A
Consumption class	Residential	Residential and small commercial	Residential, commercial, industrial and agricultural	Residential, commercial, industrial and agricultural	Residential, commercial, industrial and agricultural	Residential, commercial, industrial and agricultural
Compensation period	12 months	12 months	12 months	12 months	12 months (extendable to 24)	12 months (extendable to 24)
Treatment of net excess generation (NEG)	NEG purchased at avoided costs	No-compensation (unless a puschase agreement is signed by the utility)	No-compensation (unless a puschase agreement is signed by the utility)	No-compensation (unless a puschase agreement is signed by the utility)	Net Surplus Compensation (NSC): 12-month rolling average of retail rate	Net Surplus Compensation (NSC): 12-month rolling average of retail rate
Utility territory caps	0.1% of utility's aggregate peak demand (as of 1996)	0.1% of utility's aggregate peak demand	N/A	0.5% of utility's aggregate peak demand	5% of utility's aggregate peak demand	N/A

Source: Own elaboration

By 2014, approximately 150,000 residential customers had installed photovoltaic systems. Among this amount, only 492 systems were not included in NEM, suggesting that the policy played a central role in developing photovoltaic distributed generation (Stokes, 2015).

Currently, more than 90% of the photovoltaic capacity connected to the grid, in the operation area of the three main investor-owned utilities, is registered in the NEM (CPUC, 2016a). This capacity corresponds to a total of 594,685 systems (residential and non-residential), what is equivalent to a capacity of approximately 4.7 GW, as of December, 2016. Table 3 shows the evolution of installed capacity under the NEM scheme, from 1996 to 2016.

Table 3: Evolution of California net-metered photovoltaic installed capacity (1993-2016) in MW

California	Annual installed capacity (MW)	Accumulated Capacity (MW)	Annual Variation
1996-2002	12	12	
2003	20	32	166,7%
2004	30	62	93,8%

2005	34	96	54,8%
2006	50	146	52,1%
2007	83	229	56,8%
2008	128	357	55,9%
2009	117	474	32,8%
2010	176	650	37,1%
2011	283	933	43,5%
2012	337	1270	36,1%
2013	474	1744	37,3%
2014	642	2386	36,8%
2015	1049	3435	44,0%
2016	1262	4697	36,7%

Source: California Distributed Generation Statistics (2017)

2.2.2. The case of Brazil

Brazilian net-metering scheme was introduced in 2012, through the Normative Resolution 482, from ANEEL. The resolution established the rules for the access of micro and mini generation systems to the distribution grid, defining micro generation as system with the maximum capacity of 100 kW, and mini generation as systems with a capacity cap of 1 MW. It also defined that the electricity produced in these systems could be used for self-consumption or injected into the distribution grid, resulting in energy credits that could be compensated afterwards, over a period of 36 months. In the sense of simplifying the energy exchange process, the energy injected into the grid is supposed to be transferred, as a free loan, to the distribution company, in return for which the consumer receives the credits based on the amount (and not on the value) of active power injected, thus the number of credits isn't affected by electricity tariffs fluctuation (ANEEL, 2012). If the credits were not used until the end of the 36 months period, no compensation method would be applied. Thus, it is important to highlight that the commercialization of electricity surplus was forbidden. In this context, the following business models were allowed: self-consumption; and remote self-consumption, i.e. the transferring of electricity generation to another site, registered in the same private individual's registry number (CPF) or legal entity's national registry (CNPJ) (ANEEL, 2012).

In the face of the timid response to the net-metering system implemented in 2012, on November, 2015, the 482 Resolution was amended, through the Normative Resolution no. 687. The main changes in the legislation were: redefinition of system's capacity caps, so micro generation maximum capacity dropped to 75 kW, and mini generation capacity cap increased to 5 MW; extension of energy credits compensation period to 60 months; and the creation of two additional business models. The first one is the enterprise with multiple consumer units, which allows for the installation of photovoltaic systems in condominiums, so the generation is divided among the condominium members. The second one is the shared generation, through which legal or private individuals, in the same utility area, can create a cooperative (or a consortium) and install a renewable energy distributed system, sharing the electricity generation among the members, proportionally to their participation in the venture. It is also important to note that through the 687 Resolution the bureaucratic process to connect the system to the distribution grid was also simplified. Finally, the trade of overproduction remained forbidden (ANEEL, 2015). A summary of the main features regarding the evolution of Brazilian net metering scheme can be found in Table 4.

Table 4: Brazilian Net metering policy evolution from 2002 to 2015

	2012	2015
Capacity cap	100 kW (micro); 1 MW (mini)	75 kW (micro); 5 MW (mini)
Compensation period	36 months	60 months
Business models	self-consumption; remote self-consumption	self-consumption; remote self-consumption; condominiums; consortiums/cooperatives
Treatment of Net Excess Generation (NEG)	No compensation	No compensation

Utility territory caps	Not apply	Not apply

Source: Own elaboration based on ANEEL (2012) and ANEEL (2015).

From the publication of the 482 Resolution, in 2012, to September, 2015, 1,144 photovoltaic systems were installed around the country, corresponding to circa 1.1 MW. However, despite this increase, in 2015 photovoltaic distributed systems generated 22 GWh, what meant just 0.004% of the country electric consumption [6].
One of the effects of the regulatory change implemented in 2015, through 687 resolution, was the acceleration of diffusion. From October, 2015 to October, 2016, 4,696 distributed photovoltaic systems were connected to the grid, which represented an increase of 381%, against 261% in the preceding period (from October, 2014 to October, 2015). Currently there are approximately 7,570 photovoltaic net-metered systems connected to the grid, summing-up a capacity of 7.6 MW. The evolution of photovoltaic distributed capacity can be found in Table 5.

Table 5: Evolution of Brazilian net-metered photovoltaic installed capacity (2002-2016) in MW

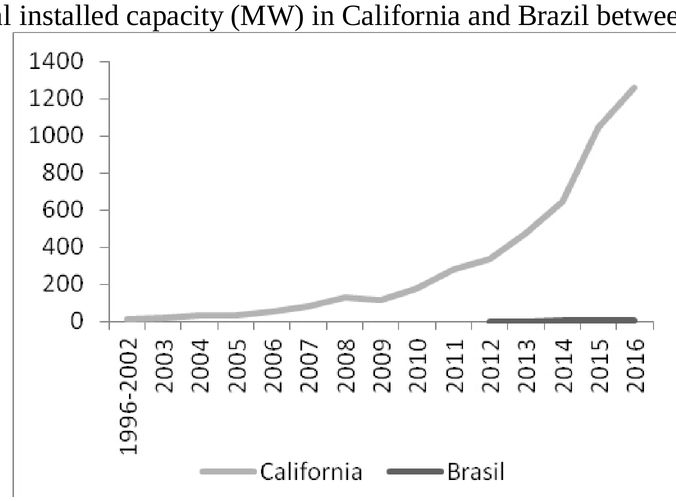
Brazil	Accumulated capacity (MW)	Annual installed capacity (MW)	Annual growth
2012	0.004	0.004	
2013	0.07	0.07	1750%
2014	0.4	0.3	464%
2015	1.8	1.4	329%
2016	7.6	5.8	323%

Source: Sauaia (2017)

2.3. Net-metering policies comparative analysis

Brazil's and California's net metering policies presents quite different levels of development, and the countries' photovoltaic markets, as can be seen in Figure 1, which shows the annual installed capacity in both cases. While in 2016 only 5.8 MW were installed under the Brazilian net metering scheme, in California the number jumps to 1,262 MW. While such distinct scales seem to reveal barely comparable cases, some important insights can be derived from this analysis.

Figure 1: Annual installed capacity (MW) in California and Brazil between 1996 and 2016.



Source: Own elaboration based on Sauaia (2007) and California Distributed Generation Statistics (2017)

First of all, it must be highlighted that California net energy metering does not exist in a vacuum, since California implemented many other strong support policies that are not verified in the case of Brazil.
Although Brazil also counts with other photovoltaic distributed generation incentive mechanisms, besides the net-metering scheme, they are applied in quite smaller scales, and are really far from the amount of incentives available in California. In the Brazilian case, the incentives such as credits to private persons, tax exemption, and other benefits are still very dependent

of state and, in small scale, municipal initiatives. As these incentives usually depend on the state government, and in Brazil still there isn't the same level of consensus about the role of photovoltaic generation in the electric sector as there is in California. This is directly related to the already high penetration of renewable sources in the country's generation mix, so the implementation of this kind of measure in Brazilian states faces many barriers. An example of this is the tributary issue that came into light in 2015. In the first years after the net-metering implementation, a tributary rule was approved, stablishing that even the electricity produced in the distributed systems should be included in the tributary calculation basis. In 2015, however, this decision was amended, but the option for the tax exemption was delegated to the states. Nevertheless, currently, almost two years after the decision was taken, there are five states (19%) which still haven't join the exemption, reinforcing the possible lack of a national consensus over the importance of the technology.

Thus, unlike Brazil, California has relied on a wide range of support policies, going from Renewable Portfolio Standard to Net Energy Metering, government subsidies (California Solar Initiative) and customer rebates for photovoltaic technologies.

It being said, some considerations about the net metering policies can be made. Brazilian policy has a really conservative policy, which also helps to explain quite timid results in terms of diffusion.

Currently, the cost of photovoltaic systems is much lower than it was during de 90s when California first implemented its net-metering policy. Even so, from 1996 (when net metering law became effective) to 2002, California could achieve 9 MW of installed capacity, performing better than Brazil did since its policy has been in place, as in 2016 there were 7.6 MW of micro and mini photovoltaic systems installed in the country. Although one can argue that this data refers to a slightly longer period in the case of California, it must be considered that 1996-2002 was a period when the technological development and the photovoltaic market were far less favourable than they are today. In this sense, considering the context of the 90s against 2000s, Brazilian net metering performance seems to be less effective than NEM.

Another feature that seems to be important to the success of California, and the deficiency of Brazil, is the issue of allowing the commercialization of the energy produced in the distributed systems and injected into the distribution grid. In the case of California, the trade of electricity surplus is allowed, creating opportunity for the development of many business models, as it turns the distributed generation a profitable activity, attracting many players and so developing the market. In contrast, in Brazil the net excess generation can't be traded, turning the development of these business models difficult, or even impossible, and so acting as a barrier to the market improve.

Finally, although the analysis of Brazilian and Californian net-metering policies reveals different trajectories, the most clarifying drivers behind such different result might be the ones exogenous to the policies by their own.

3. Feed-in tariffs

3.1. Theoretical approach

Basically, a feed-in tariffs (FITs) mechanism impose on the utility the obligation of purchasing the electricity produced by a photovoltaic distributed system at a certain price, defined by the regulator, and valid for a fixed period, also defined by the regulation (Campoccia et al., 2009). In this sense, FiTs represents "the full price received by an independent producer for any kWh of electric produced and injected into the grid by a RES-based system, including a premium above, or additional to, the market price" (Dusonchet and Telaretti, 2015).

Although the design of FiT mechanisms can vary a lot from case to case, there are some basic elements that are common to most FiT policies, which are: long term contracts, usually between 15 and 20 years; distinction among renewable technologies which are being promoted, considering the different costs and specificities; free access to distribution grid, as well as the obligation on the utility to purchase all the electricity injected into the grid, by the defined FiT value; a fixed FiT, or still variable, but indexed to the electricity wholesale price (Cox & Esterly, 2016; Klein et al., 2010). On the other hand, the main differentiating features are: structure of the basic tariff mechanism, which can be a feed-in tariff (fixed rate per kWh) or a feed-in premium (top-up rate on average electricity price per kWh); treatment of changes to the FiT value over time; the mechanism to re-distribute the policy costs to the utilities' customer base; and the rationale behind the support level definition (Hawkes, 2014)

FiT are usually perceived as a low risk mechanism, as it provides a well-specified level of support over a defined period, what usually makes the investment on microgeneration economically attractive (Hawkes, 2014). Besides that, as distributed generation capacity increases, FiT policies can prove increasingly expensive, raising some concerns over the policies sustainability, and, in many cases, imposing some challenges.

Currently, FiT mechanism is being applied in 20 EU member countries, and Germany is one of the most outstanding cases, followed by Italy (Dusonchet and Telaretti, 2015; Campoccia et al., 2009)

Among the many different incentive schemes for the promotion of renewable energy technologies, the feed-in tariff scheme has cemented itself as a popular policy mechanism. Germany is often used as a model example, not only for being one of the early adopters of feed-in tariffs, but for its radical success in using this incentive mechanism to propel itself to the forefront of renewable energy capacity, in the world. On the other hand, we have Japan, who in many ways has been a leader in photovoltaic technology diffusion up to 2005 without the use of a FiT, and who has been a late adopter of this policy tool, when in 2009 it managed to provoke a resurgence of photovoltaic diffusion with the implementation of a FiT. Today Japan has overtaken Germany, in its annual growth of photovoltaic energy capacity, yet it remains to be seen how the country will learn from the lessons of the past. In the following, this paper will offer a brief overview of some of the major feed-in tariff reforms relevant to photovoltaic installations, in order to subsequently discuss some of the differences and challenges each country is facing.

3.2. Feed-in tariffs case studies

3.2.1. The case of Germany

Germany has a long history of promoting renewable energy in general, and photovoltaic energy in particular. While an early form of feed-in tariff was introduced in Germany going back as far as 1991, it became a true catalyst for the diffusion of photovoltaic energy after the reforms in 2000 and more specifically 2004. The countries incentive policy went through innumerous reforms since its initial implementation. As a result, the policy changed and adapted along the way by addressing challenges and limitations. The following paragraphs will give a summarized overview of some of these policy reforms in order to better illustrate some of the key changes implemented over time.

The 2000 reform was important, in the sense that it guaranteed photovoltaic installation access to the grid, a fixed remuneration for 20 years and a drastic increase in its remuneration from 8 cents/kWh to 51 cents/kWh. This, together with the financial investment benefits guaranteed through other programs, allowed for the financial feasibility of photovoltaic installations.

Yet it is the 2004 reform of the feed-in tariff what represents a hallmark for the diffusion of photovoltaic energy, as it established a number of key characteristics which have made the German incentive policy so successful. Firstly, it established sub-categories for photovoltaic installations and with it, a differentiated remuneration based on capacity installed. Table 6 exemplifies this categorization for 2004, using the case of photovoltaic systems. Secondly, the reform set into place an automatic annual 5% regression n mechanism for remuneration. In addition, remuneration for photovoltaic installations was increased as compared to 2000, which meant that for the first time the feed-in tariff on its own was economic incentive enough to attract investment.

Table 6: Remuneration for photovoltaic systems installed in 2004.

Installations on buildings and sound barriers			Installations in open areas
up to 30 kWp	from 30 kWp	from 100 kWp	no limited
57,40 cents/kWh	54,6 cents/kWh	54,0 cents/kWh	45,7 cents/kWh

Source: Bundesregierung 2004

In 2009, the German government implemented another important reform process, which adapted and added some new characteristics. On the other hand, the remuneration levels were reduced in response to the growing number of PV installations. This would happen again several times between 2010 and 2012 because of the unexpected acceleration of PV diffusion. Additionally, the annual regression mechanism was increased to between 8% and 10%, with a special clause that allows for acceleration or deceleration of the regression depending if the annual capacity installed surpasses a defined threshold.

Besides adapting and refining the existing aspects of the feed-in policy, the German government in 2009, introduced a new element related to auto consumption. For the first time, auto consumption became a viable model to co-finance photovoltaic systems. While the feed-in tariff for electricity injected into the grid was still a lot higher than the electricity price, the reform introduced an additional remuneration for electricity that is auto consumed. In other words, consumers could save buying less electricity from the grid and receiving an additional remuneration. This marked an important shift towards incentivizing auto consumption.

Since 2012, the remuneration rate is adapted on a monthly basis using a specific formula, defined by law, which takes into consideration the new capacity installed over the last few months. At the same time, the government established a desired

growth in installed capacity between 2.5 and 3.5 GW per year.
In that same year, the extra remuneration for self-consumption introduced in 2009, was cancelled. None the less, self-consumption continued to be a viable model for co-financing photovoltaic systems, because the remuneration for injecting electricity into the grid was lower than the electricity price. The reform also made self-consumption exempt from paying volumetric taxes (such as grid fees, renewable energy tax etc.), which are usually included in the electricity price.
In addition, the 2012 reform created an alternative model to the feed-in tariff called feed-in premium. In it, the operator of the photovoltaic system (or any renewable energy generator) could sell this energy on the short term market. This means that under this model, part of the remuneration is attained through the selling of electricity and, in addition, a premium is added (which represents the difference between the remuneration guaranteed and the actual market price). As can be seen in Table 7, the diffusion of photovoltaic capacity decelerated starting with 2013, after experiences a previous three years of strong expansion.

Table 7: Diffusion of Photovoltaic Capacity from 2000-2015 in Germany

Germany	Annual installed capacity (MW)	Accumulated Capacity (MW)	Annual Variation
2000	44	114	63%
2001	62	176	54,4%
2002	120	296	68,2%
2003	139	435	47,0%
2004	670	1105	154,0%
2005	951	2056	86,1%
2006	843	2899	41,0%
2007	1271	4170	43,8%
2008	1950	6120	46,8%
2009	4466	10586	73,0%
2010	7358	17944	69,5%
2011	7485	25429	41,7%
2012	7604	33033	29,9%
2013	3304	36337	10,0%
2014	2006	38343	5,5%
2015	1444	39787	3,8%

Source: BMWi, 2016

In 2014, the German incentive policies for photovoltaic energy went through another reform process. A key change was made in regards to the feed-in premium. From that year onwards, the government established that the feed-in premium model is mandatory for all systems bigger than 100kWp. In practice, consumers with photovoltaic systems bigger than 100kWp have to find a retail energy sales company, which assumes the role of selling their electricity. The classic feed-in tariff continued to be implemented for smaller installations.
During the same year, the German government introduced a tax on auto consumption. This meant that starting in 2014, consumers would pay 30% of the renewable energy tax, and 40% starting in 2017 (Bundesregierung 2014). This rule was only applicable to systems with a capacity above 10kWp. In Table 8 the main aspects regarding the reforms just described are summarized.

Table 8: German feed-in policy evolution from 2000 to 2014

	2000	2004	2009	2012	2014
Capacity Categories	No categories	<30 kWp; 30-100 kWp; > 100kWp;	<30 kWp; 30-100 kWp; > 100-1000kWp;	<30 kWp; 30-100 kWp; > 100-	<40 kWp; 40-100 kWp; > 100-

		unlimited*	> 1000kWp; unlimited*	1000kWp; > 1000kWp; unlimited*	1MWp; 1-10MWp; <10MWp*
Remuneration model	Feed-in tariff	Feed-in tariff	Feed-in tariff; Feed-in premium; autoconsumption premium	Feed-in tariff; Feed-in premium	Feed-in tariff[2]; Feed-in premium
Remuneration rate	57 cents/kWh	57,40 cents/kWh; 54,6 cents/kWh; 54 cents/kWh; 45,7 cents/kWh	43,01 cents/kWh; 40,91 cents/kWh; 39,58 cents/kWh; 33 cents/kWh; 31,94 cents/kWh	28,74 cents/kWh; 27,33 cents/kWh; 25,86 cents/kWh; 21,56 cents/kWh; 21,11 cents/kWh	13,15 cents/kWh; 12,80 cents/kWh; 11,49 cents/kWh; 9,23 cents/kWh; 9,23 cents/kWh
Time frame	20 years	20 years	20 years	20 years	20 years
Regression rate	None	5% annually	Flexible 8-10% anually, depending on anual installed capacity	Monthly determined regression depending on growth of capacity	
Business models	Injection into grid	Injection into grid	Injection into grid; self consumption	Injection into grid; self consumption	Injection into grid; self consumption
Photovoltaic installed capacity cap (system level)	Do not apply	Do not apply			

*For instalaltions in open areas (predominantly centralized generation systems)

Source: Bundesregierung 2004, 2009, 2012, 2014

3.2.2. The case of Japan

While Japan has had a long history of investment in photovoltaic energy technologies, the 2011 earthquake and its subsequent energy crises (triggered by the Fukushima disaster), undeniably put the country in situation of urgency. The crises turned out to be an important motivator for the expansion of renewable energy (Goto e Sueyoshi, 2015). Before Fukushima, the country's long-term energy strategy focused on an ever-increasing share of nuclear power (Huenteler, 2012). The nuclear disaster laid bare the fragility of countries energy policy and the necessity to fundamentally overhaul and diversify its energy sector. To illustrate this, nuclear energy represented 11% of total energy generation before the crises, and dropped to 0% in 2014, after increasing again in the following years (FEPC, 2015). What further aggravated the energy crises was a peculiarity in the countries national electricity grid, which is divided into two zones that use different frequencies (50Hz in the east and 60Hz in the west), representing a challenge for balancing energy needs between these two regions (FEPC, 2015). As a consequence, a key pillar in strengthening the energy supply has been the promotion of renewable, especially photovoltaic energy sources.

Regardless of the events of 2011, Japan has been a relatively early adopter of photovoltaic energy technologies, and its incentive policies in the form of investment credits, and also the others, can be traced all the way back to the 1990s. This being said, it was only in 2009 that the government introduced a policy instrument labelled Purchasing Scheme for Solar PV

[2] Only for systems that fall into the category <100 kWp.

electricity, which allowed for the remuneration of excess energy injected into the grid by photovoltaic systems.
The program for purchasing excess electricity consisted of a type of feed-in tariff which was guaranteed for a period of 100 years. Additionally, the remuneration was only applicable to photovoltaic systems with a capacity of up to 500kW (Myojo e Ohashi, 2014). The tariff was set at ¥48 per kWh for residential systems with a capacity below 10kW and ¥24 per kWh for non-residential systems with a capacity of 10kW or above. The cost incurred through the purchase of this excess electricity, is passed down and divided among the consumers (Muhammad-Sukki et al., 2014).
In 2011, the Purchasing Scheme for Solar PV electricity was reformed, redefining the remuneration values at ¥42 per kWh for residential systems and ¥40 per kWh for non-residential systems (IEA e IRENA, 2016; JFS, 2011). Even though the program restricted remuneration to excess electricity produced by photovoltaic systems, it was successful at promoting the diffusion of photovoltaic installations.

Table 9: Diffusion of Photovoltaic Capacity in Japan from 2000-2015

Japan	Annual installed capacity (MW)	Accumulated Capacity (MW)	Annual Variation
2000	121	330	
2001	213	453	64,5%
2002	184	637	40,6%
2003	223	860	35,0%
2004	272	1132	31,6%
2005	290	1422	25,6%
2006	287	1709	20,2%
2007	210	1919	12,3%
2008	225	2144	11,7%
2009	483	2627	22,5%
2010	991	3618	37,7%
2011	1296	4914	35,8%
2012	1718	6632	35,0%
2013	6967	13599	105,1%
2014	9740	23339	71,6%
2015	10811	34150	46,3%

Source: Parnell, 2014; Yamada and Ikki, 2012

The following year in July of 2012, this reform process saw its conclusion with the adaption of the "Act on Purchase of Renewable Energy Sourced Electricity by Electric Utilities". One major change in this reform, was allowing for the purchase of all generated energy from photovoltaic systems, not just its excess. Yet these new rules only applied to more centralized, non-residential systems, while residential installations with a capacity below 10kW continued to be restricted to selling only their excess electricity. As a consequence, the reform process of 2011-12 strengthened the incentive policies for non-residential photovoltaic installations by guaranteeing a remuneration on the total electricity produced, increasing the remuneration, increasing the period for the guaranteed feed-in tariff to 20 years and exempting them from a majority of taxes (IEA e IRENA, 2016; JFS, 2011).
In 2016, the Japanese government has set into motion plans to reform the feed-in tariff beginning in April of 2017. Some of the motivating circumstances for this reform are the growing sense of necessity to diversify the renewable energy source. This is due to the fact that a majority of previous renewable energy expansion was based on photovoltaic systems and there has been a growing discrepancy between registered projects and projects in operation. Specifically, this means that, the bulk of the energy generated under the scheme, 64%, has come from PV, even though only 29% of the total 80 GW of PV capacity

approved to date has actually been installed (Dokei et al. 2016). In addition, among other things, the government hopes to propose mechanisms to control the costs of maintaining its incentive policies[3] (White & Case, 2016; Beetz, 2016).

Table 10: Overview of FiT reform in Japan

	2009	2012	2013	2014	2015	2016
Capacity Categories	<10kWp; >10kWp.	<10kWp; <10kWp + energy storage; >10kWp.	<10kWp; <10kWp + energy storage; >10kWp.	<10kWp; <10kWp + energy storage; >10kWp.	<10kWp; <10kWp + energy storage; >10kWp.	<10kWp; <10kWp + energy storage; >10kWp.
Remuneration model	Feed-in tariff (only for excess generation)	Feed-in tariff	Feed-in tariff	Feed-in tariff	Feed-in tariff	Feed-in tariff
Remuneration rate	42 JPY/kWh; 32 JPY/kWh	42 JPY/kWh; 32 JPY/kWh; 40 JPY/kWh	38 JPY/kWh; 31 JPY/kWh; 36 JPY/kWh	37 JPY/kWh; 30 JPY/kWh; 32 JPY/kWh	33-35 JPY/kWh; 27-29 JPY/kWh; 29/27 JPY/kWh*	31-35 JPY/kWh; 25-27 JPY/kWh; 24 JPY/kWh
Time frame	10 years	10 years for residential systems; 20 years for non-residential systems	10 years for residential systems; 20 years for non-residential systems	10 years for residential systems; 20 years for non-residential systems	10 years for residential systems; 20 years for non-residential systems	10 years for residential systems; 20 years for non-residential systems
Regression rate	No automatic rate	No automatic rate	No automatic rate	No automatic rate	No automatic rate	No automatic rate
Business models	Self consumption; Injection into grid of excess generation	Self consumption; Injection into grid	Self consumption; Injection into grid	Self consumption; Injection into grid	Self consumption; Injection into grid	Self consumption; Injection into grid
Photovoltaic installed capacity cap (system level)	Do not apply	Do not apply				

*In this year the feed in tariff for non-residential systems was reduced twice during the same year.

[3] It is estimated, that the current anual costs for maintining the incentive politices are aprox.. US$ 16 billion. This value can be divided into US$ 11,5 billion which are passed on to consumers through the Renewable Energy Levy, which amounts to a second consumption tax on electricity of nearly 9% of the electricity bill for an average family household with a monthly average consumption of 428kWh. The remaining US$ 4,5 billion is collected from the electricity distribuitoras, as evaded costs through the purchase of electricity (White & Case, 2016).

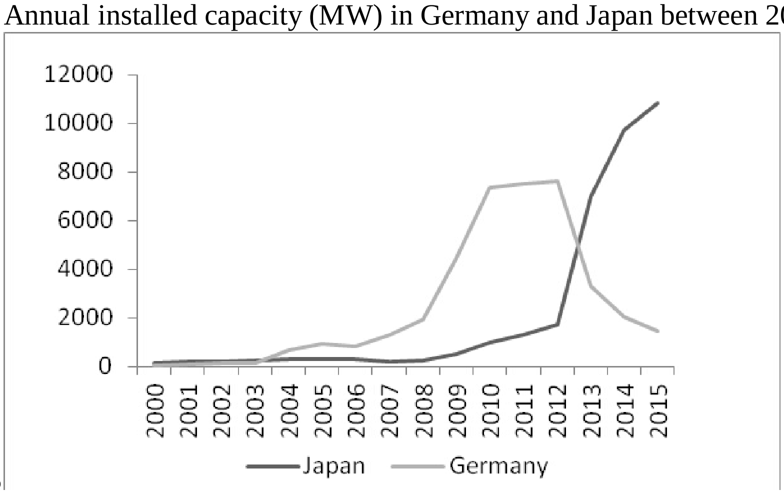
Source: IEA and IRENA (2016); Muhammad-Sukki et al., 2014

3.3. Feed-in policies comparative analysis

Naturally there are always some considerable challenges and limitations in comparing the effectiveness and success of a policy mechanism in two different countries. Consequently, comparing the German and Japanese experience with FiT and attempting to draw some parallels has to be done with caution. Yet when analysing the trajectory of this policy tool in each country, one can observe similar patterns and recognize potential challenges and solutions which each case has met. While Germany has been an early adopter of FiT, the earlier reforms were focused on defining cost-efficient remuneration levels and categories. Only in 2009, did the reform introduce elements which incentivized self-consumption. In the same year, Japan introduced a FiT which emphasized self-consumption and introduced two categories, for residential and non-residential installations. Thus a crucial difference was that German FiT for solar electricity was exclusively fed into the grid and makes it more affordable for the customers. Whereas in Japan, solar electricity is used for auto consumption first and only excess electricity is fed into the grid.

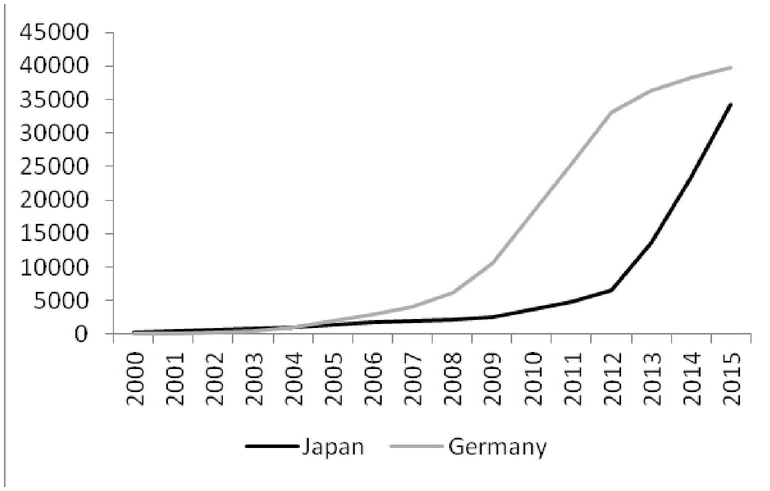
In both cases (in Japan more so than in Germany), there had been important advances made in the diffusion of photovoltaic technologies, but in both countries, the introduction of FiT marked a drastic acceleration of the deployment of photovoltaic installations. Interestingly enough, both cases demonstrate, that implementing a FiT is not enough in order to guarantee the successful diffusion of such electricity. While japan has been witnessing a boom of photovoltaic installations, the country has been facing a serious problem in getting many of these projects operational. Part of the reason for this, has been the lack of a bureaucratic framework, which defines timeframes in which this projects have to be realized. On the other hand, electricity distribution companies are able to block projects, if they are deemed to hinder the safe supply of electricity. While Germanys institutional and bureaucratic framework has been efficient in processing and integrating new photovoltaic installations, the country has been struggling with the growing costs associated with remunerating photovoltaic electricity generation. On the one hand, strong reductions of remuneration rates have been implemented, in addition to incentivizing auto-consumption and introducing levies on auto-consumption in order to finance the FiT. On the other hand, remuneration categories have been reformed, and FiTs have been limited to small capacity installations and projects that have undergone auctioning processes. Japan has also begun to recognize the challenges related to the growing costs of its policies, and is planning to put in place an auctioning system for larger photovoltaic projects. In this regard, Figure 2 offers some interesting illustration of this deceleration of new photovoltaic capacity in the case of Germany (after 2012) and the rapid expansion in Japan beginning in 2012.

Figure 2: Annual installed capacity (MW) in Germany and Japan between 2000-2015



Source: BMWi, 2016; Parnell, 2014; Yamada and Ikki, 2012

Figure 3: Total installed capacity (MW) in Germany and Japan between 2000-2015



Source: BMWi, 2016; Parnell, 2014; Yamada and Ikki, 2012

Thus it seems, that both countries have undergone similar processes and transformations, with japan joining this process nearly a decade later. Figure 3, visualizes this time deferred expansion process between the two cases. None the less, both countries have and are facing similar concerns and challenges in regards to cost control of the policy. This being said, one cannot underestimate the importance that these policies have been implemented under completely different political, institutional, cultural and historical circumstances. These have had a tremendous effect on the trajectory and success of these policies promoting the diffusion of photovoltaic technologies.

4. Net-metering and feed-in policies comparative analysis

Having analysed the implementation of net-metering and FiT in these four countries some preliminary conclusions can be drawn. On the one hand, as a policy of incentive, FiT creates stronger economic signals for investment. Both in the case of Germany and in the case of Japan, the FiT policy played a crucial role in the promotion of photovoltaic energy. Japans photovoltaic boom up to 2005 was based on strong investment incentives through tax and investment credits. With the abandonment of these policies, the following years up to 2009, witnessed a considerable slow down of photovoltaic investment, which only experienced a resurgence with the adoption of FiT policies in 2009 and 2012. Germany, on the other hand, abandoned its major credit incentives in 2004, with the end of its 100.000 roof-tops program and established a lucrative FiT for photovoltaic systems in the same year. From that point onwards, the country catapulted itself to the top of world photovoltaic capacity installed. The policy was by some considered “too successful” and the reforms should be interpreted as an attempt to control the expansion and with it the rising costs of photovoltaic diffusion. Thus today, remuneration schemes in Japan are much more lucrative than in Germany, which explains some of the differences in diffusion over the last years. Nonetheless, the challenges japan is currently facing, demonstrate the necessity to look beyond the simple incentive policies, in order to understand the success or failure of such policies.

This insight is further exemplified by the comparison of net-metering policies in California and Brazil. Both countries have similar net-metering policies in place today, yet the diffusion rate of these two cases differ tremendously. In order to fully understand their difference in performance, one has to take a more holistic look at the different incentive mechanisms in place in these two countries. In addition, this discrepancy illustrates that net-metering policies as a stand-alone mechanism, might not be sufficient to attract investment in photovoltaic systems. In the case of California, net-metering is part of a wider tool-box of incentive policies, which have enabled the rapid expansion of photovoltaic energy, such as the California Solar Initiative, which provides financial incentives to support the diffusion of solar photovoltaic, and also the Renewable Portfolio Standard, according to which a defined percentage of utilities’ electricity must come from renewable resources.

On the other hand, in the case of Brazil, net-metering has been applied as the principal policy for incentivizing investment in these technologies, but their timid success up to date demonstrates a lack of a larger incentive framework in order to create stronger economic signals.

A distinction needs to be made, about the nature of remuneration between FiT schemes and net metering. While the former is a pretty straight forward mechanism of remunerating electricity generated, the economic incentive of net-metering revolves around the evaded costs paying electricity bills. Consequently, measuring the costs of these two policies schemes requires different approaches. In a sense, FiT can create stronger economic incentives on their own, which can help explain the exponential rise in photovoltaic capacity in countries which have adopted this policy tool. On the other hand, these strong

economic signals have been shown to be associated with greater economic costs, which are also dependent on the adjustment mechanisms. In addition, the intrinsic nature of FiT, allows for people to invest in photovoltaic systems, with a capacity that exceeds their personal consumption, as they can receive remuneration on the generation level as a whole. The example of Germany, illustrates this phenomenon very well, because a great part of its reform processes involved experimenting and creating adequate regression rates for the remuneration.
Furthermore, evaluating the advantages and disadvantages of net-metring and FiT schemes, requires a common definition and understanding of what characterizes a successful policy. When looking at quantity and velocity of diffusion, the FiT seems to be more effective. Yet when taking in considerations the costs, perhaps an argument could be made, that net-metering schemes are more advantageous. This further complicates the debate and makes it questionable, if a decisive answer can/should be found.
This is not to say that there are no costs associated with net-metering. Net metering doesn't have direct costs associated to the policy, such as the case of FiT, but there are costs related to changes in the consumption patterns of consumers, which have an effect on the traditional business models within the electricity sector, and more specifically, on distribution companies. In particular, an increase of distributed capacity is challenging the traditional electricity value chain of generation, transmission and distribution, associating with it, new costs and challenges, which need to be addressed. These costs are universal to the process of the diffusion of distributed generation (be it photovoltaic or not) but can be witnessed in a more dramatic way in systems which emphasize self-consumption (such as the case of net metering).
Finally, and perhaps most importantly, one needs to recognize that none of these incentive policies were implemented in a policy vacuum. In order to truly understand and analyse the evolution of photovoltaic systems in different countries, one needs to take into account the policy framework as a whole, which often times includes tax exemptions, investment credits etc. and which all together contributed to the diffusion of these technologies. This becomes particularly evident in the case of Brazil, which has implemented a net-metering policy, in some ways similar to earlier experiences in California, but within a policy context, which lacks further substantial economic and political support. Thus one can argue that the countries limited success thus far is less a result of an inadequate net-metering policy, but due to lack of further incentive policies.

5. Conclusion

Although studies about photovoltaic support policies usually focus on explaining the success or failure of such policies by looking at the policies on their own, and also measuring their effectiveness by the level of photovoltaic penetration reached, one of the main insights of this study is that this framework can be quite limited.
First of all, the comparison between Brazil and California net-metering policies demonstrates that the diffusion level is highly associated with the availability of complementary support policies, and also with the photovoltaic market response to the regulation, in the sense that if the policy incentivizes the technology by turning it an attractive investment, it creates opportunities for the market to respond and adapt to the new context. With this in mind, the Californian photovoltaic market counts with innumerous companies which not only benefit from this process, but are also key players, as exploring the business models enabled by the excess generation trade option available in the regulation, they also leverage photovoltaic distributed generation diffusion. In the Brazilian case, otherwise, the regulation is working as a barrier to this process, as it does not allow the market to develop and take participate.
Secondly, when comparing feed-in and net-metering policies it is possible to question the effectiveness of photovoltaic penetration as a measure of comparing support policies superiority. At a first sight, through the comparison between net metering (California and Brazil) and FiT (Japan and Germany) cases, one can say that FiT seems a more effective policy. On the other hand, it must be considered that both Japan and Germany are facing barriers related to the high costs of the FiT scheme, which lead to a process of drastic reduction of the incentives. So, although the policies promoted a great increase of photovoltaic capacity, they also have resulted in huge costs.
Additionally, regarding the use of costs as an explanatory variable, another important issue comes into light. While the costs of feed-in policies can be easily measured, and are widely used for advocating the negative impacts of such policies, the costs of net metering policies still remain unclear. Although the negative impacts of net metering policies and the cost shifting issue have gained attention in the global scenario, the quantification of these impacts does not seems to be a consensus. However, it can be an important data to compare these two policies.
Finally, it is possible to conclude than when comparing support policies many other dimensions beyond the policy itself need to be considered.

Acknowledgements

In addition, this work was supported by Portuguese National Foundation for Science and Technology (FCT) through grants: PD/BD/105841/2014, UID/MULTI/00308/2013, and SAICTPAC/0004/2015-POCI-01-0145-FEDER-016434, as well as by the Energy for Sustainability Initiative of the University of Coimbra

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