London School of Economics and Political Science

Too good to be true
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How too generous PV Feed-in Tariffs are more a curse than a blessing for renewable energy investors

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Abstract:

The European Union has set itself ambitious targets to generate 20% of final energy consumption from renewable sources by 2020 and Feed-in Tariffs (FiT) are regarded as the most effective way to accelerate their deployment. Tremendous growth rates have been achieved under these systems, especially in the deployment of Photovoltaic (PV), as they provide investors with adequate returns and price certainty. However, five European countries have retroactively changed their PV FiT levels in the last three years, undermining the financial feasibility of PV projects, creating highly volatile investment cycles, and leading to a 28% decline in PV investments in the EU in 2012.

This thesis provides three contributions to understanding the origins of retroactive FiT adjustments as well as their effects on renewable energy investors. First, a theoretical model is developed to understand the retroactive changes from an economic perspective, demonstrating how over-generous FiTs can lead to such adjustments. Second, several determinants of the probability of retroactive adjustment were analyzed: higher costs in relation to the total value of electricity generated was identified as the main determinant, while higher shares of ground-mounted installations and early realization of the 2020 targets add to the effect. Third, several insights from interviews with several European renewable energy investors and experts are presented. Different strategies to overcome retroactive measures were developed while over-generous FiTs that are 'too good to be true' signal that the market might overheat and provoke retroactive changes.

Abbreviations

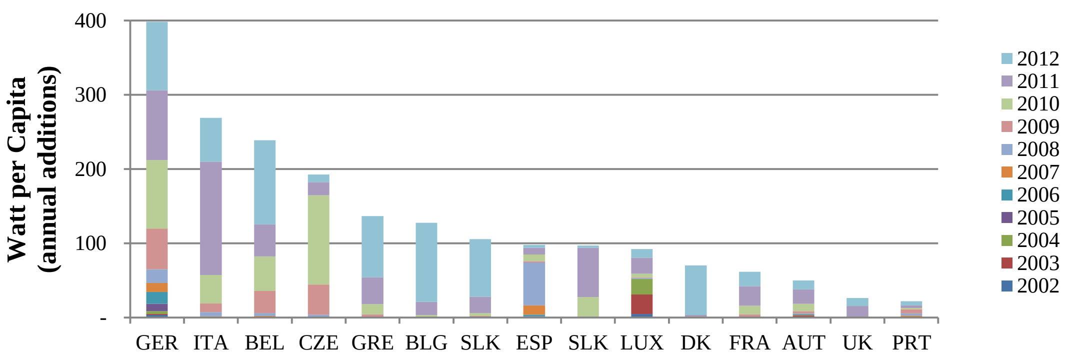
KW	Kilowatt
MW	Megawatt
GW	Gigawatt
MWh	Megawatt hours – electricity 1MW capacity generates in one hour
RE	Renewable Energies
TCI	Total Cost Indicator
ECI	Excess Cost Indicator
RAI	Remuneration Adequacy Indicator
FiT	Feed-in Tariff
PV	Photovoltaic
LCOE	Levelized Cost of Electricity
IRR	Internal Rate of Return
ROI	Return on Investment
RPS	Renewable Portfolio Standard

1. Introduction

The deployment of renewable energies (RE) has seen a tremendous growth over the past decade, with global annual investment rising from $40bn in 2004 to over $240bn in 2012, of which almost 60% is in PV (BNEF, 2013). With Europe still the biggest market for overall investments, there are plenty of opportunities for renewable energy investors. With PV system prices falling by over 80% since 2009 and over 45% in 2012, PV has already reached grid parity in moderately sunny regions such as Germany, possibly turning out to becoming a game changer for the energy transition (BNEF, 2012a). Compared to wind, PV has the advantage of being quick and easy to install, requiring low maintenance and having less impact on countryside scenery (IEA, 2012).

However, until a widespread parity is reached and guarantee of purchase is established, investors are still reliant on government programs such as purchase subsidies, tax incentives or Feed-in Tariffs (FiT) to generate revenues (Mendoca, 2009). When no incentives are in place, investments remain very low, conversely higher incentives attract capacity deployment. Following the ratification of the Kyoto Protocol, in 2007 the EU leaders set themselves an ambitious target to generate 20% of final energy consumption from renewable sources by 2020, (European Council, 2008). Several member states started improving existing incentive programs, especially Spain in 2007, Czech Republic in 2009, Belgium and Greece in 2010 as well as Bulgaria in 2011 offered very generous FiTs to PV project developers with the subsequent additional capacity installed on a per capita basis is presented in Figure 1.

Figure 1 - Additional annual Watt per capita per country



Unfortunately, the five countries listed enacted ‘retroactive adjustments’ to their Feed-in Tariffs, which are ‘changes brought upon by laws, while taking effect only from the date of publication, change existing rights and obligations of renewable energy producers and investors’ (KeepOnTrack, 2013). An overview of the countries and types of changes is presented in Table 1. Although the retroactive measures take on different forms, ranging from access fees to hourly caps and traditional taxes, they all effectively mean a reduction in revenues from existing installations with often significant impacts, jeopardizing projects’ financial feasibility (del Rio & Mir-Antigues, 2012). As in the example of Spain, after a boom of PV investments in 2007 and 2008, retroactive measures in 2010 were followed by drastic cuts and suspensions of FiTs, leading to a bust in the local PV industry and job-losses (Bechberger, 2013; Mir-Artigues, 2013). This created great uncertainty in the European PV market, with total investment volume dropping by 28% between 2011-2012, partly due to reduced system cost, but mainly due to ‘investor concern over policies to support renewable energy in its longest-established markets’ (BNEF, 2013). With calls from Germany’s minister for the environment to retroactively reduce costs, even those markets deemed safest suddenly did not look secure anymore (Murphy, 2013).

Table 1 - Overview of retroactive PV policy adjustments and drastic measures

Country	*Measure*	*Year*	*Details*
Bulgaria	Retroactive Tax	2012	‘Grid Access Payment’ of 1-39% of revenues from PV installations installed between 2011 and 2012
	Moratorium	2012	No additional RES in regulatory period 2012/2013
	Support Reduction	2012	39% reduction of FiT tariff with just 3 weeks notification time. Partly overruled by court, elements still remain.
Belgium	Retroactive Fee	2012	A fixed €54 annual fee per KW installed
	Support reduction	2012	Reduction of guaranteed certificate price of 79% within one year
Czech Republic	Retroactive tax	2010	Tax of 26-28% for system >30kW
Greece	Retroactive tax	2012	Tax of 25-30% for systems >10kW
	Moratorium	2012	Halted authorization procedure for over 6GW of projects in the pipeline
Spain	Retroactive cut	2010	Hourly production limits, which results in 10-30% FiT reduction
	Support reduction	2010	Sudden FiT reduction of 25% for rooftop PV systems and 45% for ground mounted PV systems
	Retroactive tax	2012	Tax of 7% on all PV systems

Other drastic measures			
Italy	Support reduction	2012	Italy had 3 different systems in 2 years, with often only a few months notice time. FiT system suspended in 2013
Slovakia	Support reduction	2012	Decrease of FiT by 38% with just 1 month notice
Slovenia	Support reduction	2012	Decrease of FiT with just 2 days notice
Retroactive measures discussed or proposed			
Germany	Retroactive cut	2013	Minister for Environment proposed retroactive cuts, which were overruled by Prime Minister
UK	Retroactive cut	2011	DECC intended to reduce FiT already guaranteed, this was overruled by the courts

Source - EPIA, 2012a

This thesis will contribute to the very sparse literature on retroactive changes and help create an understanding for investors on how to identify countries or FiT systems that are over-generous and are likely to collapse in the future. The scope is limited to the EU and PV only; although onshore wind energy has a considerable share of total renewable energy support, in terms of electricity generated per Euro support, wind energy is 6-8 times more effective than PV and seen less of a burden (IEA, 2012). The focus will lie on the perspective of renewable energy investors, as opposed to governments or households.

The following thesis is split into three parts: In the first part, a simple theoretical model will be introduced to explain the interaction between investors and the government, analysing under which circumstances governments enact retroactive changes. The second part contains an empirical study on the determinants of retroactive policy adjustments and will introduce indicators to help compare countries, while providing aspects for an ‘early-warning system’ for investors. The third and last part includes insights gained from interviews with renewable energy investors and experts on the effects and their responses to retroactive measures. The thesis will conclude with a brief discussion on responsibilities of government and investors as well as lessons learned.

2. Literature review

Literature on retroactive changes is neither ample, due to the relative novelty of these events, nor profound in its analysis. While the few relevant papers will be highlighted, literature on overall FiT effectiveness and design will also be discussed, as retroactive changes often have their origin in bad FiT design.

Comparing the effectiveness of FiT systems which are predominantly prevalent in Europe versus Renewable Portfolio Standards (RPS) in the US and UK, a FiT-design is generally thought as more effective and popular because it removes a portion of the risk from investors, although shifting the risk to the government and consumer (Klein, 2010, Giebel & Breitschopf, 2011; Schmalensee, 2011). Following a survey of venture capitalists, Bürer and Wüstenhagen (2009) concluded that FiTs scored the highest on investors' rating as market-pull option, with government demonstration grants on the push-side. Zhang (2013) looked at the effectiveness of FiTs on the European wind market, concluding that while FiTs were beneficial to investment, the size of the remuneration may not yield greater levels, as longer-running and successful systems may offer lower remuneration and non-economic barriers may be correlated with higher remuneration levels.

A number of policy papers and books have been written on effective FiT design, e.g. Couture et. al., (2010), Mendoca (2009), with some elements particularly relevant to retroactive measures highlighted. On the issue of applying caps on annual capacity or subsidies, some believe that when there is demand, this should not be capped and only applied as 'the last resort', while automatic tariff digressions should be preferable (Mendoca 2009:64). However, Prest (2012) points out, that many countries without interim caps were eventually forced to cap their entire system once expected targets were wildly overshot. However, systems with hard annual caps, such as Portugal and Netherlands have seen very low growth rates. Caps can therefore ensure investors that costs will not spiral out of control, while at the same time limit the total attractiveness of the market.

FiT systems also vary by their cost distribution mechanism, Germany applies a tax on electricity consumers to cover the cost for the annual expenses, while Spain did not allow the utilities to pass the full costs on to consumers and the deficit accumulated in the energy system, technically becoming a government liability of more than €25bn (Couture, 2012; BNEF, 2013). Furthermore, frequent tariff reviews and automatic digressions are an important element of effective design. Similar to caps, fixed tariffs for a longer period increase investor certainty but make the system less flexible when external factors change, such as declining PV system prices. Some countries digress on a monthly basis, others link it to cumulative capacity installed and Israel even links it to a price index for PV modules (BNEF, 2012b).

The Climate Policy Initiative (2013) has published a comprehensive report on risk gaps and the availability of risk mitigation instruments for a range of risks. Although 'retroactive cuts to support policies have significantly increased the perception of policy risks in developed countries', there are no insurances for a policy change in place, although demand would be very high. It seems as if the only way to mitigate policy risk is by requiring a higher return for greater levels of risk, according to a survey by Lüthi & Wüstenhagen (2011) on additional remunerations investors would require to accept the risk of a policy change. However, as the study was conducted before Spain's retroactive changes, the fact that higher remuneration levels might be the cause of policy changes was not considered and could undermine the results of the study.

The IEA (2012) looked at 'PV-bubbles' and identified four reasons for their boom: i) easy installation, ii) PV is sold as green investment *and* financial product, iii) central monitoring is difficult and iv) excessive returns in some countries. Although investors responded quickly to declining system prices, regulators did not react to this trend with the same speed and remuneration levels remained too high. Furthermore, especially when demand was not capped, deployment increased rapidly. Since many of the retroactive changes are very recent, the majority of the remaining literature focused on the Spanish case, a good overview is provided by del Rio and Mir-Antigues (2012) as well as Couture (2012). Especially a combination of bad policy design, excessive returns as well as macroeconomic pressures led to the retroactive changes in Spain.

Overall, no study has systematically examined the determinants of retroactive changes or their effects on the market. This thesis intends to contribute to the literature by developing a theoretical model of retroactive policy change.

3. Theoretical Model

To understand the interaction that takes place before and during a retroactive adjustment, a simple model was developed with two players: the government and a investor, where the investor is either classified as 'risk-unconscious' or as 'risk-averse', depending on his awareness and the incorporation of retroactive changes into his decision making process. To induce investment, the government gives support in the form of a FiT which the investor receives for the electricity his PV investment is generating. The interaction takes place in one period, t=1, thereby, all revenues and costs accrue in one year. Once the government knows the investment made by the investor, it will decide whether to maintain the FiT level or retroactively adjust it.

3.1. Modeling a 'risk-unconscious' investor

On the basis of Zhang (2013), I suppose that the investor can develop a PV project of size K (in MW) to maximize the expected net present value V of the investment:

$$\max V = (FiT * E) - gK \quad \text{s.t. } E = A * K^{\varpi} \tag{1}$$

Where E is the amount of electricity produced (MWh) and is subject to the load factor A, the average energy output as a percentage of total theoretical capacity (MWh/MW), times the investment K (MW). g is the capital conversion rate (€/MW) and ϖ (ϖ<1) is the solar elasticity curve, meaning that the best places for solar get built first and every subsequent investment yields lower return. A, g and ϖ are assumed fixed and only the FiT depends on the government's choice. Operational and maintenance costs are typically quite low for PV projects, around 0.7%, and are therefore excluded as well as financing costs for the project (EPIA, 2012b).

Solving the above function will yield an optimal K_{RU}^{*} that the risk-unconscious investor should invest:

(2) $$K_{RU}^{*} = \left(\frac{g}{A * FiT * \varpi}\right)^{\frac{1}{\varpi - 1}}$$

The optimal amount depends positively on A, FiT and ϖ and negatively on g. In practice, the annual maximum K is constrained due to the availability of equipment, and production capacity, which is not explicitly included here, but is part of ϖ. Furthermore, a minimum FiT of $FiT_{\min} = \frac{g}{A*\varpi}$ is required for $K \geq 1$.

3.2. Modeling a 'risk-averse' investor

Compared to the risk-unconscious investor, the risk-averse investor takes the possible actions of the government, given its own investments, into account, such as the possibility that the FiT levels will be retroactively adjusted. The adapted profit maximizing function is as follows:

(3) $$\max V = (FiT * E) * (1 - \Pr(adjustment)) - gK$$
$$s.t.\ E = A * K^{\varpi}$$

where $\Pr(adjustment)$ is the probability at which the government will adjust its policy, which will be outlined below.

3.2.1. Government's preferences and probability of policy adjustment

The goal of the government is to support investment to reach a level of PV capacity to meet its renewable energy target, K_{target}, where the level of K chosen by the investor is a function of the FiT offered by the government and the total costs are subject to budget constraint $Costs_{max}$:

(4) $$\max K_{target} = f(FiT)$$
$$s.t.\ FiT * A * K^{\varpi} < Costs_{max}$$

As with many FiT programs, it is assumed that the capacity K is not capped and therefore at every level of FiT there is a corresponding level K_{max} that will lead to total costs reaching $Costs_{max}$. This is the gross amount of total subsidies at which it is 100% certain that a government will adjust its policy. The probability of a government to retroactively adjust its remuneration is expressed as a function of the total costs of the support in relation to $Costs_{max}$:

(5)
$$Pr(adjust) = \left[\frac{FiT * E}{Costs_{max}}\right]^{\gamma}$$
$$s.t. E = A * K^{\varpi}$$

where γ is a cost-sensitivity factor (γ>1) to give the function an exponential shape and indicate that $Costs_{max}$ its sensitivity depends on factors that will be determined in chapter 6.

3.2.2. *Profit maximization function of a 'risk-averse' investor*

Returning to the profit maximization function in (3) that now includes probability adjustment in (5) :

(6)
$$\max\ V = (FiT * E) - (1 - \left[\frac{FiT * E}{Costs_{max}}\right]^{\gamma}) - \ gK$$
$$s.t. E = A * K^{\varpi}$$

The function has a first part that is increasing with FiT and K and a second part that is decreasing with FiT and K. Unfortunately, solving the above function w.r.t. K will not yield an explicit optimal K^*_{RA} due to the dependency of the probability for adjustment on K and vice versa. However, by careful studying of the equation and through simulations of the above function with different parameters, the optimal investment of the risk-averse investor must always be lower in comparison to the risk-unconscious investor: $K^*_{RA} < K^*_{RU}$.

3.3. Comparing the investment approaches

Assuming a market with only the risk-unconscious investor, he will increase his investment with higher FiTs, creating an externality from his investment by increasing the likelihood of a government to retroactively adjust its policy. If only the risk-averse investors would be active, he would internalize this increasing likelihood and would not invest more than what maximizes NPV and will therefore remain below the K_{max} threshold. With both types active on the market at the same time, the risk-averse investor will include the externalities arising from both investors in its profit maximization function, as the $Costs_{max}$ will now be reduced by the amount already allocated to the risk-unconscious investor:

(7)
$$\max \ V = (FiT * E_{RA}) * \left(1 - \left[\frac{FiT * E_{RA}}{(Costs_{max} - FiT * E_{RU})}\right]^{\gamma}\right) - \ gK$$

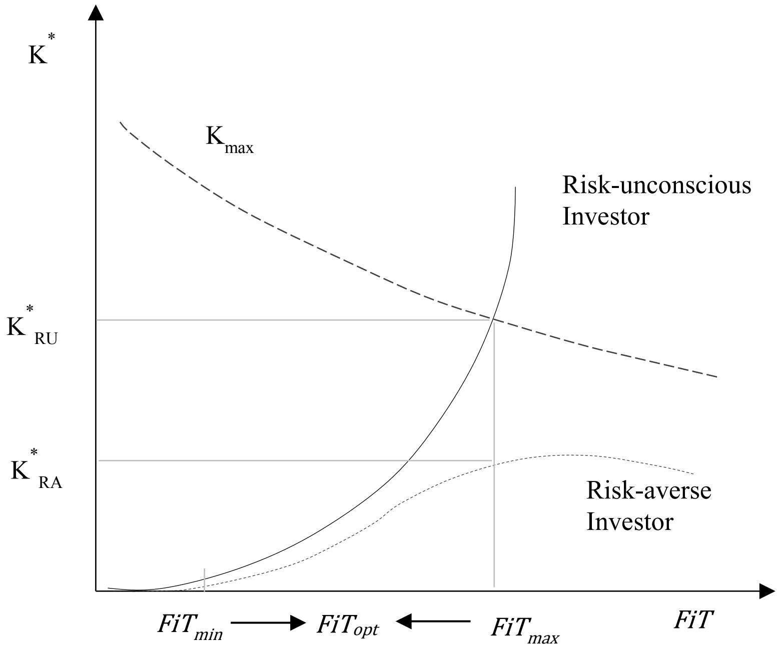
This will lead to the situation where the risk-averse investor will not invest in this market if he assumes that cumulative investments will reach critical levels. This presumption is backed up by investors interviewed, who had negative expectations regarding the Spanish PV boom in 2008, leading them to abstain from the market entirely.

3.4. Discussion on optimal FiTs under retroactive changes

The model presented above is represented stylistically in Figure 2, the optimal investment of the risk-unconscious investor K^*_{RU}, increasing with higher levels of FiT, while the K_{max} function decreases until it eventually crosses the function the former. The risk-averse investor will always remain below the K_{max} level, eventually reaching a maximum and decreasing as the FiT further continues to increase.

From the government perspective, there is an bandwidth in which the optimal FiT is high enough to induce investment, but below levels that will risk-unconscious investors to add too much capacity and thereby risk retroactive changes: $FiT_{min} < FiT_{opt} < FiT_{max}$. The minimum FiT was already derived earlier: $FiT_{\min} = \frac{g}{A*\varpi}$, however, the FiT_{max} depends on K, which in turn is a function of the FiT and cannot be derived explicitly, but it can be approximated through simulations. The optimal bandwidth is between FiT_{min} and Fit_{max}, but is dynamic over the year, as costs (g) will decrease over time and both investor curves will shift left. Therefore, governments should have systems in place that ensure that the optimal FiT stays between FiT_{min} and Fit_{max}.

Figure 2 - Stylized graph for Risk-unconscious and Risk-averse investor



4. Empirical Evidence of the Determinants of Retroactive` Policy Adjustment

For investors it is crucial to understand why some countries enforce retroactive changes and under what conditions they are more likely to do so. This paper will empirically analyse a range of possible factors that contribute to a country's probability to retroactively adjust FiTs. Using the probability of adjustment from (5), $\Pr(adjust) = \left[\frac{FiT*E}{Costs_{max}}\right]^{\gamma}$, the analysis will on the one hand try to determine whether a $Costs_{max}$ level or other relevant cost indicator exists, while on the other hand, how other conditional factors such as socioeconomic indicators and energy relevant factors might be used to estimate the cost-sensitivity factor, γ.

4.1. Main determinant - Cost

The main motivation for retroactive adjustments FiT is to reduce costs, in the cases of Greece and Spain particularly to reduce the renewable energy budget deficit (PV-Tech, 2011; PV-tech, 2013). However, it is not clear whether the total cost, cost in relation to a certain budget or excess cost matter. Therefore two different measures will be tested:

4.1.1. Total Cost Indicator (TCI)

Adopting the methodology from the IEA (2012), the Total Cost Indicator (TCI) is applied, which is the cumulative FiT premium paid as a share of wholesale value of total electricity generation. This takes indirectly the size of the country as well as its wealth through electricity usage and electricity prices into consideration. The higher the TCI, the more likely that a government will retroactively change its policy.

4.1.2. Excess Cost Indicator (ECI)

Not only may total costs matter, but also the share of amount paid in *excess* of what was necessary. Independent of total costs, a country that feels it paid too much for what it got, the greater the probability to retroactively adjust

4.2. Conditional factors

Given that two countries may have the same cost indicator, there may be certain factors that motivate one country to adjust its policy and not the other. Socioeconomic as well as energy related factors were chosen:

4.2.1. Income and Debt-to-GDP ratio (GDPCAP and DEBTGDP)

Wealthier countries in terms of GDP per capita with lower debt to GDP ratios will be able to shoulder a larger burden and face less budgetary pressure for cost reductions. Therefore countries with a lower GDP per capita and higher debt to GDP ratio are more likely to adjust their remuneration retroactively.

4.2.2. Attitude towards climate change (ATTITUDE)

Countries where there is little support amongst citizens to advance renewable energies will likely want to keep their costs as low as possible. Therefore, countries whose citizens least believe that climate change is a global issue are more likely to adjust their policy.

4.2.3. Share of ground-mounted vs. rooftop installations (GROUNDMOUNTED)

If the majority of cumulative PV installations are on rooftops, then simple households or small enterprises may be affected by retroactive cuts. As they are also potential voters and (international) investors are a much smaller group with less political clout, countries with higher shares in ground-mounted installations will be more likely to retroactively adjust their policy.

4.2.4. Reaching NREAP target (NREAPTARGET)

In 2009/2010, every country in the EU submitted their National Renewable Energy Action Plan (NREAP) goals for 2020 and outlined their targets for specific technologies. Already 10 countries have reached their 2020 goals in 2012 or earlier, some in just one year after establishing a FiT system (EPIA, 2013). The more capacity additions are spread out over time, the lower the total costs when system costs continue to decline; overachieving creates higher costs. Hence, it is more likely that a country that already reached their NREAP goal to reduce its costs.

4.2.5. Share of wind energy in final energy consumption (SHWINDEC)

While there is a range of renewable energies for countries to invest in, the majority chooses a mixed portfolio of PV and wind to reach their NREAP targets. Countries with little endowment for wind have a greater interest to keep their PV industry stable due to a lack in alternatives. Therefore, a higher share of wind energy means less priority on PV and a greater probability for retroactive adjustments in PV.

5. Methodology

5.1. Independent variable selection

Information on the dates and legislative actions on retroactive changes was retrieved from EPIA (2012b) and updated with government sources where needed. Although the Supreme Administrative Court in Bulgaria overruled some of the retroactive changes by the regulatory body in March this year, several installations are still affected and it is therefore still treated as a retroactive measure (PVGrid, 2013).[1]

[1] Although the DECC in the UK also attempted cuts with a restrospective character, they would have affected only a small share of installations, compared to the entire capacity in Bulgaria

The variable *Adjustment* is coded as 1 in the year that a retroactive measure was announced.

5.2. Dependent variable selection

Data for renewable energy subsidies was collected from 14 countries in the EU between 2002 and 2012 that had a FiT in place or a system comparable to a FiT, such as Green Certificates with a guaranteed price. The minimum requirement per country was at least 50MW installed by 2012 as well as at least 5MW added capacity per year. Information on GDP per capita, Debt to GDP ratio, share of wind energy in final energy consumption as well as the split between rooftop and ground-mounted were retrieved from Eurostat (Eurostat, 2013) and EPIA reports (EPIA, 2010, 2012b, 2013). The natural logarithm of the share of wind energy is used to reduce the impact of outliers and GDP per capita was converted to thousand euros. Measures on attitude of Europeans on Climate Change was retrieved from Eurobarometer surveys, measuring the percentage of respondents that believe climate change is the single most serious problem facing the world as a whole (Eurobarometer, 2008, 2009a, 2009b, 2011). Figures where interpolated between missing years. The variable used for achieving the NREAP 2020 PV target early was coded as a binary variable with data retrieved from individual NREAP reports (European Commission, 2010).

5.2.1. Calculating Total Cost Indicator (TCI)

The total cost indicator (TCI) as outlined in IEA (2012) is a ratio of the cumulative premium payments to PV over the total wholesale value of all the electricity generated. To calculate the total premium payments, I use a similar approach as Avril, et.al. (2012), who compared the cost of subsidies for five countries. The average yearly FiTs for rooftop and ground-mounted installations minus the electricity price p are multiplied by the share of the respective installation type in the country and the additional annual GWh of PV produced :

$$Total\ net\ costs\ = \sum_{t=1}^{T} \left[(FiT_{t,R} - p_t) * \%rooftop_t + (FiT_{t,Gr} - p_t) * \%groundmounted_t \right] * GWh_t$$

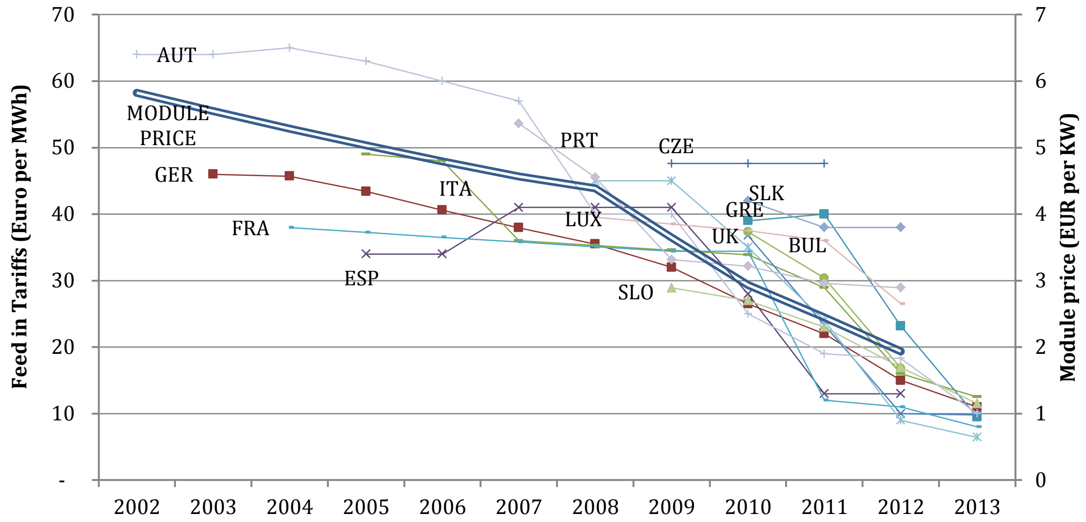
Information on the Feed-in tariffs was retrieved from official documentation through the IEA policies and measures database (IEA, 2013), RES-Legal (RES-Legal, 2013) as well as the wind-works.org (Gipe, 2013). Due to the complexity and variation in FiT policy design, several assumptions had to be made. As tariffs vary by the size of the installation, I used the tariffs for 100KW capacity for rooftop installations and >1MW for ground-mounted installations.[2] Schemes using Green Certificates with a fixed minimum price (Belgium) or net metering (Denmark) can be converted into a FiT per MWh. However, the amount of tax incentives (e.g. France) were not taken into account and thereby the total costs of the support may be underestimated in some countries. To calculate annual premium, the FiT of one year is multiplied with the total GWh produced in the same year. However, when the tariff changes in January but large capacities were installed in the previous December, then its electricity generation is not included until next year, although it receives the FiT of the previous year. This results in slightly lower cost calculation when the tariffs decrease over time.[3] However, as rooftop PV installations were assumed equally efficient in terms of MWh/MW, which they are not, the calculated costs are higher and both inaccuracies should balance each other out.

An overview of Feed-in tariffs per country for ground-mounted is presented in Figure 3 and of the cumulative costs in Table 2. Overall, the estimations were quite accurate in comparison to official figures on deficits where available. We can see that until 2008/2009 FiTs were only gradually declining, but from 2010 onwards governments started to swiftly reduce FiTs due to a rapid decline in costs for PV modules. For example, Austria paid €45 per MWh for ground-mounted installations in 2009, but in 2013 only €10 per MWh, a reduction of 80% over 4 years.

[2] Although the average residential installation is under 10KW, industrial and commercial installations can have several hundred KW capacity and overall the difference between rooftop types is smaller in comparison to the difference with ground-mounted.

[3] In the month before a new FiT, additional capacity added is often a multiple of the average

Figure 3 - Average annual Feed-in Tariffs for Ground-mounted installation in Euros per MWH



Note - The position of the module price relative to a country's FiT should not be directly interpreted, rather the rate of decrease in relation to a country's FiT schedule should be compared. Countries with no FiT for ground-mounted were excluded.

Table 2 – Estimated total cumulative net FIT premium payments for PV (in million euros)

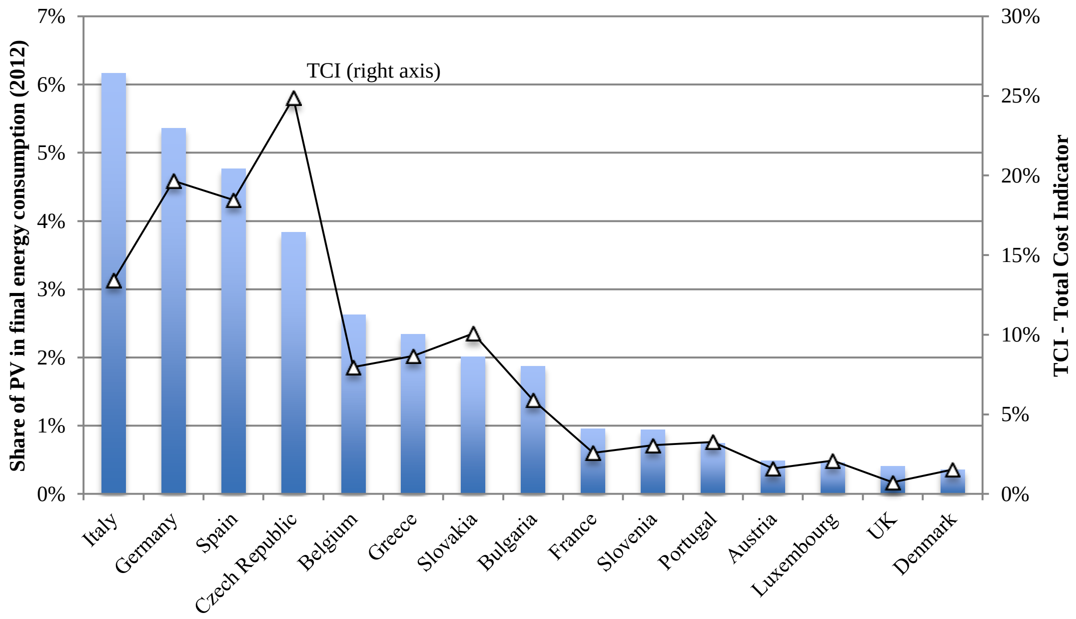
	2004	2005	2006	2007	2008	2009	2010	2011	2012	Reference
Germany	€172	€492	€876	€1,199	€1,681	€2,364	€3,701	€5,216	€6,216	€6,400
Spain			€22	€167	€923	€2,178	€2,404	€2,721	€3,111	€2,900
Italy		€1	€2	€4	€47	€184	€532	€2,646	€3,593	€6,200 (gross)
Czech						€31	€246	€898	€898	
France		€1	€2	€5	€15	€72	€219	€466	€701	
Belgium					€13	€61	€173	€306	€387	
Greece							€37	€187	€296	€400 (2013)
UK							€4	€53	€167	€152
Austria	€24	€35	€46	€58	€68	€84	€101	€125	€163	€140
Slovakia							€6	€127	€157	
Portugal				€9	€15	€47	€61	€76	€98	
Bulgaria							€4	€26	€77	
Denmark						€0	€1	€2	€23	
Slovenia						€1	€3	€14	€20	
Luxembourg					€8	€8	€8	€10	€11	

Source: Ger: (Fraunhofer, 2012), UK (Ofgem, 2012), Aut (Biermayr et al., 2012), Gre (PV-tech, 2013), Ita (GSE, 2013, figures are gross of revenues from selling electricity, my gross estimates would total €5.8bn)

Multiplying average annual wholesale electricity prices by the total electricity consumption in a country yields the total wholesale value of the electricity generated. The Total Cost Indicator (TCI) is the total premium payment divided by the above: $TCI = \frac{\text{Total Premium Payments}}{\text{Total wholesale vale of electricity generated}}$ and is plotted in over the share of PV in final energy consumption in Figure 4.

With respect to its size, the Czech Republic has the largest burden, while it generates less electricity from PV in relation to other countries. Due to tariff reductions, in 2012 Italy managed to greatly increase its share of PV while adding only little additional burden (only 4% addition TCI in 2012, although it should be noted that Italy has the highest electricity prices in the EU).

Figure 4 - Total share of PV in Final Energy Consumption in relation to TCI



Note – TCI in white triangles.

5.2.2. *Excess Cost Indicator*

Although a comparison of nominal FiTs between countries already signal great differences in their level, we need a better understanding of the underlying cost of generating PV to estimate how much countries have paid in excess of what was necessary. The Excess Cost Indicator (ECI) will express the difference between the actual premium paid to generate a unit of electricity and the minimum premium required as a percentage of the total:

$$\text{ECI} = \frac{\text{Actual net premium} - \text{minimum premium required}}{\text{Actual net premium}}$$

To calculate the minimum premium required for a unit of electricity, we can use the Levelized Cost of Electricity (LCOE), which gives a monetary amount of Euro per MWh that needs to be recuperated over a fixed lifetime of the investment, given the performance as well as the required return (Darling, You, Veselka, & Velosa, 2011). The LCOE yields a FiT the investor needs to meet his target Internal Rate of Return (IRR):

$$LCOE = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{M_{el,t}}{(1+i)^t}}$$

where I_0 is the initial capital expenditure (CAPEX), A is the annual operational expenditure (OPEX), M_{el} the annual electricity generation (MWh), i is the discount rate and n the lifetime expectancy of the plant. In the calculation applied, A includes depreciation, tax deductions as well as annual financing cost and by applying the WACC[4] as the discount rate, the cost of debt as well as the required return for the investor can be explicitly modeled. Further assumptions made are presented in the Appendix.

As a measure for the investment cost, I used information on final module prices in Germany in Euro per KW (Bundesverband Solarwirtschaft, 2013). A country's average capacity factor (MWh per MW) was used on the basis of national reports, Bloomberg (2012) and data from sun-yield.eu. If ranges were available, the average was used to generate conservative estimates, although investors will likely choose locations within a country with the highest yield, unlike households with singular choice in rooftop. According to a study by BNEF and the World Economic Forum (2011), the LCOE is particularly sensitive to CAPEX as well as return on equity requirements, which were therefore chosen conservatively. Where available, LCOEs were cross-checked with reports and the assumptions were thought acceptable (BNEF, 2012; Fraunhofer, 2012). The results of three representative countries in terms of irradiation levels (MWh/MW) are presented in Table 3**.** The LCOE is roughly halved with a doubling of MWh/year.

[4] WACC is the weighted average cost of capital, which includes the debt/equity split and the different interest rates

Table 3 - LCOE (in € per MWh) of three representative countries, 2007 - 2012

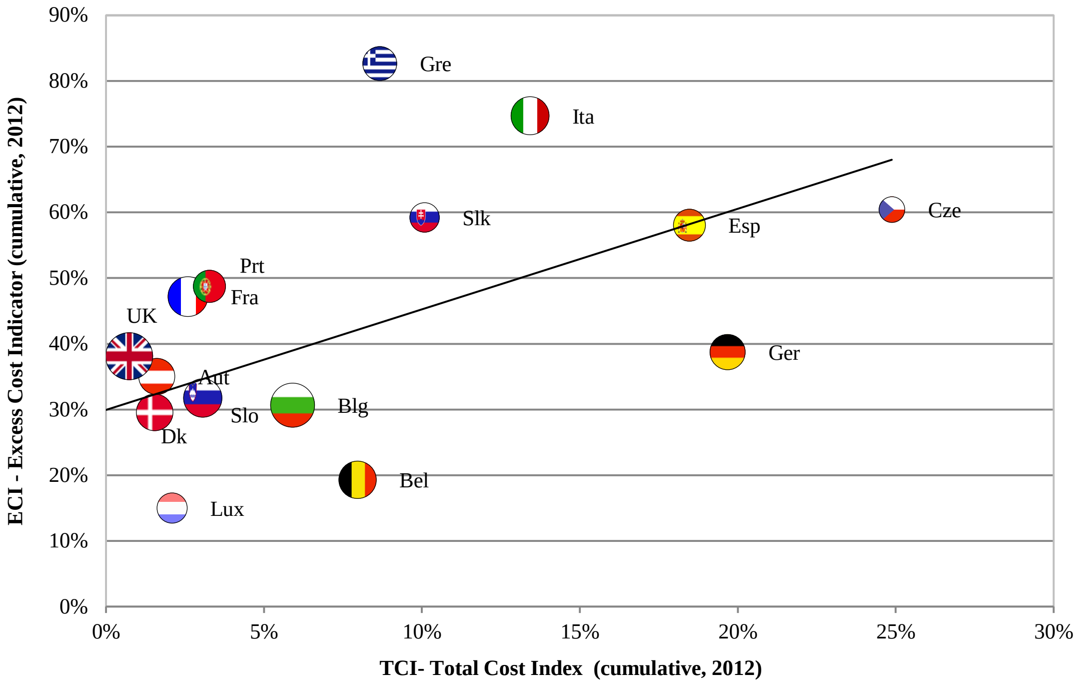
	MWh/MW	2007	2008	2009	2010	2011	2012
Euro/Watt		4.5	4.4	3.6	2.8	2.5	1.9
Belgium	850	€440	€431	€354	€277	€248	€191
Slovakia	1090	€367	€359	€294	€228	€204	€155
Spain	1550	€259	€253	€207	€161	€144	€109

The calculation of the excess cost is best done through an example: In 2011, Slovakia added 400 GWh of PV electricity to the grid, which is 1.5% of total electricity consumption. The LCOE for Slovakia in 2011 was €204 per MWh (Table 3). Therefore, the minimum *gross* total premium required to reach 1.5% share in electricity consumption is €81.6m, which is €55m *net* total premium, or a TCI of 3.7%.[5] However, the actual *net* premium paid in 2011 was €121m, 7.7% as TCI. Therefore Slovakia had excess costs of €64m, which divided by the total cost of €121 results in an excess costs indicator (ECI) of 52%.

Figure 5 shows the ECI plotted over the TCI in 2012. While Germany had a high TCI, it had relatively moderate excessive costs, compared to Greece, which had a very high ECI over a lower TCI; in terms of avoiding excessive costs, Germany was relatively efficient. However, efficiency may also be expresses as MWh per Euro invested (represented in the size of the bubbles). Even on this standard Germany scores quite well, although it has a very high legacy cost from expensive investments in the early 2000's. According to these estimates, both Belgium and Bulgaria didn't have a high TCI or ECI compared to Slovakia and Italy, although the former two enacted retroactive changes and the latter did not.

[5] 400GWh * (€204 - €64)/MWh = €55m. €64 is the wholesale electricity price per MWh.
€55m / €1500m (TWVE) = 3.7%

Figure 5 – ECI over TCI (cumulative in 2012)

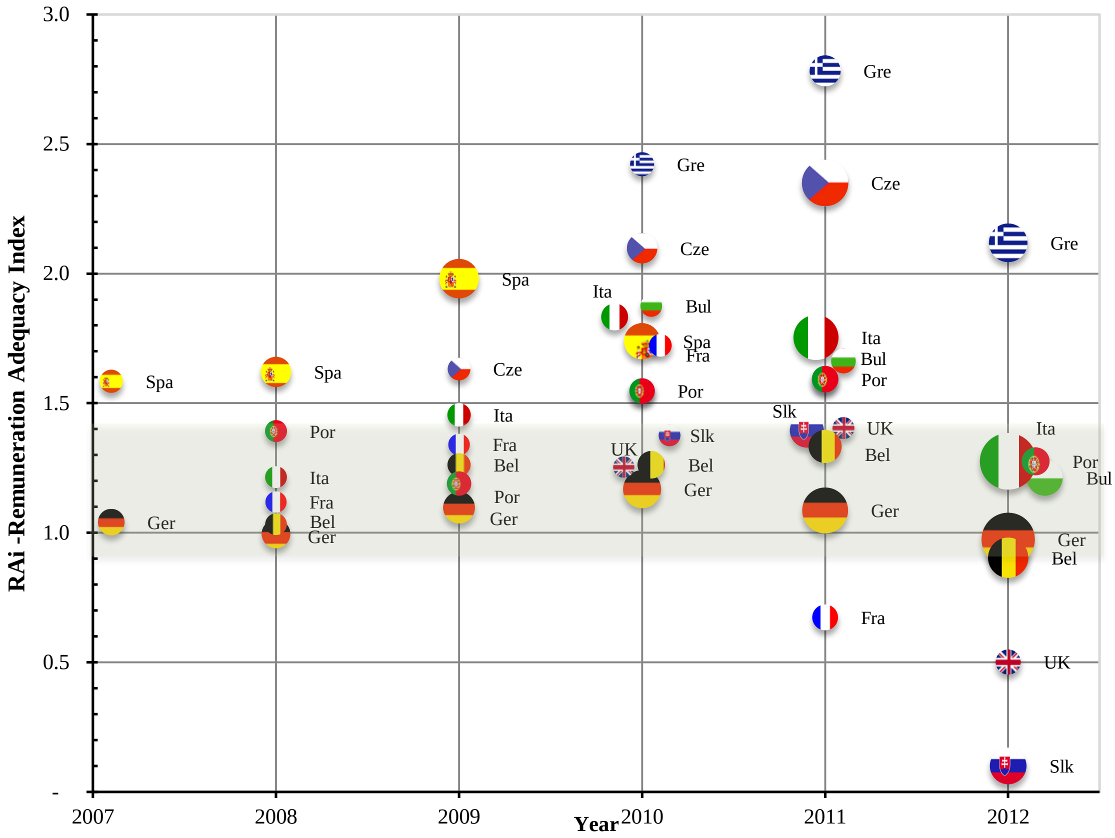


Note –The size of the bubbles represents the average MWh per Euro invested. The range is 2.4 MWh/€ in Czech Republic and 8 MWh/€ in the UK.

5.2.3. Remuneration Adequacy Indicator (RAI)

As an extension, which will be used later in the analysis, a Remuneration Adequacy Indicator, RAI, as first developed by the IEA (2012) is calculated by dividing the actual Feed-in tariffs by the LCOE: $RAI = \frac{FiT}{LCOE}$. A ratio of 1 means that the government pays exactly enough for the investor to make its required return, below 1 means smaller or no returns and everything above 1.5 should be considered as too generous. Figure 6 shows the RAI over the years. It is interesting to note that Germany has been relatively constant at a RAI of 1, decent returns but nothing out of the extraordinary. Spain, Greece, Czech Republic and Italy on the other hand had RAI ratios of 1.5 and above. According to my calculations the difference between a RAI of 1 and 1.5 is an additional IRR of 25% (on top of the 10% included in the model). The results were consistent with those from the IEA (2012).

Figure 6 – Annual Remuneration Adequacy Indicator - 2007 – 2012



Note - The size of the bubbles represents the share of PV in final energy consumption. Discontinued ranges are a result of a stop in FiT for Ground-mounted installations in the respective countries. Green band shows the RAI between 0.9 and 1.4.

5.3. Analysis

As the response variable Y= adjustment has a dichotomous outcome, using a binary logistic regression model is the appropriate choice. The variable takes on values of 0 or 1, corresponding to no adjustment or retroactive adjustment and that

$$log\left(\frac{\pi}{1-\pi}\right) = \alpha + \beta_1 X_i + \ldots + \beta_j X_j,$$

$$j = 1,2, \ldots, J$$

where π is the probability that Y = 1 and α and $\beta_1, \ldots, \beta_j$ are unknown population parameters. It is assumed that the observations Y are statistically independent from another, observations Y are a random sample from a population where Y has a binomial distribution with probability parameter π = Pr(Y=1) and a conditional variance of $\sigma^2 = \pi * (1 - \pi)$.

Data points after a retroactive change took place were removed as this would skew the analysis, equally, data without any significant annual additions to PV were not included (<5MW), which leaves us with 56 observations.

It would be beneficial for the strength of the model to control for unobserved heterogeneity between countries using a binary panel logistic regression with fixed effects. However, these effects would remove all observations with unchanging independent variable, which is not ideal as those observations contain information why countries do not apply retroactive changes. While random effects might be possible to use, it is unlikely that the country specific effects are uncorrelated with the independent variable, for example ex-communist country and rule of law. Therefore, the data is not treated as panel data, which comes with its disadvantages, especially if unobserved heterogeneity may be an explanatory factor.

6. Results and Discussion

Table 4 - Results of logistic regression model

	Model 1			Model 2			Model 3			Model 4		
Dependent variable - Retroactive Policy Adjustment												
	B	S-E	OR	B	S-E	OR	B	S-E	OR	B	S-E	OR
LogTCI	5.743*	(3.096)	312.01*	-	-	-	6.738*	(3.740)	843.87*	4.14**	(2.082)	62.78
ECI	-	-	-	-2.573	(4.5326)	0.076	-	-	-	-	-	-
DebtGDP	0.696	(1.603)	2.005	1.534	(2.0447)	4.638	1.395	(1.726)	4.033	-0.626	(1.662)	0.535
GDPcapk	-0.189	(0.115)	0.828	-0.163	(0.1019)	0.849	-	-	-	-	-	-
LogSHWINDEC	1.019	(0.817)	2.771	0.712	(0.5227)	2.038	1.099	(0.788)	3.002	0.591	(0.583)	1.807
NREAPachieve	2.525	(1.958)	12.496	3.606	(1.6026)	36.83	4.229*	(2.481)	68.67*	2.230	(1.584)	9.30
Ground-mounted	-	-	-	-	-	-	4.975*	(2.981)	144.72*	-	-	-
Attitude	-	-	-	-	-	-	-	-	-	-0.068	(0.12)	0.9
CONSTANT	10.385	(5.66)	32,357	2.418	(3.7309)	11.228	0.700	(4.224)	2.013	5.558	(4.017)	259.21
obs	56			56			56			56		
$LR(\chi^2)$	17.57***			10.18*			17.99***			13.72**		
Pseudo R^2	0.5215			0.302			0.5338			0.4072		
H-L	p=0.989			p=0.81			p=0.999			p=0.991		

Note Standard errors are reported in parentheses. *** indicates significant at 1% level, ** indicates significant at 5% level, * indicates significant at 1% level

6.1. Results

The results from the different model runs are presented in Table 4. Due to selection criteria and availability, the number of observations only allow for 5 explanatory variables at a time for the model to converge, with the rule of thumb of 10 events per predictor variable. Descriptive statistics and correlation matrix are presented in the Appendix.

In all models where the log of TCI was used as the main explanatory variable, the effect is positive and significant at the 10% level and even 5% level in model 4. In model 2 where the ECI was tested as main explanatory variable, the coefficient is surprisingly negative and not significant. The negative effect can be explained since the share of excess cost might decrease over time when the FiTs are reduced and the overall capacity becomes larger, compared to the TCI that accumulates over time. This results indicate that total costs matter a more than a share in excess costs. Controlling for the other variables, increasing the logTCI in Model 3 by 1, multiplies the odds of a retroactive change by 843, i.e. increases them 84,300%. This seems very high and is caused by the scaling of LogTCI and it does not render it easy to interpret, which will be continued in the following discussion.

Looking at the effects and significance of the conditional explanatory variables, in models 1-3, Debt-to-GDP has a positive effect on the probability of adjustments: countries with a higher debt burden are less willing to cover additional costs from PV generation. The variable is negative in model 4, which seems odd. Although the coefficient is quite strong, it is insignificant in all models.

A wealthier nation in terms of GDP per capita, is able to absorb some of the costs and is therefore less likely to introduce retroactive changes. However, the effects is not very strong, probably due to a high correlation between total wholesale value of electricity and GDP, as well as insignificant.

Greater shares of wind-energy in final consumption, increase the likelihood of a retroactive FiT adjustment, although the effect is not significant. Almost all countries that enacted retroactive changes achieve their NREAP 2020 target early, *NREAPachieve* and it is therefore not surprising that the effect is positive. In model 3 the variable is positive and significant at the 10% level.

Due to a high correlation between the variables *ground-mounted* and *Attitude* with *GDPcapk*, they were fitted in separate models, it seems that richer countries have more spending available for PV on rooftops and rate climate change more importantly. Adding *Attitude* does not add explanatory and although the coefficient is negative as expected, it is insignificant. Including *ground-mounted* in the model 3 reduces the explanatory power of *logTCI*, but it still remains significant at a 10% level. As expected, the larger the share in ground-mounted, the more the odds of a retroactive change increase and the effect significant at the 10% level. From data on retroactive changes we can also see, that these were mainly aimed at larger installations of >30KW.

The likelihood ratios, testing the null that the group of explanatory variables does not determine the distribution of the dependent variable, can only be rejected at a significance level of 1% in model 1 and 3. In combination with the Hosmer-Lemeshow test, which assesses whether or not the observed event rates match expected event rates in subgroups, model 3 appears to have the best fit and highest explanatory power. Overall, the models provide the reader a clear insight that costs are a primary and determining factor for whether a country enacts retroactive changes and how the other factors compound the likelihood under different circumstances.

However, given the limited number of observations as well as limited ability to control for unobserved heterogeneity, the results should be interpreted with caution.

6.2. Discussion

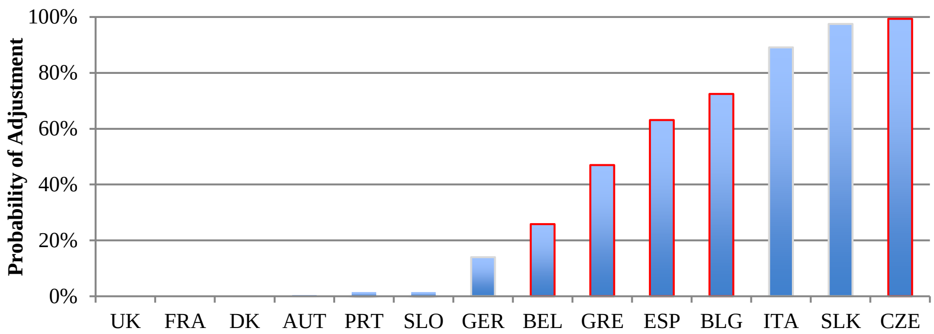
The first point that will be discussed are the results in relation to the raw data as well as calculating the probability of adjustment using most recent data, followed by how the results can help investors identify a risky FiT system in advance.

6.2.1. Understanding the probability of adjustment

There are especially two countries that stand out which can be used as examples to show greater differences: Belgium and Slovakia. Belgium has added large quantities of PV in 2011 and 2012, which now contribute 2.6% of final electricity consumption, overwhelmingly from rooftops. According to my estimates, Belgium did not have an average RAI greater than 1.3 in any of the years and although its TCI is moderately high with 8%, its ECI did not exceed 20%. Of the conditional variables, only its relatively high debt levels (100%) increase the probability of a retroactive change. Contrary to Slovakia, which had a tremendous PV boom in 2011 and 2012 and discontinued all further FiTs since. Its TCI is higher than Belgium's (10.2%) although its total share of PV in final energy consumption is lower (2%). Therefore it is not surprising that its RAI of over 1.5 during the period led to sustaining higher costs than necessary, resulting in an ECI of 62%. The majority of its capacity is installed on the ground and regarding other factors it has more in common with the Czech Republic and Bulgaria.

Using the estimated coefficients from model 3 with actual data from 2012, the Probability of Adjustment for all countries was calculated, Figure 7. Belgium has a probability of 26% while Slovakia has the second highest with 95%. Therefore I would not be surprised if sooner or later a debate will commence in Slovakia on possible retroactive measures to contain its costs.

Figure 7 - Probability of Adjustment using coefficients of Model 3, 2012 data

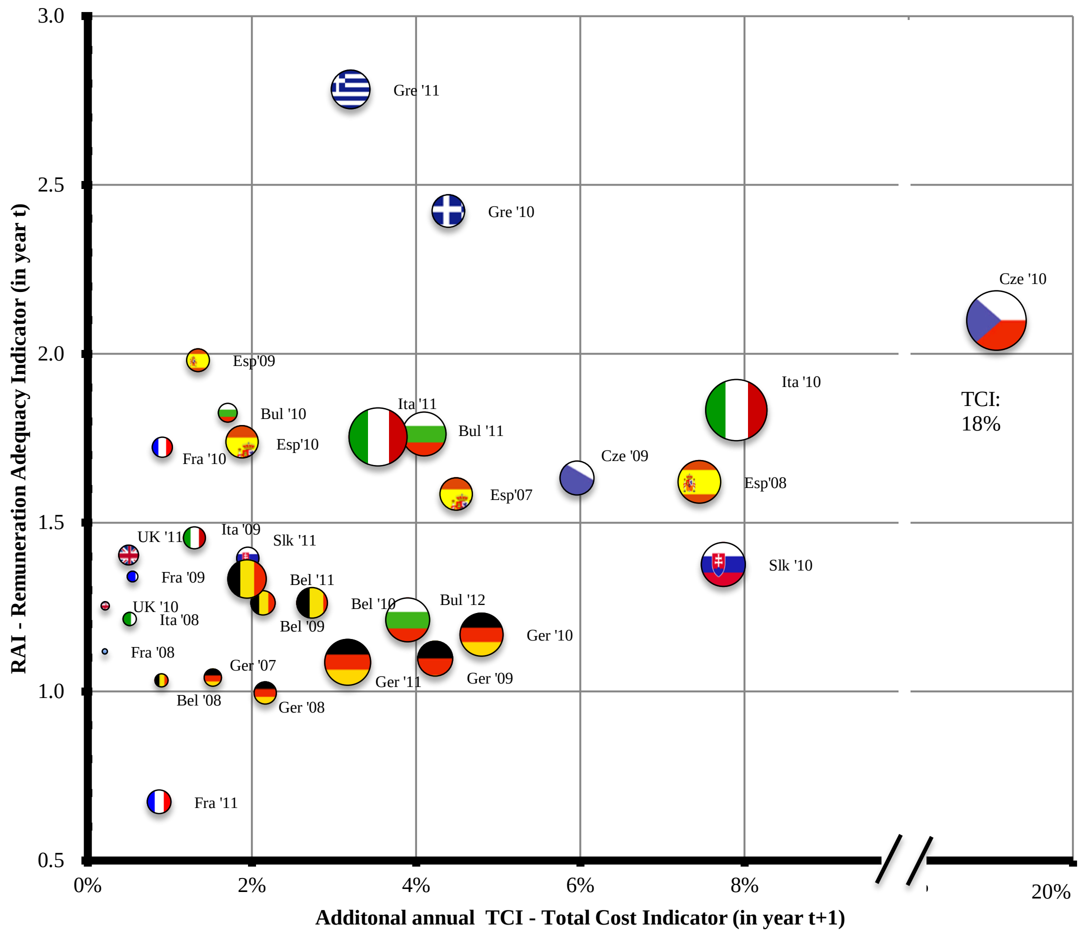


Note - Countries with a red outline have enacted retroactive changes.

6.2.2. <u>Early warning signals</u>

Based on the insights from the theoretical model in chapter 3, an investor needs to assess the expected level of investments by other risk-unconscious investors based on the current FiTs and whether the investments will lead to extremely high costs. Through a single graph and insights from investors, I would like to highlight the relationship between over-generous Feed-in tariffs (high RAI) and rapid increase in additional cost (high TCI) that eventually lead to retroactive changes. In Figure 8 the RAI in year t and additional annual TCI in year t+1 were plotted, as it will take at least a year for investors to react to new FiTs. The size of the bubble is in proportion to additional annual share of PV as % of final consumption. As we can intuitively see, Spain, Czech Republic, Bulgaria and Greece all started with RAIs well above 1.5, which lead attracted investment and yielded very high total costs, especially in relation to their actual PV contribution. Although a country can reduce additional future spending, there is no way to reduce the total costs, unless it enacts retroactive cuts. This figure shows that over-generous FiTs that are too good to be true, lead to higher costs and are a greater risk of retroactive changes in the future.

Figure 8 - Additional Cost as % of GDP in year t+1 over the FIT/LCOE ratio in year t



Note –Size of bubble proportional to additional share of PV in final energy consumption. Range is between 0 and 2.75% (Cze ’10). Most other countries not depicted are in the lower left quadrants and we excluded due to lack of visibility

7. Investor preference change following policy adjustments

During the course of this research, 7 investors in renewable energy as well as 3 topic experts were interviewed. These investors had a total of 600MW in PV capacity under (co)ownership in 9 countries, while five of the investors had a considerable portfolio in Spain and were therefore affected by the retroactive measures. An overview is presented in the Appendix.

The main questions addressed were:

1) How did the assessment of policy risk change following the retroactive changes in Spain?
2) What other factors changed?
3) How are FiT systems rated in comparison with other systems?

7.1. Assessment of policy risk

Before Spain announced its retroactive FiT adjustments in 2010, policy risk in this sense was not included in financial calculations of the investor or lenders. Spain was definitely a 'wake-up call' for everyone, although of an unpleasant sort. Since then, investors consider factors such as the general stability of the government, its renewable energy policy as well as its budget deficit, credit worthiness and grid access. Furthermore, how the costs are distributed matters, where an equal distribution as in Germany is preferred to a government budget the likes of Spain.

In hindsight, there were indicators in Spain that investors would consider now, as some investors already did in 2008, as early-warning signs, particularly how over-generous FiTs led to too much PV capacity addition and how project developers and intermediaries sold overpriced PV projects to final investors. One expression from an expert on the level of the FiTs in Spain motivated the title of this paper: 'They looked too good to be true – and they were'.

7.2. Increase in project-finance cost

Across the range, every investor interviewed mentioned the increased difficulty of access to project finance, in terms of lower leverage possibilities, shorter duration of the loan and higher interest rates. Unfortunately, due to the economic recession and higher standard for banks through Basel III, it is not possible to disentangle the additional difficulty due to the overall economic situation or as a result of retroactive changes. Furthermore, I learned that some projects could be financed at over 90% debt in the late 2000's, which in hindsight seems very unsustainable as well.

One interesting aspect that investors mentioned were the increases in the debt-service coverage ratios (DSCR), which is the ratio of annual expected cash flow over debt servicing. The DSCR is used to hedge against annual fluctuations in irradiation or wind, but increasingly include the possibility of a permanent, one-off reduction in revenues through a retroactive change. 'Will the project still remain profitable after a cut of x%?' is one of the questions investors and banks ask themselves. This additional risk is then translated into lower debt/equity ratios, shorter-term loans, higher interest or a combination of the aforementioned. Overall, the terms under which projects are eventually financed are still acceptable for investors, but projects that were financed in 2009 might not be viable under today's standards.

7.3. <u>Invest in countries/systems with government 'independent' returns</u>

Once the decision is made to invest in a country where the revenues are largely reliant on the FiT, the investor is 'dependent' on the government to ensure stability over the guaranteed period. Some investors therefore made decisions not to invest in government dependent systems and invest in quantity-based systems. So far these Green Certificate systems don't yet exist for PV, but are more widely used for wind in the UK and Scandinavia. The government sets a minimum amount of credits energy utilities need to buy per year, but the price is determined according to demand and supply.[6] Investors see the risk of price fluctuations as a 'merchant risk' and therefore more manageable and able to hedge against through portfolio diversification, compared to the possibility of retroactive changes.

However, although the price is determined by the market, there is always the risk that these extra costs of renewable energies will drive the government to revise the minimum requirements downwards, creating an oversupply of wind or PV energy, eroding the base for profitable operations. Furthermore, as another investor mentioned, the recent popularity of the green certificates system may be a result of the failure of other FiT systems, not necessarily better design in itself. Due to 'herd

[6] Although a price floor might also be set by the government

mentality', many investors rushed into Spain or Czech Republic; similar to the UK and Swedish wind markets, which are now the next best opportunity, but I heard diverging opinions from investors on the longer term perspectives.

So are there any 'safe' systems at all? Most likely not, although some risks are more manageable than others. Even when some countries reach grid-parity, this will not guarantee revenues through the normal electricity price. Decentralized power generation will add extra cost to the networks and judging by the number of recent retroactive grid-access fees, these will most likely be covered by the renewable energy investor. Moreover, no other country than Germany gives 'green' electricity purchase preference (merit order) and unless investors have a direct purchasing agreement with a company or municipality, the returns will always remain in some form government dependent, but the perception of risk might differ.

7.4. Safe-haven strategy and the journey to stormy sea

Many investors interviewed felt that the cuts and retroactive changes mainly took place at the 'periphery' of the EU, whereas its 'core' is still seen as a 'safe haven' for renewable energies, although discussion on retroactive measures in Germany have even questioned this perception. Especially institutional investors that were lured by the spectacular returns available in Spain and other countries, returned focus on the 'core' countries: stability was preferred over higher returns. These spillover effects from retroactive changes meant that safe-haven countries such as Germany attracted many of these investors with lower return requirements, thereby being able to offer lower FiTs while still attracting sufficient investment volume. There are two possible adverse consequences:

For many Venture Capital and Private Equity investors, returns in the 'core' may be too low and have chosen to invest in countries that offer higher returns, although with higher risk profiles. In metaphorical terms, if the safe haven is full, investors are forced out to stormy sea. The larger the perceived gap between 'core' and 'periphery' grows, the higher FiT investors and banks require for taking on the additional risk, leading to over-generous FiTs which in turn are an early-warning sign for retroactive changes, further widening the gap.

As a second point, capacity increased in 'core' countries such as Belgium and Germany, which are not particularly renown for their levels of irradiation. While this is good for the environment in those countries, it is less efficient from an overall economic perspective. One unit of PV invested in Spain can almost yield twice as much electricity as one unit in Belgium; PV in Spain would therefore be twice as efficient per unit invested. One study claims that with greater flexibility in choice of location to reach the EU 2020 targets, savings of up to €17bn could be achieved (Eurelectric, 2008).

The two issues show that the different PV markets are interconnected and spillover effects occur. All EU members should therefore have an interest in overall stability of individual FiT systems and avoid gaps between safe and risky countries emerging, as complete halts in PV investments are bad from the perspective of overall efficiency.

8. Discussion – Who is responsible and lessons learned

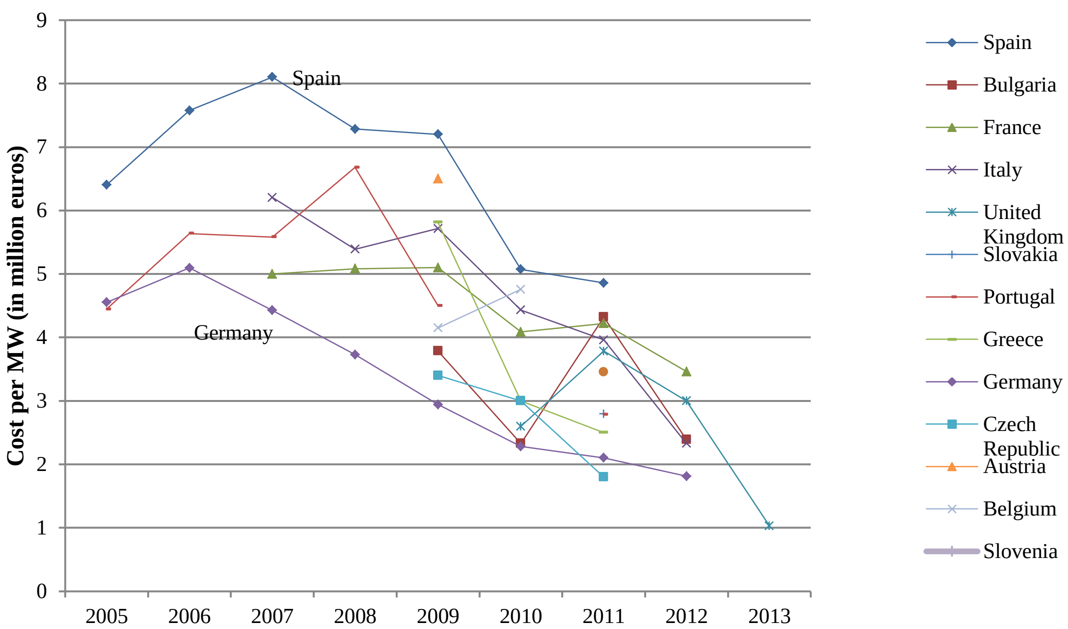
So far, the thesis has painted a rather gloomy picture on FiTs in the light of retroactive changes and looming uncertainty over many PV markets. However, this must not mean the end or a failure of FiTs themselves, the retroactive changes are a bittersweet proof that they are an extremely effective tool to quickly develop PV infrastructure. Encouraging evidence from Germany shows that a FiT system with regular reviews, automatic digressions as well as equitable cost distribution brings down rates and spurs investment. Two questions might be appropriate to ask in the end: Who should take the responsibility for the retroactive changes and (what) have investors and governments learned from past mistakes?

Who is responsible?

As the UK court of appeal made it quite clear, a government making retrospective changes in legislation 'offends the legality principle', in ruling against the Department for Energy and Climate Change's effort to retroactively reduce FiTs (Court of Appeal, 2012). However, governments also have an obligation to act in the best interest of their citizens and a 20% increase in average household electricity prices just to guarantee high profit margins for PV investors may be a strong argument to hold in favour of government intervention. I would even go as far as to give a conditional yes, the state should recover part of the excess cost if, and only if, the investor is not affected in such a way that he may face existential uncertainties. Unfortunately, final investors did not benefit from the complete generous FiTs.

According to the IEA (2012:129) ‘generous incentives [have] allowed for intermediaries to appear in the PV development business [and while] final investors harnessed reasonable returns, intermediaries captured excessive remuneration.’ While final investors buy a project and expect a 15% return over its lifetime, the intermediaries receive high returns and exit the market after the trade. One investor interviewed referred to these intermediaries as ‘locusts’, selling overpriced projects just before the PV bubble bursts, while the final investors are left with the losses after retroactive changes. Comparing transactions between investors and project developers/intermediaries for Germany and Spain in 2008 (Figure 9), projects of the same capacity almost cost double in Spain. Competition, supply shortages and experience may explain parts of the gap, but excessive remuneration of intermediaries is responsible the rest of the additional €3.5m per MW. However, unless they left the market completely, many intermediaries lose in the long run as retroactive changes and/or moratoria lead to busts in the PV industry, the EU’s deal on minimum prices for Chinese modules is the latest evidence of their struggle (Bloomberg, 2013a).

Figure 9 – Transaction value of PV projects per MW (in million euro)



Source: BNEF investment data (2012); own calculations

Investors benefited greatly when the music was playing and felt unfairly treated when it suddenly stopped. This may be a bit naïve and pure profit and loss rationale might have caused investors to overlook the larger picture that in the end somebody has to foot the bill. Bad FiT design is surely to blame for a great deal of the consequences, but nobody forced investors to seek those high returns and to a certain extent receiving very high returns from public funds could have been seen as risky.

Fool me once, shame on you. Fool me twice, shame on me.

To save the reputation and credibility of FiT, investors and governments should have learned by now that over-generous FiTs lead to overpriced and overheated markets, which hurt the country, consumers, investors and also hurt the environment and project developers in the long-run when the PV market dries up. Did investors apply more prudence and foresight to new FiT markets?

Japan currently has the most generous Feed-in tariffs in the world, with €380 per MWh, almost four times as much as Germany and is set to become the biggest PV market in 2013 in terms of annual installations. However, Japan exhibits all of the characteristics of a country likely to retroactively adjust its FiT: the majority of its installations are non-residential, it has a very high debt/GDP ratio, its Total Cost Indicator is around 10%, rent-seeking by intermediaries has driven up system prices to twice the level of China or Germany, and its prime minister prefers nuclear energy (Bloomberg, 2013b, 2013c; Solarserver.com, 2013; The Economist, 2013). Are investors fooled again by over-generous FiTs or did they learn from experiences in Europe? According to my estimates, Japan has a probability of adjustment of 99.981%.

9. Conclusion

This thesis has made a first attempt to analyse and quantify the determinants of retroactive changes for PV feed-in tariffs. The first contribution consists of a theoretical model on the interaction between investors and governments including the possibility of retroactive changes. The insights of the model show theoretically how over-generous FiTs can lead to retroactive measures and why some investors will abstain from these markets.

Second, using an empirical analysis of 14 European countries to identify determinants of retroactive changes, the total cost of the subsidies as a ratio of the total value of electricity has been identified as the main explanatory variable. A higher share of ground-mounted installations as well as reaching the 2020 NREAP PV targets early further increase the probability for adjustment at a statistically significant level.

Third, interviews with renewable energy investors and experts were conducted to outline their reactions on retroactive measures: A greater number of factors are now included in their assessment of policy risks such as over-generous FiTs and macroeconomic stability, but also how investment strategies shifted towards ‘safe havens’ and green certificate systems. Furthermore, the thesis outlined how the FiT systems are interconnected and retroactive changes in one country have spillover effects that influence investment decisions on renewable energy in the rest of the EU.

The outcome of this thesis provides renewable energy investors with a better understanding of drivers of retroactive adjustments. In particular, FiT systems that appear over-generous and ‘too good to be true’ will more likely lead to retroactive adjustments and should be measured with caution.

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11. Appendix

Appendix 1 - Outline of Interviews

Overview of Investors	
Number of investors	7
Of which	
• Private Equity	- 4
• Institutional	- 1
• Project Developers/ Independent Power Producers	- 2
Total MW installed, of which:	2.4 GW
• Wind	- 1.8 GW
• Solar	- 0.6GW
Countries invested	Spain, Italy, France, Poland, UK, Sweden, Germany, Switzerland, Scotland, India
Country of Origin	UK, Germany, Italy

Outline of Interview questionnaire:

Countries invested:
Primary technology:
MW installed:
Type of investor:
Take on development risk:
Other:

1. How did the assessment of policy risk change following the retroactive changes of Spain
2. What other factors changed (project finance, duration of finance etc.)
3. How do you assess the attractiveness of FiT systems?
4. How do you rate the attractiveness of other incentive measures?
5. Other

Appendix 2 – Data, Sources and Descriptive Statistics

Table 5 - Data, Sources and Descriptive Statistics

Overview of variables								
Code	Definition	Measurement	Source	Obs	Mean	Std. Dev.	Min	Max
Adjustment	Retroactive FiT adjustment	0,1	EPIA (2012,b)	56	0.0892857	0.2877364	0	1
TCI	Total Cost Indicator	%	Eurostat (2012), RES-Legal (2013), IEA (2013)	56	0.0430505	0.0552133	0.000135	0.2488135
logTCI	Total Cost Indicator	log(%)	idem	56	-1.827861	0.7810266	-3.867695	-0.6041261
ECI	Excess Cost Indicator	%	idem	56	0.4401281	0.195561	0.01	0.836309
GDPcapk	GDP per capita in thousand euros	€	Eurostat (2013)	56	25.05	9.102	4.8	43.8
DebtGDP	Debt-to-GDP	%	Eurostat (2013)	56	0.7798929	0.3321552	0.162	1.703
SHWINDEC	Share of Wind in final energy consumption	%	Eurostat (2013)	56	0.063890	0.070762	0.00020	0.311343
LogSHWINDEC	Share of Wind in final energy consumption	Log(%)	idem	56	-3.456073	1.547093	-8.512297	-1.166859
NREAPachieve	NREAP 2020 PV targets already achieved	0,1	European Commission (2010)	56	0.1964286	0.4008919	0	1
Groundmounted	Share of total capacity that is ground-mounted	%	EPIA (2012)	56	0.4189286	0.34895	0	0.95
Attitude	Attitude of citizens towards the importance of climate change	1-100	Eurobarometer (2008-2011)	56	18.18196	6.323816	7	31.61881

Appendix 3 – Correlation matrix

Table 6 - Correlation Matrix

	LogTCI	ECI	DebtGDP	GDPcapk	LogSHWINDEC	NREAPacieve	ATTITUDE	Groundmounted
LogTCI	1							
ECI	0.3605	1						
DebtGDP	0.0678	0.2898	1					
GDPcapk	-0.1702	-0.5779	0.1962	1				
LogSHWINDEC	0.1002	-0.0504	0.2158	0.2824	1			
NREAPacieve	0.419	0.1001	-0.1379	-0.0779	-0.3283	1		
Attitude	-0.0227	-0.3684	0.0267	0.7224	0.0342	0.0332		
Groundmounted	0.2686	0.5918	-0.2797	-0.8801	-0.2138	0.0691	-0.5557	1

Appendix 4 – Assumptions on LCOE Model

Detail	Assumption
Opex	0.7% p.a.
D/E	80/20
Interest rate on loan	5% p.a.
Length of Loan	
Return on Equity	10%
WACC	6%
System life	25yrs
Performance degradation	0.7% p.a.

	Overall	2007	2008	2009	2010	2011	2011
CAPEX (m euros)		4.5645	4.386	3.6465	2.9325	2.448	1.938

	Solar Yield (MWh/MW)	LCOE (Euro per MWh)					
		2007	**2008**	**2009**	**2010**	**2011**	**2012**
Austria	1,065	€ 377	€ 368	€ 301	€ 234	€ 209	€ 159
Belgium	900	€ 446	€ 436	€ 356	€ 277	€ 248	€ 188
Bulgaria	1,220	€ 329	€ 321	€ 263	€ 205	€ 183	€ 139
Czech republic	1,100	€ 365	€ 356	€ 292	€ 227	€ 203	€ 154
Denmark	880	€ 456	€ 446	€ 365	€ 284	€ 253	€ 192
France	1,250	€ 321	€ 314	€ 257	€ 200	€ 178	€ 135
Germany	1,100	€ 365	€ 356	€ 292	€ 227	€ 203	€ 154
Greece	1,550	€ 259	€ 253	€ 207	€ 161	€ 144	€ 109
Italy	1,350	€ 297	€ 290	€ 238	€ 185	€ 165	€ 125
Luxembourg	850	€ 472	€ 461	€ 377	€ 294	€ 262	€ 199
Netherlands	900	€ 446	€ 436	€ 356	€ 277	€ 248	€ 188
Portugal	1,600	€ 251	€ 245	€ 201	€ 156	€ 139	€ 106
Slovakia	1,090	€ 368	€ 360	€ 294	€ 229	€ 204	€ 155
Slovenia	1,050	€ 382	€ 373	€ 306	€ 238	€ 212	€ 161
Spain	1,550	€ 259	€ 253	€ 207	€ 161	€ 144	€ 109
United Kingdom	850	€ 472	€ 461	€ 377	€ 294	€ 262	€ 199