VALUATION AND ANALYSIS OF THE EUROPEAN UNION'S RENEWABLE ENERGY SUPPORT MECHANISMS USING OPTION THEORY

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Abstract

We examine the economic efficiency of incentive mechanisms used to promote renewable energy as a policy in the European Union (EU). We evaluate the financial performance of renewable investments and employ real option theory to model and analyze their impact in the EU's liberalized electricity markets. Our analysis covers key European countries and uses five years of the most recent historic electricity price data from 2009 to consider sensitivities in key parameters. As renewable energy policies are presented as public goods to address environmental concerns, we explain how the financial performance of these policies can strike a balance between social costs and private benefits. We consider how markets may incorporate renewable energy without major adjustments. For other regions, our research offers lessons on effectiveness and cost-efficiency in designing renewables incentive schemes.

Keywords: Feed-in tariffs, Feed-in premiums, Real-Option Theory, Investor Returns

1 INTRODUCTION

In many regions of the world, reducing fossil fuel use by means of support for wind turbines, solar cells and other technologies is one of the main objectives of energy policy, alongside security of supply, reliability of delivery and affordability. Meanwhile, concerns have been raised about the affordability of renewables from the standpoint of consumers, business and industry. If such policy objectives cannot be achieved without incentives and government support, at the heart of the resulting renewable electricity generation debate must be the question of support mechanisms and, including design alternatives, their scope and coverage.

Using standard financial and economic theory, we evaluate the widely used renewable support mechanisms which have been adopted by the largest economies of the European Union, excluding the United Kingdom, and assess their economic efficiency as measured by the returns to investors in renewable and social costs, including externalities. We use the market value of incentives paid to investors to analyze the financial performance of renewables under the various support mechanisms in a number of EU countries and observe whether or not the returns provided were commensurate with the risks. Further, to examine the social optimality of such

investments, we employ option theory to measure the indirect costs of renewables, comparing them with the private benefits earned by investors. We use representative plants, costs, localized operating characteristics -- such as solar irradiance -- and historic country level electricity price data from 2009 to 2013. We also consider how changes to key parameters may impact the value of support for renewables. The fact that Germany, Italy and Spain have recently revised their support schemes lends weight to the growing perception that many schemes could perhaps have been calibrated differently in order to achieve greater economic efficiency [1, 2, 3].

This paper is organized as follows: in section 2 we provide perspectives on renewables support mechanisms and then consider the efficiency of these, as covered in the public finance and environmental economics literature. Section 3 explains how we use financial option theory to model the exposure created by the dispatch priority currently afforded to renewable generation to address the issues raised in the literature review on the economic efficiency of renewables incentive mechanisms, social costs included. In section 4 we present measurements of the financial performance of renewable generation, both in terms of private benefits and social costs, in order to observe the calibration

of incentive support mechanisms in liberalized, traded markets for electricity. The concluding section relates our findings to some of the critiques of the EU energy and environmental policies.

2   RENEWABLES AS PUBLIC GOODS

According to public finance theory, the nature and size of public goods must be decided through collective or social decision-making rather than through market processes [4]. Renewable energy is supported as a public good in mitigating the externalities associated with fossil fuels such as greenhouse gas emissions (GHG), especially when effective taxation of carbon dioxide (CO_2) has proved difficult. To maximize social benefits and reduce social costs, various incentive mechanisms have been put forward to encourage renewables investment, particularly in wind turbine or photovoltaic electricity generation. But how should the social benefits of renewables in reducing GHG be quantified and used to determine by how much support this form of energy requires? Formally, the definition of how much of a public good is justified is based on finding the level of production which maximizes the difference between marginal social benefits and marginal social costs [5]. Given the global nature of GHG and atmospheric warming, it is difficult to decide how much renewable energy is required. But with governments having set targets for renewable investment and de-carbonization, such as the latest 2015 UN targets, we can investigate how large incentives need to be to achieve such objectives and ensure allocative efficiency, i.e. aligning private benefits with social costs. The literature on these issues exposes several research frameworks and opinions.

2.1 Supporting Renewables: A Literature Review

The premise of policymaking in the design of effective support mechanisms for renewables is that, although the short-run marginal cost of such generation is negligible, the fixed costs are very high compared with fossil fuel electricity generation and, thus, it is assumed that renewables would likely not be developed without incentives. The alternative of putting a price on CO_2 and changing the merit order of dispatchable electricity generation has

been attempted but, arguably, for many reasons it has been unsuccessful [6]. In designing incentives for the liberalized markets of Europe and North America there are special challenges as markets are relied upon to deliver renewable generation on grounds of public good, but the consensus varies on what works best [7].

In traded electricity markets, support mechanisms usually involve removing or modifying the various risks faced by renewable investors through combinations of guaranteed prices above a floating price, a fixed premium or uplift to a floating electricity price, and a transfer of risks to other parties or the greater system [8]. Indirect support may also be derived through the possibility of revenue from trading renewables certificates [9]. What works best in delivering renewables investment continues to be debated, although according to US Department of Energy National Renewables Laboratory [10], tariffs are more compatible with deregulated generation markets. In summary, there has been varied research into the effectiveness of policies in promoting renewable targets but no consensus has emerged. Given the levels of renewable investment now achieved in Europe, North America and elsewhere, the focus of debate has shifted to the costs and efficiency of delivery mechanisms, as explained below.

2.2 Allocative Efficiency and Renewables

The premise that deregulated and privatized electricity markets require sufficient incentives to attract investors begs the issue of how to ensure economic efficiency in delivering policy goals. To do this, various approaches have been used to calibrate the previously mentioned schemes, including calibrating incentives (i) using the levelized cost of renewables (LCOE); (ii) according to the avoided utility generation cost; (iii) based on the value of renewables to society; (iv) using renewable project costs plus a reasonable return; and (v) using an auction to calibrate the right to supply renewables to promote price discovery and avoid economic rent [11].

Calibrated in different manners and often revised, the sheer variety of such methods suggests a lack of consensus on how to deliver supply while avoiding economic rents and how to align social costs with private benefits and ensure economic efficiency. For example, a

study of wind parks in Portugal found that owners of such renewables were over compensated under the feed-in tariff scheme. The Portuguese authorities used a LCOE model to determine the necessary and appropriate level of support. The researcher showed that under Portugal's 2005 legislation $4.1 billion was spent on feed-in tariff support and, in addition, its 2013 legislation required another $840 million of public spending on wind energy support [12]. In Ontario, Canada, a debate over whether a support scheme for wind and solar renewables would be cost or revenue-based was resolved by adopting the German approach of benchmarking incentives for local wind and solar renewables [13]. In numerous countries a surge in renewable investment has been followed by reductions in incentives, suggesting a divergence between how policymakers value subsidies such as feed-in tariffs or premiums and how the markets and investors may see them [14, 15].

To calibrate a support mechanism to ensure its economic efficiency, it is necessary to compare the direct cost of the incentive price against the market price as well as any indirect costs, given the nature of renewables and the market setting. The intermittency of renewable energy and the lack of dispatchability must be considered in the valuation of renewables: because electricity is not storable, its price will vary depending on when it is produced. In deregulated, liberalized markets, electricity is usually priced hourly or half-hourly. The common method of comparing renewables with fossil fuel generation uses LCOE and treats electricity as a homogenous good and power supply from different fuels and technologies as commoditized perfect substitutes. This is problematic, however, because it ignores temporal and spatial issues and their consequent system impact [16, 17].

To tackle the system costs created by renewable energy, the US Department of Energy recently proposed a new metric: Levelized Avoided Cost of Energy (LACE) to measure the economic merits of renewables. This includes the cost to the grid or system of generating the electricity that is otherwise displaced by a new generation project. This is currently being evaluated, but has not yet gained acceptance [18]. However, using LACE requires system level knowledge and may involve arbitrary decisions as to what represents the marginal plant. Altogether there is little consensus on the best way to calibrate renewable energy incentives in liberalized markets so as to determine appropriate compensation and, ultimately, promote economic efficiency. To address the issues around valuation of incentives, we suggest a new way of looking at renewable energy to analyze the appropriate level of returns, given the risks and impacts. This is based on how its costs may be hedged, which affords an understanding of the financial performance of renewables in liberalized market settings and of how incentives might be calibrated to reward renewables investments efficiently.

3.   METHODS, MODEL AND DATA

To propose appropriate calibration for renewables incentives, it is necessary is to know the value derived from operating renewables in integrated, liberalized traded electricity markets, such as those in the EU. A number of questions arise. First, from the empirical perspective of a renewable energy investor, what returns were earned under the various incentive schemes offered in the EU? Second, from the perspective of economic efficiency, taking into account the full impact of renewables in liberalized markets, has the return provided to investors been generous? Third, do such returns to investors include all direct and indirect costs from the operation of renewable generation? And, last, as the priority dispatch of renewable electricity into an integrated liberalized system may make markets more volatile and reduce prices, how could the full impact of this, in terms of system cost, exposure and economic efficiency, be assessed?

3.1 Renewables in Liberalized Markets

Setting the right incentives for renewables in liberalized, traded electricity markets presents many challenges. In the 1990s most programs to deregulate and liberalize electricity markets gave a prominent role to trading. Through the interaction of supply and demand, markets were balanced and reliability ensured, with the marginal price set by the most efficient generators, the combined-cycle gas turbine plants. In such markets, fossil fuel

generators compete on short-run marginal costs in order to sell to a centralized grid that owns the high-voltage transmission systems and substations. In liberalized electricity markets, wholesale prices for electricity are made half-hourly, reflecting the requirements of the largest users, which are metered 48 times per day. By means of system planning and the right mix of flexible and less flexible plants, grid operators may use short-term balancing, allied to trading markets, to cover demand prediction errors or unplanned outages, while entering into longer term contracts to avoid supply disruptions and ensure adequate reserve margins.

Introducing renewable energy into this market presents challenges as it cannot be dispatched on demand but generates when the wind blows or the sun shines. For this reason, renewables are given 'dispatch priority'. When they are generating, other plants with flexible and controllable output must reduce their output. Dispatch priority creates short-term balancing costs for the grid and incumbents, plus long-term costs such as the need for grid connections and investment in more dispatchable generation as back-up. The average thermal efficiency of incumbent plants may be reduced and the frequency of unexpected outages and breakdowns may increase. Such externalities need to be included when assessing the value of renewables. Setting incentive mechanisms for renewables -- such as feed-in tariffs or feed-in premiums -- while excluding the benefits of not paying for the common resource of dispatchable back-up generation and grid management means the true returns and benefits to renewables are under estimated and resources are wasted.

3.2 The Value of Renewable Energy

To properly value renewable energy, the private return to investors needs to be compared with the total costs of renewables schemes, including not just incentive prices but any indirect costs of created exposures. To do this in a liberalized market setting, we employ option theory as it has been applied to model and optimize flexible, dispatchable plants [19, 20, and 21]. The renewables purchase obligation that covers grid operators, supply companies and consumers across the EU means that, whenever renewables are generating, other output must be reduced and all other

dispatchable plant must be re-prioritized or even shut down. Typically, a renewable operator will enter into a long-term supply contract with a renewable aggregator or integrated utility. This is similar to a contract for differences (CfD) between the market price and the price paid through the feed-in tariff or premium. The difference between the value stream to the renewable operator from a feed-in tariff or a feed-in premium and the normal wholesale price of electricity faced by the renewable energy purchaser creates an exposure for the buyer and ultimately for society. Under most schemes, if hourly prices exceed the tariff the renewable operator must return the excess [22]. Through applying option theory we can quantify the value of this exposure.

In agreeing to take renewable electricity under a contract by which the buyer is liable for the difference between the market and incentive price -- effectively a CfD -- an exposure is created and ultimately imposed upon the greater system. This exposure theoretically could be hedged by buying a strip of put options – giving the buyer the right, but not the obligation, to sell -- with strike prices equal to the feed-in tariff price. The theoretical price of the option represents the cost of accepting such risk for the purchaser, which is ultimately borne by the system. If market prices fall, the exposure arising from such a contract increases, but through using put options conferring the right to sell at the incentive price, a purchaser of renewable energy could theoretically hedge the exposure. The price of the put option represents the cost of having to take renewable power under the purchase obligation, a cost that is ultimately borne by society's stakeholders, as it is equal and opposite in value to neutralize the exposure.

To price the exposure created by the difference between the market price and that of renewable energy – created through, for example, a feed-in tariff -- we use put options with strike prices set at the price paid for such energy, because this method could neutralize and off-set the cost of purchasing electricity above the market price. In summary, the combination of dispatch priority and incentive pricing enjoyed by renewable operators creates an exposure for the buyer and, ultimately, for the system or grid which may be priced and

theoretically hedged using put options. Other approaches have been considered to quantify the exposure to renewable energy, such as comparing it with the LCOE, but, as explained, this excludes any indirect costs for the renewables. One researcher has tried a statistical approach to value the CfD contract against futures markets, but lack of liquidity and risk aversion may render such results tentative [23].

3.3 Data

For the years 2009 through 2013 data were collected for the following: (i) support levels for renewables for the major countries of the EU; (ii) wholesale prices for electricity across within these countries; (iii) price volatility in the same countries; (iv) daily sun irradiation, by countries; (v) average capacity factors for wind turbines and photovoltaic facilities and (vi) costs per installed MW of renewable investments. Data from the Council of European Energy Regulators (CEER) was used for support levels by country and technology, per MWh as summarized in Table 1 below.

Table 1. Renewables incentives

RE Incentives for Belgium, France, Germany, Italy, Netherlands, and Spain (Euros MWh)	2009 - 2013	SOLAR PV	SOLAR OTHER	WIND OFFSHORE	WIND ONSHORE
	Minimum	€ 220.53	€ 68.04	€ 41.05	€ 41.05
	Maximum	€ 496.03	€ 290.90	€ 135.50	€ 224.80
	Average	€ 381.34	€ 177.34	€ 102.23	€ 92.60

For comparing what was paid for renewable energy as against the wholesale market price of electricity, day-ahead marker pricing data for the specified EU countries was taken from Bloomberg. Several sources were checked for solar irradiation [24]. Data from the International Energy Agency (IEA) and the US Department of Energy, Energy Information Agency (U.S. DOE) were consulted for capacity factors of both wind and photovoltaic electricity generation [25 and 26]. Both official -- EIA and IEA -- and commercial sources were examined for the price per installed unit of wind and solar capacity, with the IEA's World Energy Outlook for 2014 proving the most useful [27]. To adjust the time value of the cash flows arising from renewable generation, a weighted average cost of capital of 10 percent was assumed as this

reflects the average opportunity cost of capital among Europe's major integrated energy utilities, while the return on investment averaged at 8 percent. Given the nature of the cash flow arising from renewable electricity generation, we have also discussed (below) whether a different rate is applicable. To calibrate the option pricing model, day-ahead price volatilities were taken from Bloomberg. Since historic wholesale electricity price data at half-hourly frequency is not readily available, a scalar adjustment was made to the option model calculations, based upon differences in value between day-ahead and half-hourly options to estimate the exposure which buyers of renewable energy faced. Option strike prices were set at the various incentive prices, as in Table 1. Incentive prices minus the historic market prices together determine by how much intrinsic value the option has. DerivaGem, Version 3.00 was used.

4 MODEL SET-UP AND RESULTS

We examined the returns earned by renewables investors using a return on capital employed measure, specifically:

$$\text{ROCE (percent)} = \frac{\text{Earnings before interest and tax}}{\text{Capital employed}} \quad (1)$$

Capital employed is the capital required to purchase renewable generation capacity and excludes funding liabilities. As operating costs of renewable plant are low for wind turbines, especially during the first ten years of operation, and even lower for photovoltaic -- estimated at just 1 percent -- such costs were excluded from earnings. Return on capital employed (ROCE) shows the value of a business and whether it can create value exceeding its weighted average cost of capital (WACC). To validate the ROCE results, we also extended the 2009 to 2013 results by 20 years to 2029, and computed an Internal Rate of Return (IRR) comparing the initial investment against the historic and projected revenues. The IRR results resemble the ROCE results.

To analyze the value in renewables, we compute a ROCE using the total amount received for generated output by an owner/operator. Sellers of renewables receive a combination of the wholesale market price for

electricity, plus the incentive premium paid by the buyer, while buyers of this energy are exposed at half-hourly granularity to the difference between the incentive price and the wholesale market price of electricity. We have averaged the result over the five years of available data and then compared it to capital employed. Summary results appear in table 2.

Table 2. ROCE

RETURN ON CAPITAL EMPLOYED				
RE Incentives for Belgium, France, Germany, Italy, Netherlands, and Spain (Euros MWh)	SOLAR PV	SOLAR THERMAL	WIND OFF-SHORE	WIND ON-SHORE
Minimum	17%	1%	6%	3%
Maximum	50%	36%	16%	68%
Average	32%	18%	10%	25%

Our calculations show that returns to renewables owners and operators varied between generous and very generous. Solar photovoltaic technology earned the highest return on capital employed followed by onshore wind energy. The average ROCE for solar photovoltaic exceeds 30 percent, while for onshore wind generation the ROCE was also very high. In Italy, for example, the returns for solar and wind were spectacular. Across the EU, only Spain made noteworthy investment in solar thermal technology and the ROCE earned by investors exceeded 30 percent. Compared with the rate of 10 percent so as to discount the time value of future earnings, ROCE results exceeded the assumed cost of capital. Given the guaranteed off-take, the dispatch priority afforded to renewables investors, the credit quality of counterparties taking the generated electricity and the government backing to incentive prices, the generosity of the terms provided to investors is surprising. As the relationship between incentive prices and ROCE is linear, reducing incentives by half would still have generated returns equal to, or exceeding, the WACC in all countries analyzed. In summary, although the various programs across the EU were effective in getting renewables plant built, the cost of the incentives was economically inefficient, offering supra normal returns for essentially risk free investments.

We also assessed the exposure created by the operation of renewable power that is faced by its grid operators, integrated utilities and ultimately consumers and taxpayers. Buyers of renewables, aggregators and integrated utilities under dispatch priority face the exposure arising from having to purchase electricity at the difference between the renewables incentive price and the traded wholesale price of electricity. To hedge such an exposure, buyers of renewables could purchase a strip of half-hourly put options to neutralize the potential downside of having to purchase electricity above the wholesale traded market price. Even if such options were not tradable, the price of the option would represent the cost involved in accepting the risk. At day-ahead frequency, using the scalar adjustment noted in section 3.3 for five years, the prices of put options were computed using the standard put option model and parameters [28].

To appreciate the profitability of renewables shown above, we quantify the externality of operating renewable power, per MWh of capacity, and compare it to what was earned per MWh of installed capacity. As shown in Table 3 below, it would cost the renewable energy buyers on average nearly twice as much to hedge the exposure arising from the difference between the feed-in incentive prices as what the renewables owner/operator received. For example, while the renewable operator with solar PV earned €342,100 per MW of capacity, it cost buyers of such energy €669,598 to hedge the exposure. For onshore wind the cost of the externality is the difference between €228,082 and €441,827.

Table 3. Revenues versus Hedging Costs

AVERAGE ANNUAL REVENUE OVER FIVE YEAR PER MW OF CAPACITY VERSUS COST OF HEDGING THE CONSEQUENT EXPOSURE				
COUNTRY	SOLAR PV	SOLAR THERMAL	WIND OFF-SHORE	WIND ON-SHORE
BELGIUM				
RE Owner/Operator Revenue	€ 256,891		€ 236,124	€ 229,284
Cost to Buyer to Hedge Exposure	€ 558,305		€ 494,240	€ 431,982
FRANCE				
RE Owner/Operator Revenue	€ 363,390		€ 311,525	€ 174,308
Cost to Buyer to Hedge Exposure	€ 788,972		€ 632,533	€ 348,868
GERMANY				
RE Owner/Operator Revenue	€ 250,184		€ 217,322	€ 99,099
Cost to Buyer to Hedge Exposure	€ 532,015		€ 451,584	€ 232,130
ITALY				
RE Owner/Operator Revenue	€ 503,184			€ 476,839
Cost to Buyer to Hedge Exposure	€ 858,351			€ 946,254
SPAIN				
RE Owner/Operator Revenue	€ 483,132	€ 359,723	€ 223,374	€ 223,374
Cost to Buyer to Hedge Exposure	€ 839,326	€ 617,290	€ 444,620	€ 375,802
THE NETHERLANDS				
RE Owner/Operator Revenue	€ 195,819	€ 42,147	€ 223,345	€ 165,587
Cost to Buyer to Hedge Exposure	€ 440,620	€ 86,489	€ 446,541	€ 315,923
AVERAGE				
RE Owner/Operator Revenue	€ 342,100	€ 200,935	€ 242,338	€ 228,082
Cost to Buyer to Hedge Exposure	€ 669,598	€ 351,889	€ 493,904	€ 441,827
AVERAGE DIFFERENCE	70%	63%	71%	67%

As shown in Table 3, the costs of hedging renewables exposure exceeds the gains from renewables operation. The result is intuitive: intermittency must be hedged for every half of the year while renewable operation is for only a small proportion, driven by the vagaries of the weather. The costs of hedging solar PV generation are greater in the southern countries of Europe than those in the north due to the many more operational hours over which exposure is created. Although buyers of renewables are only exposed to purchasing energy from solar facilities during daylight hours, the higher incentives provided for the former make the cost of hedging its exposure generally greater. Since renewable energy owners and operators do not bear the externalities in hedging costs imposed upon the greater market, and ultimately on consumers, their financial returns are enhanced. If roughly one-half of that part of the costs imposed upon dispatchable generators and, ultimately on consumers and taxpayers, in hedging renewables exposure were shifted back to its owner/operators, the returns for them would be eliminated. Given the attractive returns provided to renewables owner/operators and the externalities imposed upon buyers of their output, there would seem to be a strong empirical case for re-designing electricity markets to manage externalities and reduce the returns provided.

5   CONCLUSIONS

We made two sets of observations based upon empirical research and analysis. The first concerns the financial performance from operating or owning a renewable energy facility, while the second draws attention to the significant externalities arising from renewables. We calculated the financial performance of various renewable technologies across the key EU countries using a ROCE approach. We have found that the ROCE results, as incentivized for the range of renewable technologies under the various EU schemes, were high. At a time when Europe's major energy utilities were earning less than their cost of capital, investors in renewables earned generous returns while bearing little if any risk. Using option theory to quantify the exposure created for buyers of renewables we have found

that the costs amounted to nearly double what was earned from the operation of wind and solar facilities. Incorporating the costs to utilities and ultimately society of hedging against the risk profile of renewables, rather than the already expensive incentive costs as measured in returns to renewable investors, the full costs would be greater.

It has been suggested that the operation of renewables may lower market prices and contribute to price volatility, because prices and volumes are generally correlated [29]. In addition, renewable energy may create system wide costs as more thermal plants are paid to be on standby or minimum stable generation, lest the wind stops blowing or clouds appear. From option theory we see that if the electricity market were to become more volatile, this would make the cost of hedging such exposure greater. Further, with the variable cost of operating renewables close to zero, this operation could depress electricity prices by increasing the spread between the feed-in premium or tariff and the market price, which would increase the cost of hedging against such an exposure. Renewables impose costs upon incumbents, the system and ultimately society but, with growing output, become more profitable. In conclusion, although the EU countries' support policies have been successful in getting renewable energy facilities built, the direct costs of incentivizing renewables plus the indirect costs to society have raised legitimate questions as to their economic efficiency. Promoting renewables requires a more fundamental consideration of market design rather than the addition of specific incentives.

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