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The Effect of REFIT on Irish Electricity Prices[‡]

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Abstract: This paper evaluates the likely effect of REFIT, the Irish scheme to support renewable electricity generation, on the wholesale price of electricity. The cost of REFIT is passed on to Irish consumers. Here we calculate that when there are 4071MW of on-shore wind in the Republic of Ireland the cost of the REFIT scheme is between 5 per cent and 10 per cent of the gross wholesale price of electricity. Off-shore wind has higher levels of support than on-shore wind, as do technologies that are still in development such as wave and tidal. When off-shore wind, wave and tidal are added to the system, the cost of REFIT increases significantly. We argue that wave and tidal should be sustained with a different scheme that provides capital grants, and that off-shore wind that is channelled to exports should not be supported by Irish consumers.

Keywords: Ireland; renewable electricity; feed-in tariff

JEL Classification: L94; Q40; Q42

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1. Introduction

The promotion of renewable energy resources has increased recently in response to more stringent European legislation and greater environmental awareness. In 2009 the European Commission approved the 20-20-20 plan. One of the goals is that 20 per cent of all energy use in the European Union comes from renewable resources by 2020. For Ireland this has translated into a requirement that renewables provide 16 per cent of total energy demand by 2020. Most of the responsibility of meeting this target will fall on electricity generation, given the limited renewable resources available to fuel other sectors such as heating and transport (the focus on renewable resources in electricity generation applies to other countries as well, such as the UK; see Newbery, 2010). The renewable energy target is legally binding, and should Ireland not achieve this target domestically, it will have to pay for the statistical transfer of renewable energy from another member state.

In order to reach the 16 per cent economy-wide target, the power sector will have to generate about 40 per cent of electricity demand using renewable resources, primarily wind. This target is consistent with Irish government plans, as set out in 2007 (DCMNR 2007) and amended in 2008 (DEHLG, 2008). The method chosen to incentivise investment in renewable electricity generation is a system of support payments. The cost of the scheme is then passed on to Irish consumers in the form of a Public Service Obligation (PSO) levy.

The price of electricity is important to consumers and policy makers. There have been extensive discussions of the price of electricity during the past couple of decades. There is concern about how it affects residential consumers (and energy poverty) and the competitiveness of exporting companies (for recent examples see SEI 2010 and Diffney *et al*. 2010). This paper estimates how the Renewable Energy Feed-In Tariff scheme (REFIT) influences electricity prices in 2020. We compare the cost of electricity for different levels of renewable generation as fossil fuel prices change. Note that the PSO in Ireland includes not only payments for renewable energy, but also payments to peat generating plants and plants that were built to maintain electricity reliability standards. This paper will focus exclusively on payments related to renewable generation. We calculate the cost of REFIT for 2020 and find that the effect of the scheme depends greatly on exogenous factors such as the price of fossil fuels. When prices are high the scheme is less costly, adding up to 6.8 per cent to wholesale electricity costs. On the other hand when fuel prices are low, the wholesale price of electricity can be raised by up to 17.2 per cent due to the REFIT scheme.

Previous research shows that wind generation can be used to hedge against high fossil fuel prices (Berry 2005; Diffney *et al.* 2009). Graves and Litvinova (2009) find that the hedging properties tend to be more valuable in the long run, when financial hedges are unlikely to be available.[1] The work undertaken in this paper shows that the REFIT scheme maintains renewables' hedging properties when it passes the cost on to consumers, although it is somewhat dampened.

Section 2 introduces the renewable support scheme and describes how it works. Section 3 presents the model used for the analysis and outlines the main assumptions used in the simulations. Given the uncertainty that exists in energy markets we provide the results for a series of fuel price scenarios. Section 4 presents the results of the simulation. Finally, Section 5 summarises the results and concludes.

2. REFIT scheme

In the Republic of Ireland, investment in new renewable electricity generation is supported by the Renewable Energy Feed-In Tariff (REFIT) scheme, which guarantees a minimum price for renewable electricity to investors. This scheme replaces the Alternative Energy Requirement scheme (AER).[2] The first phase of REFIT was announced in 2006 and provides support for wind generation, hydro and biomass for up to 15 years. The level of support increases with inflation (measured by the Consumer Price Index) if inflation is positive.

[1] The authors also conclude that in areas where wind does not blow at times of peak demand (for example areas where the annual peak coincides with extensive use of air conditioning) hedging through renewable resources will only be economic if fossil fuel prices are expected to be high.

[2] The AER accounted for about 532MW of wind investment support, designed to last 15 year. The last round of competitive tendering under the AER took place in 2005.

Table 1 shows the amounts for all categories for 2006 and 2010, where the 2010 figures are equal to the 2006 figures adjusted for inflation.[3] The REFIT payment is composed of three parts. The first part is independent of the market price of electricity. In Table 1 it is defined as "Fixed Payment" and is paid for each MegaWatt-hour (MWh) of electricity produced by generators. The second part is a reference price (equal to €66.35/MWh in 2010). If the price obtained on the market is smaller than the reference price, a payment is made for the difference between the two. Finally the third part is the technology difference payment, paid in addition to the reference price for all renewables other than large scale wind. Large scale wind refers to any wind farm with an installed capacity larger than 5 MegaWatt (MW).

In Table 1 the "Guaranteed Price" is the sum of the reference price and the technology difference payment for all technologies. For renewable generators that fall within the first phase of REFIT (from now on referred to as REFIT I), the technology difference payment is paid independently of the market price.

Table 1. Level of support for renewables in REFIT I, €/MWh

	2006		2010	
	Fixed payment	**Guaranteed price**	**Fixed payment**	**Guaranteed price**
Large scale wind	All receive 15% of 57	57	All receive 15% of 66.353	66.353
Small scale wind		59		68.681
Hydro		72		83.814
Biomass -LFG		70		81.486
Biomass - other		72		83.814

Source: DCMNR (2006) and DCENR (2009)
www.dcenr.gov.ie/Energy/Sustainable+and+Renewable+Energy+Division

In 2009 the Department for Communications, Energy and Natural Resources extended the support to additional categories of renewable generation (DCENR 2009). We refer to the second phase of the scheme as REFIT II. Support prices for bio-energy were subsequently revised, raising the price level for smaller generating units and lowering it for non-CHP anaerobic digestion.

[3] The adjustment is upwards only, so guaranteed prices did not decline following the negative CPI in 2009.

Table 2. Support for renewables in REFIT II, €/MWh

	2010	
	Fixed payment	**Guaranteed price**
Off-shore wind*	All receive 15% of 66.353	140
Wave and Tidal*		220
Anaerobic Digestion CHP ≤500kW		150
Anaerobic Digestion CHP >500kW		130
Anaerobic Digestion non-CHP ≤500kW		110
Anaerobic Digestion non-CHP >500kW		100
Biomass CHP ≤1500kW		140
Biomass CHP >1500kW		120

*** Off-shore wind and wave and tidal energy support prices are not linked to CPI.**

Table 2 reports the level of support suggested for REFIT II. The payment is again made of three parts. The fixed payment is identical to REFIT I and is equal to 15% of the support per MWh given to large scale on-shore wind installations. The reference price for REFIT II is higher than the price given to any technology in REFIT I. In addition there is the technology difference payment which varies by renewable resource. The sum of reference price and the technology payment is reported in Table 2 as “Guaranteed Payment”.

There are a couple of significant differences between REFIT I and REFIT II, in addition to the different prices. First of all the guaranteed prices in REFIT II for off-shore wind, wave and tidal energy are not indexed to the CPI, so their real value decrease over time in line with inflation. Biomass support prices are indexed to CPI. In addition in REFIT I the technology difference payment is paid independently of the market price, whereas in REFIT II it is not paid if the market price is high enough.

The scheme allocates the payments through a somewhat complicated procedure. Due to historic circumstances, the money does not go directly to renewable generators, but instead to supply companies who have entered into long term contracts with the generators. In 2006 the electricity market in Ireland worked on the basis of bilateral contracts between generators and suppliers to final consumers. Generators had to put in place 15 year agreements with suppliers (called Purchasing Power Agreements or

PPAs). The payment therefore was set up to go to the companies supplying final consumers, to compensate them for the difference in cost between buying from renewable generators and buying from conventional generators. Since the advent of the Single Electricity Market (SEM) in November 2007, the Irish electricity market has moved away from bilateral contracts.

The SEM is a wholesale market that encompasses both the Republic of Ireland and Northern Ireland. It is structured as a compulsory pool market with capacity payments. All generators (with an installed capacity larger than 10MW) must bid their short run costs into the pool.[4] In general, in each period generators are ranked according to their bid and the cheapest plants needed to meet demand are dispatched. As an exception to this rule, a small number of plants have been designated priority dispatch generators, and are chosen to generate regardless of their bid. Every generator producing electricity during the period receives the bid of the marginal plant (i.e. the most expensive plant needed to meet demand). In addition generators receive capacity payments, designed to remunerate them for their capital investment and thereby cover their long run costs.

The change in market structure eliminated bilateral contracts between generators and suppliers for all generators with a capacity larger than 10MW. The REFIT program, however, still requires these bilateral contracts and is set up to compensate what is essentially now a middleman: the supplier to final consumers. The middleman is delegated to bid the power generated by the renewable generator into the pool.

In practice therefore the middleman or supplier enters into a PPA with the renewable generator, generally for 15 years, the length of time the REFIT will be paid for. The agreement specifies the amount that the supplier will pay the generator for each unit of electricity produced. Over the course of a year the generator using renewable technology r produces e^r MWhs and receives the amount per MWh negotiated in the PPA. The supplier pays the price agreed in the PPA and receives the wholesale price W_h achieved in the market in the half hour of generation, and the three components of REFIT for each MWh of e^r. The guaranteed price components of REFIT are

[4] Generators with an installed capacity smaller than 10 MW have the option of bidding in the pool or operating outside of the market with bilateral agreements.

calculated using the average wholesale price per MWh received by the supplier over the course of the year, W_{ave}.

1. $F = (0.15 \; x \; P^{REFIT_I})$

2. $ME = \begin{cases} (P^{REFIT_j} - W_{ave}) & if \quad P^{REFIT_j} > W_{ave} \\ 0 & otherwise \end{cases}$

3.a. $TD^r = \begin{cases} (G^r - P^{REFIT_I}) & if \quad P^{PPA} \geq G^r \\ (P^{PPA} - P^{REFIT_I}) & if \quad P^{REFIT_I} \leq P^{PPA} < G^r \\ 0 & if \quad P^{PPA} < P^{REFIT_I} \end{cases}$ (REFIT I)

3.b. $TD^r = \begin{cases} (G^r - W_{ave}) & if \quad P^{PPA} \geq G^r \geq W_{ave} \\ (P^{PPA} - W_{ave}) & if \quad W_{ave} \leq P^{PPA} < G^r \\ 0 & if \quad P^{PPA} < W_{ave} \end{cases}$ (REFIT II)

Equation 1 shows how the fixed payment F is calculated: P^{REFIT_I} is the REFIT I reference price, or the reference price in the first phase of REFIT. As mentioned above, the fixed payment per unit of renewable energy is independent of the market price.

Equation 2 calculates ME, the market equalisation payment: if the average wholesale market price W_{ave} is smaller than the reference price P^{REFIT_j} (where j indexes either I or II, the first and second phase respectively), the supplier receives the difference between the two prices.

Finally the technology difference payment TD^r depends on the REFIT phase. Equation 3.a. shows that for technologies that fall under REFIT I, it is independent of the market price. It only depends on P^{PPA}, the price per MWh specified in the contract between generator and supplier; G^r the relevant technology reference price for each generation type r; and the appropriate REFIT reference price. For technologies that fall under REFIT II, the technology payment also depends on the average wholesale price W_{ave}. As the market price increases, any additional payment to the supplier decreases.

The PPA price will depend on the negotiating power of the generator and the supplier. In practice it is unlikely that the PPA price would be lower than the technology-specific reference price G^r. Even when $G^r = P^{PPA}$ the supplier still receives the fixed payment and any positive difference between the market price and the guaranteed price, unless any or all of this amount is negotiated away by the generator.

Summarising, the total yearly REFIT payment paid to a supplier who has entered into PPA i with a generator using technology r can be defined as:

$$REFIT_i^r = (F + TD^r + ME)e_i^r$$

where F, ME and TD^r are described in equations 1-3 above, e_i is the amount of electricity produced under PPA i in the given year, and r indexes the technology.

The formal need for a PPA in the REFIT scheme does not affect the amount that consumers eventually have to pay, but it does influence the returns to generators. The contract terms in the PPAs will depend on their negotiating power vis-à-vis the supplier. There is evidence that some generators have set up a new company that sells exclusively to their plant in order to avoid negotiating with independent (and possibly powerful) suppliers.[5] This set up increases transaction costs (either by the cost of setting up the company or by the cost of negotiating with limited power with a supplier).

The cost of the scheme is then passed on to Irish consumers in the form of a Public Service Obligation (PSO) payment. The PSO levy is charged to all electricity customers as an additional cost in the electricity bill. The PSO is used to compensate suppliers for additional costs incurred not only as a result of supporting renewable electricity sources, but also indigenous fuels (mostly peat) (CER 2010). In this paper we limit our attention to PSO payments related to renewable sources.

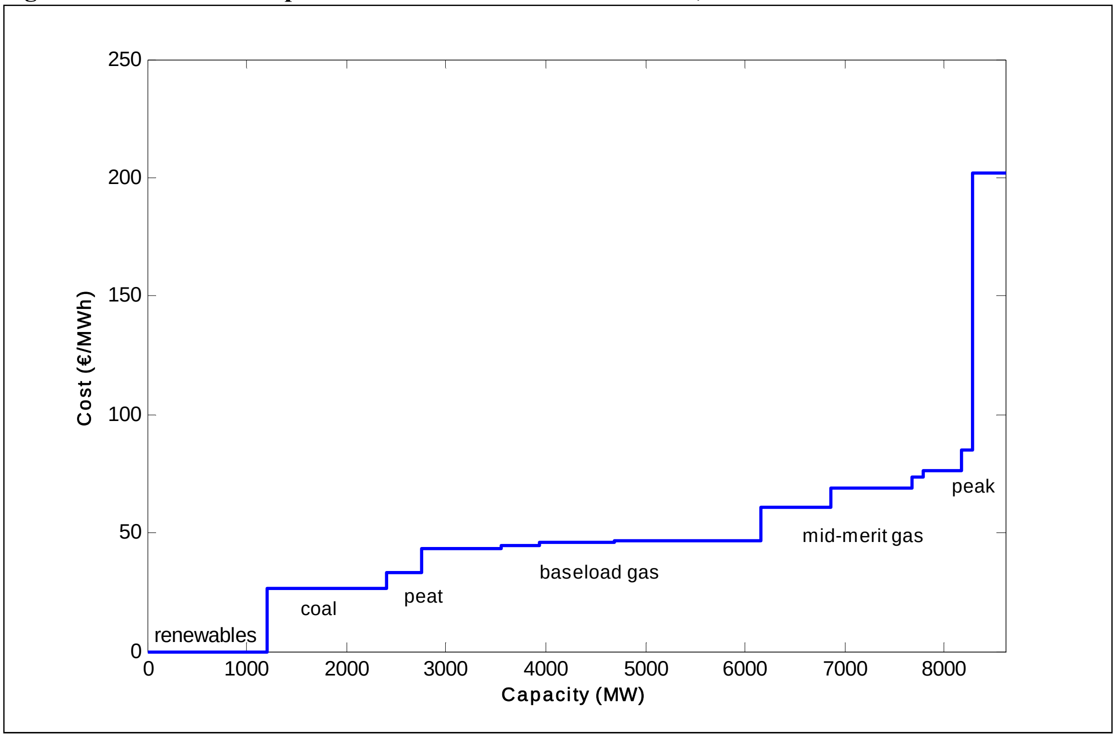
[5] The Statutory Instrument 444 of 2009 (http://www.irishstatutebook.ie/2009/en/si/0444.html) shows several instances where the generator and the supplier share very similar names. This is the case for many small scale wind farms, but also for a few large scale ones.

3. Model and assumptions

We calculate the cost of REFIT for 2020. The year 2020 is chosen because it is both far enough to allow for the deployment of significant additional infrastructure, and close enough that the majority of exiting thermal plants are expected to still be operating. Moreover, there are well-defined targets for renewable energy in 2020.

Section 2 explains why defining the wholesale electricity price in each half hour of the year is necessary to measure the total cost of REFIT. We use IDEM, the Irish optimal Dispatch of Electricity Model, to determine the wholesale price. This model stacks all the plants in the All-Island market according to their bid price in each half hour to build a merit order curve, such as the one displayed in Figure 1, which builds the merit curve for the All-Island market and reflects fuel prices at the end of 2007.[6] The merit order varies as fuel prices or the cost of carbon change. If coal becomes more expensive than natural gas, coal plants will tend to be dispatched after natural gas plants and will move to the right in Figure 1. Wind generation is assumed to have a bid price of 0, since wind itself is free. Electricity demand is exogenous, which is equivalent to saying that it does not change in response to electricity price changes.

Figure 1. Merit order dispatch curve for the island of Ireland, end of 2007



[6] At the end of 2007 the price of carbon in the EU Emissions Trading System was essentially 0.

IDEM determines the least costly way to meet demand in each half hour. The most expensive plant needed to meet demand sets the marginal price, which is paid out to all generators producing electricity during that period. The marginal price essentially reflects the cost of fuel and carbon needed to generate the last MWh of electricity.

Since wind generation is assumed to have a short run cost of 0, more wind tends to put downward pressure on electricity prices, up to a point. Wind generation is by its own nature variable. When wind dies down thermal plants (typically fuelled by natural gas or coal) must be available to pick up the slack in order to maintain a reliable electricity system. It takes several hours for a thermal plant to warm up to the point where it can generate electricity. To take this feature into account, we assume that a certain number of thermal plants must always be on at their minimum stable capacity. The number of plants that are constrained on depends on the time of the year and the level of electricity demand and is determined on a monthly basis by the model. When thermal plants are constrained on and would not otherwise have been dispatched by the market, they do not bid their marginal cost into the market; rather, they are compensated for this generation through constraint payments which equal their marginal cost, regardless of market prices. At times the need to constrain on thermal plants might also cause the curtailment of available wind generation. In this study, to avoid unrealistic cycling of the Moneypoint coal plants in the medium fuel price scenario, we force the model to adopt the same constrained-on thermal plants as in the high fuel price scenario.

Ireland is connected to Great Britain by an existing electricity cable between Northern Ireland and Scotland. In addition, contracts have been signed for the building of an East-West Interconnector between Ireland and Wales. In this study we assume that there will be a further interconnector in place by 2020, bringing the total electrical connection between Ireland and Great Britain to 1400MW. Without this additional interconnection wind generation would have to be curtailed in order to allow baseload thermal plants to run and maintain a reliable electricity system (Diffney *et al.*, 2009).

In calculating the total REFIT payments we make several simplifying assumptions. First of all we assume that all REFIT I payments go to large scale wind. Wind represents about 99 per cent of all generation in REFIT I and large scale wind accounts for about 90 per cent of wind generation.[7] Second, for REFIT II we focus on changes in off-shore wind and ocean energy capacity. Third, we avoid having to estimate the negotiating power of generators and suppliers by assuming that there is a single generator/supplier unit that receives the REFIT payment. This does not affect the REFIT cost to consumers.

These assumptions allow us to simplify the calculation of the REFIT payment system. The only prices that remain relevant are the wholesale price of electricity and the REFIT prices relevant to each technology.

The market equalisation payment from equation 2 and the technology difference payments described in equations 3.a and 3.b in section 2 can be combined into one equation:

$$4.\ GPay^r = \begin{cases} (G^r - W_{ave}) \cdot e^r & if \quad G^r \geq W_{ave} \\ 0 & otherwise \end{cases}$$

$GPay^r$ is the guaranteed payment to technology r, and the wholesale price per MWh for half-hour h, W_h, is defined as follows:

$$5.\ W_h = SMP_h + CapPay_h + ConstrPay_h$$

SMP is the System Marginal Price, determined in the pool market. *CapPay* represents Capacity payments to renewable generation, based on the amount of electricity generated by these plants. Additionally, if wind or wave generators are curtailed at any time (for example to allow thermal plants to continue generating at their minimum stable capacity) they receive constraint payments *ConstrPay*, based on the amount they would have generated had they not been constrained.

The total cost of REFIT depends on many factors, but the most prominent are the actual amount of renewables on the system, and the price of fossil fuels and carbon dioxide permits. To evaluate the cost of REFIT to final consumers we consider two different levels of wind penetration on the Island of Ireland for the year 2020: 2000MW or 6000MW of wind. 2000MW of on-shore wind are likely to be reached

[7] Volumes are calculated on the basis of the description of renewable generators in Schedule 3 of the Statutory Instrument 444 of 2009 (http://www.irishstatutebook.ie/2009/en/si/0444.html).

without any further incentives, so this scenario can be interpreted as a baseline. 6000MW of wind are likely to be sufficient to meet the target of generating 40 per cent of all electricity from renewable sources, as set out in DCMNR (2007) and modified by the Carbon Budget (DEHLG, 2009). In addition, we analyse a scenario using the wind, wave and tidal generation portfolio outlined in Ireland's National Renewable Energy Action Plan (NREAP, 2010). The plan suggests generation capacity for Ireland (excluding Northern Ireland) of 4094MW of on-shore wind, 555MW of off-shore wind, and 75MW wave capacity. For this study, we increase on-shore wind capacity in Northern Ireland proportionately to increases in Ireland, after the horizon of the Eirgrid Generation Adequacy Report (Eirgrid 2009). Including this on-shore wind capacity for Northern Ireland increases total on-shore wind capacity in this scenario to 6034MW. We abstract from payments to small scale wind, biomass and hydro in 2020. This is clearly a simplification, although the effect of these renewable technologies on REFIT payments is likely to be much smaller than the combined effect of wind and ocean energy.[8]

Table 3 summarises the assumptions for the different scenarios in 2020, distinguishing between the amount of renewables on the island as a whole and in the Republic of Ireland.

Table 3. Renewable scenarios, installed capacity (MW) in 2020

	All-Island on-shore wind	Rep. of Ireland on-shore wind	Rep. of Ireland off-shore wind	Rep. of Ireland Wave & Tidal
1. Low wind	2000	1357	--	--
2. High wind	6000	4071	--	--
3. High mixed renewables	6034	4094	555	75

The installed capacity reported in Table 3 includes the capacity of windfarms that fall under a previous AER scheme, although the AER capacity is excluded from the calculation of REFIT payments. The AER supported 532MW of investment in wind power. Towards the end of 2009 there were 1167MW of wind in the Republic of

[8] There is little additional development expected in future years for hydro generation. Biomass generation on the other hand may increase significantly over time, especially if more fossil-fuelled plants move to cofiring with biomass. However, the scale of biomass penetration is likely to be much smaller than wind in Ireland.

Ireland, 237MW of hydro (most of it installed decades ago) and 34MW of biomass capacity (EirGrid 2009).

We assume that electricity demand growth in the Republic of Ireland averages 0.8 per cent per year, in line with the World Recovery scenario from Bergin *et al.* (2009).

Table 4 outlines the assumptions on fuel prices. We report the price of oil mainly for reference purposes. Its level has limited direct effect on the Irish electricity system, but we assume that the price of natural gas is linked to oil prices. Most of the Irish plants run on natural gas (in 2008 it fuelled 55 per cent of generation; see SEI, 2009). The price of coal is less volatile and we assume it is constant across the different fuel scenarios.

Table 4. Fuel price assumptions for 2020, measured in 2008 currency

	Low fuel price	Medium fuel price	High fuel price
Oil ($/barrel)	57	87	107
Natural gas (€/MWh)	17	26	32
Coal (€/MWh)	10.2	10.2	10.2

The cost of carbon dioxide permits traded in the European Union Emissions Trading Scheme is set at €30/tonne of CO_2, measured in 2008 currency.

We assume that on-shore wind has an average (ex-ante) load factor of 33 per cent at installed capacity of 2000MW (1357MW in the Republic of Ireland, referred to as ROI from now on). This is equivalent to saying that it can achieve electricity output in line with its stated capacity about a third of the time during a year. This load factor reduces to 30% at 6000MW (4071MW ROI) as optimal windfarm locations are used. The load factor for off-shore wind is set at 35 per cent reflecting the fact that wind tends to blow more off-shore. The same factor of 35 per cent is set for wave and tidal. The historic wind profile for Ireland for 2008 is used to simulate wind generation in this study. Over 2005 to 2008, the wind load has varied between 29 per cent and 33 per cent (EirGrid 2009). We normalise the wind profile to have a 31 per cent load.

For lack of better data on the load curves of off-shore wind, wave and tidal, we assume that on-shore wind, off-shore wind and wave and tidal are perfectly correlated, so that when on-shore wind dies down, so do the other options. If we allowed off-shore wind, wave and tidal to generate electricity at different times than on-shore wind, we would expect a slightly lower system marginal price in the market with the 'mixed renewables' option. This would be potentially accompanied by somewhat higher REFIT payments if curtailment of renewable generation were more limited. The net effect is uncertain, but we do not expect it to deviate significantly from the numbers presented here.

We assume an inflation rate of 2 per cent per year going forward. An assumption on inflation is necessary to determine the guaranteed price that applies to REFIT II renewables in 2020.

Table 5. Level of support in 2020, measured in 2020 and 2008 prices, €/MWh

REFIT II Guaranteed price	2020 prices	2008 prices
Off-shore wind	140	108.2
Wave & Tidal	220	170.0

4. Results

The cost of REFIT is calculated for all the wind, wave and tidal renewables installed in the Republic of Ireland. Renewable generation located in Northern Ireland provides electricity within the same All-Island market, but is subject to a separate renewable support scheme.[9]

Table 6 shows how REFIT affects the cost of electricity in 2020 when fuel prices are at their medium level (corresponding to €26/MWh for natural gas in 2008 currency). It compares the cost of the REFIT scheme for three different scenarios. In the first column there are 2000MW of wind island-wide, of which 1357MW in the Republic of Ireland. Of these 1357MW, 825MW are supported through the REFIT scheme (the remaining 532MW fall under the previous AER scheme). The second column reports the case where there are 6000MW of on-shore wind on an all island basis, of which 4071MW in the Republic of Ireland (3539MW in REFIT). Finally the last set of four

[9] Renewables in Northern Ireland are supported by NIRO (Northern Ireland Renewable Obligations), which is tied to the system of Renewable Obligation Certificates in Great Britain.

columns disaggregates the cost of having a mixed portfolio of renewables by renewable technology. In this case there are 6664MW of renewables on the island as a whole and 4724MW in the Republic of Ireland. REFIT supports 3562MW of the 4094MW of on-shore wind in this scenario. Fixed payments for the amount of capacity subject to REFIT are calculated as shown in Equation 1. The payments that depend on guaranteed prices are calculated as shown in Equation 4 and summed over the different existing technologies.

Not surprisingly, as more renewables get on the system their cost in terms of REFIT increases. Note that the REFIT cost increases a bit less than the increase in installed capacity. When a lot of wind is deployed, a small proportion of it is curtailed to allow a few thermal plants to generate and therefore maintain reliability of the system.

Table 6. REFIT costs in 2020 (€ million, 2008 currency), medium fuel price

	All on-shore		**Mixed portfolio**			
All-Island capacity	**2000MW**	**6000MW**	**6664MW**			
ROI capacity	**1357MW**	**4071MW**	**On-shore (4094MW)**	**Off-shore (555MW)**	**Wave & Tidal (75MW)**	**Total**
REFIT capacity	825MW	3539MW	3562MW	555MW	75MW	
Fixed payment	22.8	88.0	90.0	15.8	2.1	108.0
Guaranteed price payment	-	42.0	-	73.4	23.8	115.1
Total	22.8	130.0	90	89.2	25.9	205.2
Total: €/MWh consumed	0.74	4.25	2.94	2.92	0.85	6.70

For medium fuel prices, on-shore wind receives the bulk of its REFIT compensation from the fixed payment portion of the scheme. The guaranteed price is often below the estimated market price, contributing very little to on-shore wind compensation. Also note that as more wind is deployed, the average price of electricity decreases. Wind has very low variable costs of electricity generation, due to wind being free in and of itself. This means that when more wind generation is available, it displaces more expensive thermal power and therefore on average decreases the cost of electricity in each half hour. Off-shore wind, wave and tidal receive a far greater proportion of their compensation from the guaranteed price portion of the scheme.

Table 7. REFIT costs in 2020 (€ million, 2008 currency), low fuel price

	All on-shore		Mixed portfolio			
All-Island capacity	**2000MW**	**6000MW**	**6664MW**			
ROI capacity	**1357MW**	**4071MW**	**On-shore (4094MW)**	**Off-shore (555MW)**	**Wave & Tidal (75MW)**	**Total**
REFIT capacity	825MW	3539MW	3562MW	555MW	75MW	
Fixed payment	22.8	87.4	89.9	15.8	2.1	107.9
Guaranteed price payment	26.4	123.9	123.7	95.3	26.7	245.7
Total	49.2	211.3	213.7	111.1	28.8	353.6
Total: €/MWh consumed	1.61	6.90	6.98	3.63	0.94	11.55

When the price of fuel decreases, the price of electricity in the Single Electricity Market also decreases and the cost of REFIT increases for all options, as shown in Table 7.

Conversely when the fuel price increases, the cost of REFIT decreases, although because of the effect of the fixed payment, the reduction is less than proportional to the increase in the SMP. The exception is the case with low wind generation capacity installed; here the low levels of 'free' wind generation do not reduce SMP sufficiently to require any guaranteed price payment, even in the medium fuel price scenario. The only REFIT contribution is the fixed payment, so a move to higher fuel prices does not change the overall REFIT cost. With high fuel prices most of the cost is due to the fixed payment component of the REFIT scheme, as shown in Table 8. This also suggests that the hedging properties of renewables are somewhat dampened by the REFIT scheme.

Table 8. REFIT costs in 2020 (€ million, 2008 currency), high fuel price

	All on-shore		Mixed portfolio			
All-Island capacity	**2000MW**	**6000MW**	**6664MW**			
ROI capacity	**1357MW**	**4071MW**	**On-shore (4094MW)**	**Off-shore (555MW)**	**Wave & Tidal (75MW)**	**Total**
REFIT capacity	825MW	3539MW	3562MW	555MW	75MW	
Fixed payment	22.8	88.0	90.0	15.8	2.1	108.0
Guaranteed price payment	-	-	-	60.5	22.0	82.6
Total	22.8	88.0	90.0	76.4	24.2	190.6
Total: €/MWh consumed	0.74	2.87	2.94	2.50	0.79	6.23

One interesting point to make here, that we will return to later, is that wave and tidal account less than 2 per cent of total renewable generation capacity, but are responsible for between 8 and 13 per cent of the total PSO cost. They receive an average yearly payment per MW of installed capacity equal to €385 thousand when fuel prices are high, €345 thousand with medium fuel prices and €322 thousand when fuel prices are low.

We have shown how different levels of renewable energy influence the REFIT payment. In the following paragraphs we discuss how the REFIT payments affect consumer prices. We compare the size of REFIT per MWh consumed with the wholesale cost of electricity.

The gross wholesale price is composed of the System Marginal Price (SMP), capacity payments, possible constraint payments, plus uplift and balancing costs. We do not model the uplift and balancing payments, but assume that they will average €8 per MWh (see MMU, 2009). The constraint payment here refers to payment given to renewables (wind and wave) if they are curtailed, and to thermal plants should they be constrained on to avoid cycling.

As mentioned earlier, the REFIT payment is eventually funded by consumers through the PSO payment. The PSO payment is calculated here as the total REFIT payment divided by the amount of MWhs consumed during the year. This closely approximates the actual calculation of the PSO, which apportions a slightly higher share of REFIT costs to the residential sector and a slightly smaller one to the non-residential sector.

Table 9. 2020 average wholesale electricity price (all island) €/MWh, 2008 currency.

	All on-shore (4071MW, of which 3539MW REFIT)		
	Low fuel price	**Med. fuel price**	**High fuel price**
SMP	45.1	56.8	64.0
Capacity & Constraint payments	15.0	18.7	17.5
Uplift and balancing costs	8.0	8.0	8.0
Total gross wholesale	68.1	83.5	89.5
REFIT PSO	6.90	4.25	2.87
PSO as % gross wholesale	9.8%	5.1%	3.2%

Table 9 analyses the size of PSO payments with respect to the average yearly gross wholesale price for 2020 when there are 6000MW of on-shore wind on the island as a whole and 4071MW of on-shore wind in the Republic of Ireland.

Table 9 shows that as the fuel prices increase, the cost of REFIT decreases, as expected. When moving from low to medium fuel price, the price of natural gas (the fuel that is most important in the Irish electricity system) increases by 53 per cent and the PSO cost decreases by about 48 per cent. When moving from medium to high fuel price the cost of natural gas increases by 23 per cent and total PSO cost decreases by about 37 per cent. We don’t expect the cost of the PSO to decrease linearly with the increase in fuel costs for several reasons. First of all, the electricity half hourly cost is determined by the merit order and this involves a calculation that is inherently non-linear. Second, the REFIT scheme itself is non-linear due to the fixed payment component. The last row of Table 9 measures the size of the PSO relative to wholesale costs. When fuel prices are low the PSO is 9.8 per cent of gross wholesale prices. This decreases to 5.1 per cent with medium fuel prices and 3.2 per cent with low fuel prices.

Table 10. 2020 average wholesale electricity price (all island) €/MWh, 2008 currency.

	All on-shore (1357MW, of which 825MW REFIT)		
	Low fuel price	**Med. fuel price**	**High fuel price**
SMP	46.4	59.8	69.1
Capacity & Constraint payments	16.0	19.5	17.4
Uplift and balancing costs	8.0	8.0	8.0
Total wholesale	70.5	87.4	94.5
REFIT PSO	1.61	0.74	0.74
PSO as % gross wholesale	2.3%	0.9%	0.8%

Table 10 describes the size of the PSO payment in the scenario with 2000MW of wind on the island (and 1357 MW in the Republic of Ireland). The size of the PSO payment decreases as expected. The PSO is between 0.8 per cent of gross wholesale cost (high fuel price) and 2.3 per cent (low fuel price).

Table 11 shows that PSO costs increases when the renewables are both on-shore and off-shore. This is hardly surprising given the higher guaranteed payments to off-shore renewable. For this scenario, the PSO is between 6.8 per cent and 17.2 per cent of the gross wholesale price, depending on the fuel price level.

Table 11. 2020 average wholesale electricity price (all island) €/MWh, 2008 currency.

	Mixed portfolio (on-shore, off-shore wind, wave and tidal)		
	Low fuel price	**Med. fuel price**	**High fuel price**
SMP	44.3	57.4	65.9
Capacity & Constraint payments	14.8	18.8	18.0
Uplift and balancing costs	8.0	8.0	8.0
Total gross wholesale	67.1	84.2	91.9
REFIT PSO	11.55	6.70	6.23
PSO as % gross wholesale	17.2%	8.0%	6.8%

The absolute size of the scheme might be politically relevant, in part due to the current financial constraints facing Ireland. The appendix includes the detailed breakdown of the calculation of total wholesale costs and how they compare to total REFIT costs. Table 12 summarises the overall cost of REFIT for all scenarios.
Table 12 also allows us to compare the PSO costs of an on-shore only portfolio with a similar portfolio including off-shore wind, wave and tidal generation. The move to a mixed portfolio results in an increase in the PSO cost of 67 per cent when fuel prices are low, 58 per cent with medium fuel prices and 117 per cent with high fuel prices. This is due to the much higher guaranteed price for off-shore and wave generators.

The large relative increase in the PSO when moving to more off-shore renewable generation does, however, cause a few concerns. If off-shore wind is successful and adopted at high rates, it will become quite expensive for the final consumer. This is before accounting for the cost of undersea cables, necessary to connect off-shore resources to the main grid. There are no consensus estimates for the cost of off-shore cables, but they are likely to be much larger than on-shore cables. Wave and tidal are not mature technologies. They have not been deployed at a large commercial scale yet. The results presented in Table 11 show that sustaining these technologies through REFIT has a relatively large impact on consumers. At the same time the REFIT payment is unlikely to foster the development of this technology. For each MW of installed wave or tidal renewable generation, companies receive €322 thousand to

€385 thousand per year from REFIT, as discussed above. For comparison, the Wave Hub project in Cornwall (UK) has cost up to now about £42 million (about €48 million at current exchange rates) for a capacity of 20MW.[10] In general, tying funding to generation is not optimal at the development phase of a technology, since the trial projects are going to produce very little electricity.

Table 12. REFIT PSO total payment in 2020, €, 2008 currency.

	Low fuel price	Med. fuel price	High fuel price
All on-shore (1357 MW, of which 825MW REFIT)	49m	23m	23m
All on-shore (4071 MW, of which 3539MW REFIT)	211m	130m	88m
Mixed portfolio (on-shore and off-shore wind, wave and tidal – 4724 MW, of which 4192MW REFIT)	354m	205m	191m

It would be interesting to measure how REFIT affects final retail prices, but that is beyond the scope of the current paper. It would involve estimating the costs of the additional electricity transmission and distribution lines needed to accommodate the amount of renewable in each scenario and the size of the retail margin.[11] The cost of undersea cables needed to connect off-shore wind farms, wave and tidal generation to the grid is undoubtedly large, but still uncertain. There is also uncertainty on the size of the retail margin in Ireland, which will depend on the number of players in the retail sector and on its level of regulation, issues that are beyond the scope of this paper.

We can however measure the historic relation between wholesale and final retail prices. In Ireland in 2008 wholesale costs (including capacity payments, uplift and dispatch balancing costs) accounted for slightly less than 60 per cent of the final

[10] Numbers reported in www.oceanpowermagazine.net/2010/11/05/wave-hub-%E2%80%98plugged-in%E2%80%99-and-open-for-business/

[11] The retail margin is added to the wholesale cost of electricity by the company that provides the electricity meters and the billing services.

residential cost of electricity and about 80 per cent of the final industrial cost in the Republic of Ireland.[12]

Using these wholesale to retail price shares and the size of the PSO measured in the presence of a mixed renewable portfolio as shown in Table 11, the PSO would be between 4.1 per cent and 10.3 per cent of the final retail electricity price for the residential sector and between 5.4 per cent and 13.7 per cent for industry.

5. Conclusion

In this paper we have estimated the cost of REFIT, the Irish renewables support scheme, for the year 2020. We have compared the cost of REFIT for three levels of renewable generation. Fuel prices are historically very volatile, so we have also evaluated the sensitivity of the results to different fuel price levels.

The REFIT payment to renewable generation includes a fixed component and a minimum price guarantee. The fixed component is paid any time generators produce electricity and is independent of the return that generators achieve on the market. The guaranteed price component is only paid if the generators do not receive a high enough price (i.e. the guaranteed price level) on the market.

A few studies have shown that wind generation may have hedging qualities. When fuel prices are high, wind generation dampens the price of electricity. When fuel prices are low, the price of electricity is going to be a bit larger when more wind is on the system (if the capital costs of wind are to be covered). This is true in this study as well. The REFIT scheme, however, dampens the hedging qualities of wind slightly, due to the presence of fixed payments. Fixed payments essentially increase the cost of renewables on the system independent of the price of conventional fuels.

Adding more wind to the electricity system is not costless. The introduction of large amounts of intermittent generating capacity on the Irish system imposes costs in the form of curtailing wind generators at times where too much wind energy would be

[12] Final industrial and residential costs for the Republic of Ireland come from IEA (2009). The estimate of the cost of electricity in the SEM is reported in MMU (2009).

generated to allow a stable system and also of more fluctuations in the output of conventional thermal plants. Increasing wind generation also increases the need for more transmission and distribution lines. Moreover, if there is a lot of wind on the system the price of electricity will be lower when the wind blows. This means that returns to wind generators will get lower as more wind generation is established. We take into account the curtailment costs of wind in this study, but not the costs of transmission and distribution and the effects of lower electricity prices on wind generators' returns to investment. In general, this means that as more windfarms are connected to the grid they will decrease the average generation (and returns) of previously existing windfarms. This is what is normally referred to as a 'negative externality'. Each single windfarm will therefore have a higher incentive to start producing than the benefit it brings to the system as a whole

We find that when there are only 2000MW of wind on the All-Island system, the price of REFIT is fairly small, between 0.8 per cent and 2.3 per cent of the wholesale electricity price. When there are 6000MW of wind, a level that is consistent with reaching the goal of meeting 40 per cent of electricity demand through renewables, REFIT costs between 3.2 per cent and 9.8 per cent of the gross wholesale price. It is important to note that the wholesale price itself decreases with more renewables, by about 5 per cent when fuel prices are high. These costs are approximately between 2 per cent and 6 per cent of residential retail prices. They are between 2.5 per cent and 8 per cent of business retail prices, since the wholesale price of electricity is a larger share of the final retail price for businesses than for residential customers. Note that we expect transmission and distribution costs to also increase in 2020, and the costs will be higher the more renewables are on the system. As mentioned above, we do not estimate the cost of additional distribution and transmission lines in this study

Combining on-shore, off-shore, wave and tidal generation significantly increases REFIT costs over an on-shore only portfolio. The analysis in this paper excluded the costs of reinforcing and expanding the transmission and distribution grid. There are no consensus estimates for the cost of off-shore cables, but they are likely to be much larger than on-shore cables, further increasing the differences between the on-shore and the off-shore scenarios.

We argue therefore that if Ireland is able to meet its renewables obligations using only on-shore wind, it is the least costly solution for final consumers. If, on the other hand, on-shore wind will not deliver enough capacity to meet the State's international obligations, there will be a need to turn to off-shore sources of electricity.

In general, if off-shore wind is deployed widely, its costs are going to be high for the Irish consumer. At the same time, it appears unlikely that the electricity system will be able to accommodate much additional off-shore wind at low cost. There has been much discussion recently of developing Ireland's off-shore electricity resources for export. This may well be optimal from a European (and specifically UK) point of view, if it is cheaper to develop these resources in Ireland than in the UK. However, it is clear that Irish consumers should not be called to fund and guarantee this business venture.

For wave and tidal, the usefulness of a REFIT scheme is even less clear. Those technologies are not at a deployment level yet. This means that a scheme such as REFIT is not sufficient to encourage research and development in the area. Instead, a competitive process of research grants should be set up to fund this type of development. A competitive grant scheme would allow more research and not weigh too heavily on consumers and businesses. It would also have the advantage of capping liabilities for the taxpayers (or consumers) who are ultimately going to fund it.

Finally, the fixed portion of the REFIT payment is a pure subsidy, not linked to market conditions. As it is set up, this element of the REFIT scheme dampens the hedging quality of wind generation and adds to the cost to final consumers. It should therefore be eliminated, leaving REFIT as a pure price guarantee scheme.

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Appendix

Table A.1. 2020 total wholesale electricity price (ROI), €, 2008 currency

	All on-shore (4071MW, of which 3539MW REFIT)		
	Low fuel price	**Med. fuel price**	**High fuel price**
SMP	1379m	1739m	1959m
Capacity & Constraint payments	460m	573m	537m
Uplift and balancing costs (12.8% of SMP)	245m	245m	245m
Total gross wholesale	2084m	2557m	2741m
REFIT PSO	211m	130m	88m

Table A.2. 2020 total wholesale electricity price (ROI), €, 2008 currency.

	All on-shore (1357MW, of which 825MW REFIT)		
	Low fuel price	**Med. fuel price**	**High fuel price**
SMP	1422m	1832m	2116m
Capacity & Constraint payments	490m	598m	531m
Uplift and balancing costs (12.8% of SMP)	245m	245m	245m
Total wholesale	2157m	2674m	2892m
REFIT PSO	49m	23m	23m

Table A.3. 2020 total wholesale electricity price (ROI), €, 2008 currency.

	Mixed portfolio (on-shore, off-shore wind, wave and tidal)		
	Low fuel price	**Med. fuel price**	**High fuel price**
SMP	1355m	1757m	2018m
Capacity & Constraint payments	454m	575m	552m
Uplift and balancing costs (12.8% of SMP)	245m	245m	245m
Total gross wholesale	2054m	2577m	2815m
REFIT PSO	354m	205m	191m

Year	Number	Title/Author(s) ESRI Authors/Co-authors *Italicised*
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