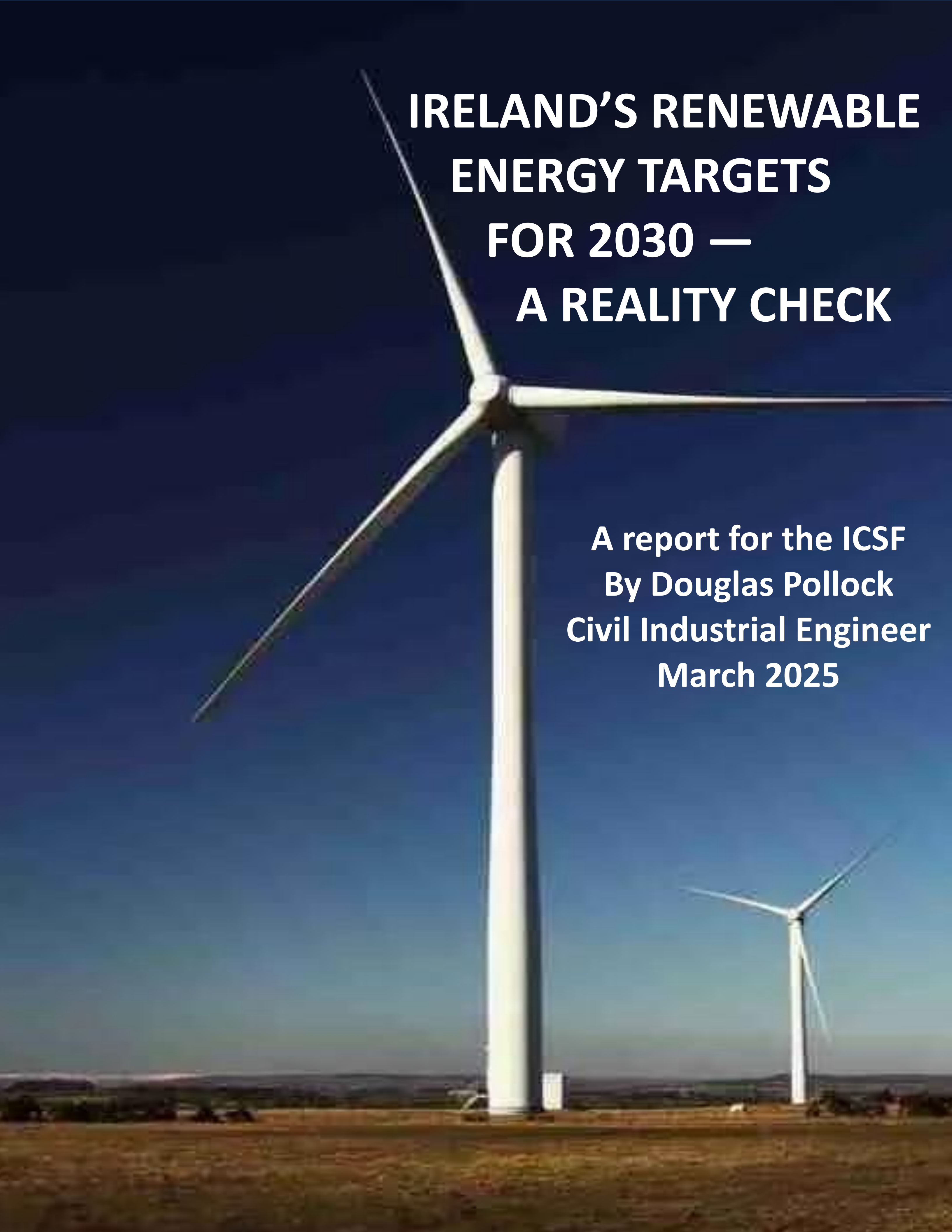

IRELAND’S RENEWABLE ENERGY TARGETS FOR 2030 — A REALITY CHECK

A report for the ICSF
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March 2025

Ireland's Renewable Energy Targets for 2030 - A Reality Check

Non-technical summary

It is surprising that nobody appears to have carried out a critical study of the engineering and economic implications of operating a very high level of renewable energy generation on the Irish electricity grid as envisaged under the latest Climate Action Plan. The popular perception is that renewables would lower prices to customers, but this brief technical paper demonstrates the case to be unfortunately quite the opposite.

The Irish Climate Science Forum (ICSF) has commissioned this Report, "*Ireland's Renewable Energy Targets for 2030 – A Reality Check*", by Mr. Douglas Pollock, an international expert on power supply to electricity grids in the presence of renewable generation. In essence, the Report finds that quadrupling the current level of renewable capacity on Ireland's electricity grid by 2030 would lead to consumer electricity costs rising by two to five times, depending on the scenario, the costs already being amongst the highest in Europe.

The Report also indicates that the aspired level of 80% renewable energy being fed onto the grid by 2030 is not feasible and that the desired reduction in CO_2 emissions will be significantly less than hoped for under the Climate Action Plan. Therefore the entire logic of aiming for such a high level of renewable generation is called into question on both engineering and economic grounds.

This reality check therefore suggests that Ireland's renewable energy ambitions for 2030 should be pragmatically reviewed to avoid serious negative engineering and economic consequences. As a corollary, a pragmatic policy of rebalancing towards conventional generation is suggested, which for the coming decades is likely to be gas-fired complemented by essential back-up gas storage.

Note on the ICSF:
Founded in 2016, the Irish Climate Science Forum (www.ICSF.ie) is an independent think-tank which promotes realism in climate science and pragmatism in energy policy in the best long-term national interest. The ICSF is entirely self-funded, without any vested interests or political affiliations. ICSF now cooperates with world-leading multi-disciplinary climate/energy professionals in more than 30 countries through the Netherlands-based CLINTEL think-tank (www.CLINTEL.org).

Note on the Author:
Douglas Pollock is an Industrial Civil Engineer who graduated from the University of Chile. He has a long experience in analyzing how electrical grids are affected under high levels of renewables, both in cost and emissions. His valuable work in analyzing the Irish Climate Action Plan ambitions is much appreciated by the ICSF. His Report was reviewed by a series of energy experts across Europe and in the USA and its key conclusions have their unanimous approval.

Content

Ireland's Renewable Energy Targets for 2030 – A Reality Check

I. Introduction

Promoters of non-conventional renewable energies (NCRE or renewables) usually argue that, by adding electricity from these sources into a power grid in replacement of fossil fuel-based generation, electricity prices should drop over time since sun and wind energies are free, their fuel costs are therefore zero and because the investment costs of these technologies have sharply declined over the last decade. Likewise, CO_2 emissions should drop also because renewables don't burn fossil fuels.

Although true, these statements may lead to false conclusions because they assume renewables to be isolated entities that don't affect the operation (operating heat rates and, thus, CO_2 output emission rates) of other generation sources involved in a power grid. Therefore, these conclusions are insufficient to explain how the grid (or full) cost of electricity (FCOE) and CO_2 emissions will change when increasing the renewable generation fraction in such an interconnected system.

What actually takes place when increasing the renewable penetration is that, given the need of backup from thermal sources due to the natural intermittencies of renewables, operational inefficiencies arise in thermal generation, causing the unit fuel consumption (operating heat rate) to rise and hence the unit fuel cost, and, consequently, the CO_2 output emission rate also increases. The fixed thermal generation costs also rise because they are increasingly being distributed across a lesser amount of generation. Therefore, on top of the effect of the renewable levelized cost of electricity (LCOE) progressively increasing as the renewable generation fraction escalates, the full cost of electricity inevitably increases regardless of any improvements from renewables, such as a reduction in their investment costs or by achieving higher capacity factors.

The facts show that there is no country in Europe (or in the world) where electricity bills fall as the renewable share increases. Figure 1 shows a sample of six European nations [1]. Ireland became the most expensive EU country for domestic electricity in 2023/24 (Eurostat data).

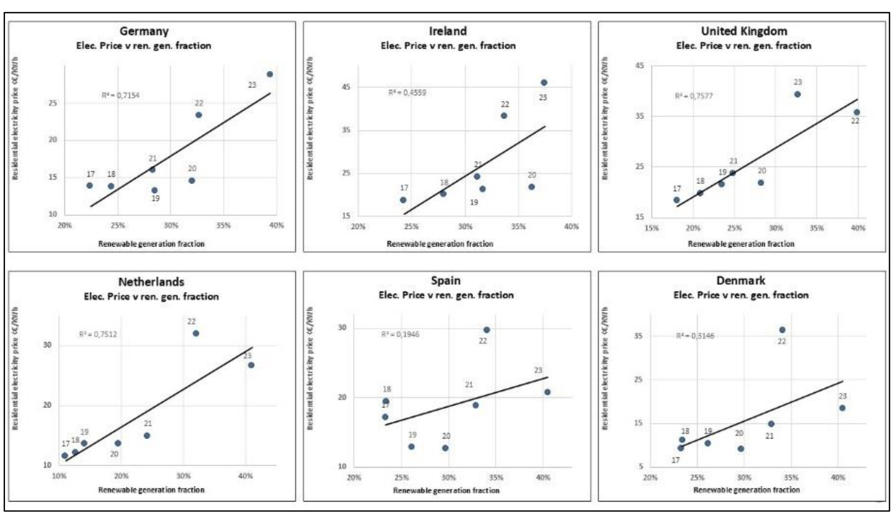

Figure 1: Domestic electricity price in six European nations correlated with their renewable generation share. The number labels are years (e.g., 18 means the data for 2018).

Supposedly, CO_2 emissions should drop as renewable generation increases because of a proportional reduction in thermal generation. However, this will depend on whether or not that reduction is capable of offsetting the increase in the CO_2 output emission rate derived, in turn, from an increasingly inefficient non-baseload thermal generation required to back up these intermittent sources. In ideal (i.e. most efficient) grids, where natural gas generation alone, mainly in combined cycle gas turbines (CCGT), is used as backup, a slight reduction in CO_2 emissions will be attainable, while making electricity progressively expensive, thus making renewables economically ineffective for this purpose. However, in real-world grids where simple-cycle gas turbines (SCGT) as well as oil are also used to back up renewables, the associated higher CO_2 output emission rates will cancel the benefit of thermal generation reduction, and cause overall CO_2 emissions to rise significantly, hence, making renewable technologies an irrational solution for the same purpose

Finally, the situation is severely aggravated when a fundamental limit of renewables is exceeded. This limit is determined when the installed renewable capacity matches the mean hourly demand. Above that point an exponential loss of electricity generation capacity will begin, while dispatched electricity into the grid will follow an exponential decay. The same will happen with CO_2 emissions abatement.

The following techno-economic analysis aims to estimate the order of magnitude of changes in electricity costs and CO_2 emissions in the Republic of Ireland if its power grid were to be subjected to an increasing share of wind and solar generation capacity, as contemplated in the Irish Climate Action Plan 2024.

II. Technical summary

Ireland's Climate Action Plan 2024 (CAP24) expects to increase solar and wind generation capacity from current 5.34 GW (2023) to 22 GW by 2030, which capacity would be divided into 9 GW onshore wind turbines, 5 GW offshore and 8 GW photovoltaic solar panels. This investment, estimated at over US$ 30 billion [2] [3] [4] (excluding grid upgrades), aims to achieve an 80% renewable generation fraction while increasing electricity generation by 25%, while reducing CO_2 emissions by 10 million tons and aspiring to making Ireland more independent of fossil fuels purchased abroad. **Note**: "tons" refers to metric tons throughout the document.

This paper presents preliminary results which, based on 2023 Irish electricity generation (imports excluded) and renewable installed capacity, have been estimated for two scenarios, ideal and realistic. The ideal scenario considers the use of gas-fired generation only, mainly in combined cycle gas turbines (CCGT), for renewables' thermal backup. The realistic scenario considers the use, to a greater degree, of other technologies and/or fuels for backup, such as simple cycle gas turbines (SCGT) and oil. For this purpose, it is necessary to have data on parameters not available in Ireland, such as the natural gas operating heat rate under the current renewable generation fraction and natural gas generation divided into base and non-baseload. This is why they will be compared with those of the US. Thus, results of Ireland's realistic scenario could be better or worse depending on whether the Irish grid is more or less efficient than that of the US. However, it is highly likely that these are close to the realistic scenario, which is the case of the US, since Ireland has a high level of gas generation (15,710 GWh or 50% of total generation in 2023) and a low level of oil-based generation, the other suitable source for backup. The key will then lie in the intensity of the use of CCGT (more efficient) or SCGT (less efficient but more flexible) power plants for the necessary thermal backup.

Ireland has already exceeded the limit above which renewable energy begins to be lost. That loss is currently near 11% [5] of its renewable generation capacity and an excess renewable capacity of 1.49 times the average hourly demand. The actual weighted capacity factor (Z) for renewables is currently 0.25 having achieved a renewable generation fraction of 37.5%. Without renewable energy loss (when the installed capacity is equal to or lower than the mean hourly demand, or equivalently, when the renewable generation fraction is equal to or lower than the weighted average capacity factor) the value for *Z* would be 0.28. Under the Irish expansion plan, solar capacity (the worst of all for Ireland since that technology has only exhibited a capacity factor of 0.09 to 0.11 since 2017) would go from the current 0.54 GW to 8 GW, making the new weighted capacity factor drop to 0.24 by 2030.

The above-described facts would imply that Ireland's weighted capacity factor *Z*, which has already fallen from 0.28 to 0.25, would drop to a weighted *Z* of 0.07 by 2030 and a loss of solar and wind generation capacity of 70%. Exports are generally not a viable option, either technically or commercially (as has been experienced in other European countries already).

This, together with the increase in the unit fuel consumption for backup, is what ultimately causes renewable and thermal LCOE, as well as the FCOE, to significantly rise.

For a realistic scenario, it is expected that the natural gas-based generation LCOE would increase by 12%, the renewable LCOE by near 345% and the FCOE by 97%. The renewable share of generation in the Irish grid would reach only 44.6%, well below the aspired 80%.

However, beyond the negative consequences that the above, by itself, would cause to the Irish economy, if the system were to pay for curtailment, constraint orders and capacity payments to both renewable and backup generators, then, by using the same rates as in the UK which in 2023 paid £1.5bn for 5 TWh of curtailment and constraint orders [6] [7], the Irish FCOE would increase by almost 430%. Whatever the rate applied could be, if the ever-increasing curtailed electricity was not paid, bankruptcies of renewable facilities would take place long before the 22 GW target is met.

Assuming that coal and oil-fired generation were completely phased out by 2030, CO_2 emissions would fall by just under 2.5 million tons, only 25% of the 10-million-ton abatement target, 6.8% with respect Ireland's 2023 emissions [8], ≈0% with respect global emissions and well below Paris and EU net-zero commitments. Thus, Ireland's power sector 2030 mitigation target will not be met.

Finally, with the necessary dependence on fossil fuels to back up renewables, Ireland would be negligibly closer to independence from imported fossil fuels, as stated in CAP24, since, by more than quadrupling its renewable capacity, it will have reduced its fossil-based generation by only 7.1%. And if Ireland were to achieve net-zero emissions with a marginal contribution from renewables, using the official figures of the IPCC, it would prevent the planet from warming by only 0.00009 °C by 2050 at a cost of 20 times its GDP.

III. Cost of electricity and renewables: background

1. Isolated versus integrated system

Advocates of renewables usually refer to the concept of levelized cost of electricity (LCOE) to try to *prove* that renewables are cheaper than thermal generation sources. This may well be true at present, like in Ireland, given the high fuel costs and because sourcing for the renewable industry has moved to China, causing its investment costs to fall. Besides, the LCOE is also useful for comparing cost variables within and between technologies because it uses common units. Therefore, it becomes easy to think that, by adding more renewables, electricity prices must drop. However, the LCOE assumes a grid as an isolated system (figure 2) and does not explain how the full cost of electricity (FCOE) is altered when increasing wind and solar generation while proportionally reducing thermal generation in a grid, thereby affecting its cost variables that define its LCOE.

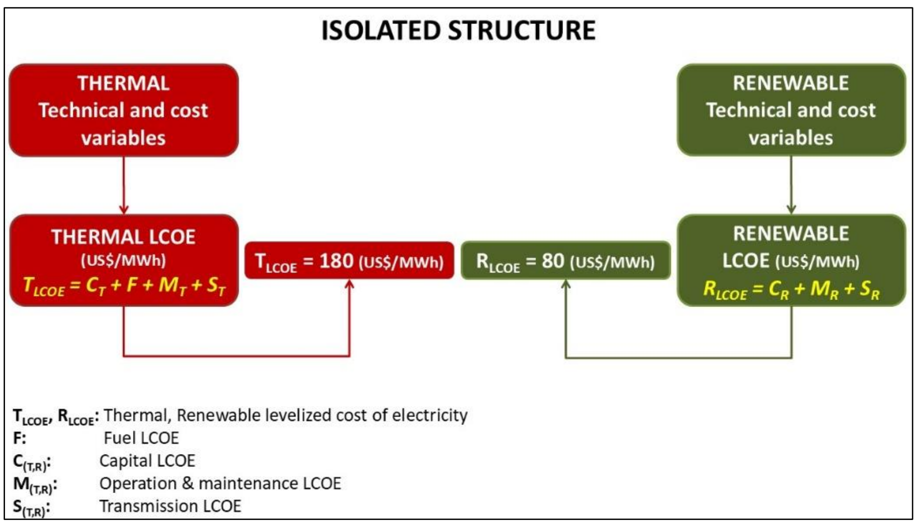

Figure 2: Power grid as an isolated system: promoters of renewables' perspective where costs are mutually independent and are not affected by interactions with other generation sources.

Actually, what takes place is that, for renewables, as long as they don't exceed demand, the electricity dispatched into the grid depends on its own capacity, keeping its unit cost (LCOE) constant. This is because of the merit order, an economic criterion used in the generation industry that describes the sequence in which power plants are designated to dispatch electricity with the aim of economically optimizing the electricity supply by means of the minimum marginal cost, that is, the fuel cost. Here is where renewables step in. While able to dispatch electricity, renewables will be selected over fossil fuel-based generators since their fuel cost is zero. For this reason, thermal sources, that come in second place, are affected both in their output (proportional reduction in generation) and in efficiency which drops because an increasing fraction of its capacity must be destined to operate inefficiently as backup (figure 3), thus inflicting a significant increase in the fuel consumption, i.e. in the fuel cost, as well as in other fixed costs that are being increasingly distributed over a lesser amount of electricity.

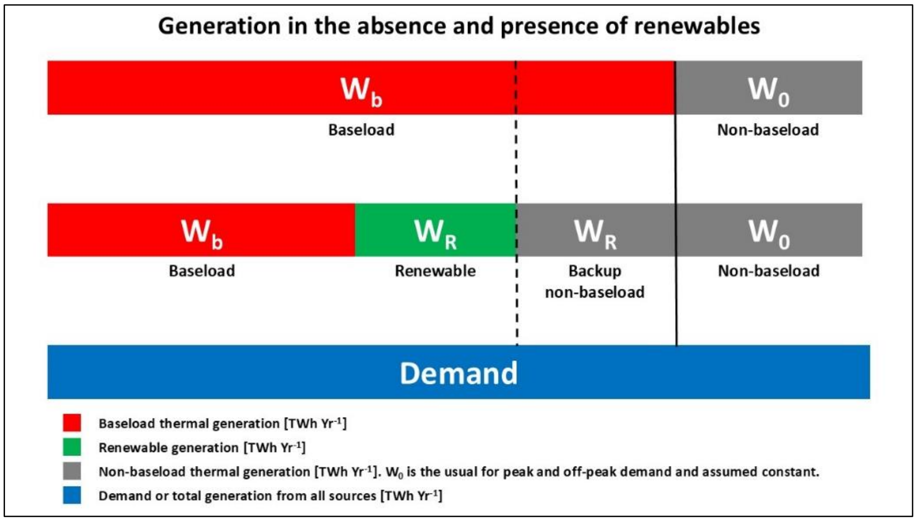

Figure 3: Generation with and without renewables. In the presence of renewables, a fraction of the thermal generation, equivalent to the renewable generations, must operate inefficiently as non-baseload destined for backup.

Rule of thumb: if grid stability is demanded, then for every MWh of renewable generation, there must be one MWh of thermal generation capacity available for backup and at least running at rotating reserve. This is because, when there is no wind or sun, thermal generators have to fully replace renewables. On the other end, when renewables operate at rated capacity, thermal sources will be operating at idle, burning fuel without generating electricity. Between these limits, thermal sources will be ramping up and down in step with the weather operating inefficiently. On average, that generation capacity is equal to the renewable generation, as the grid cannot store energy. Figure 4 shows the grid as an integrated system.

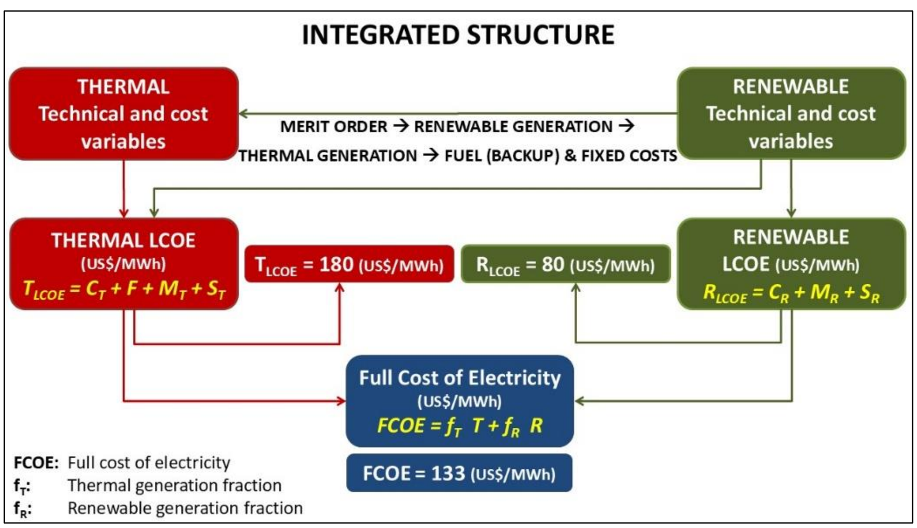

Figure 4: When increasing the renewable generation, both operating and cost variables are affected making the FCOE to inevitably increase.

2. Electricity costs according to the operating range

At a generator level, renewable LCOE is constant due to the merit order. Thermal LCOE rises due to the increase in fuel and fixed costs (Figure 5). Beyond the limit at which the renewable installed capacity equals the hourly demand, its loss of generation capacity increases exponentially. So does its LCOE as it is increasingly being distributed over less generation that now follows an exponential decay. Thermal LCOE continues to rise because its generation continues to decline, albeit at a slower rate, while renewable generation still increases, as does the need for backup.

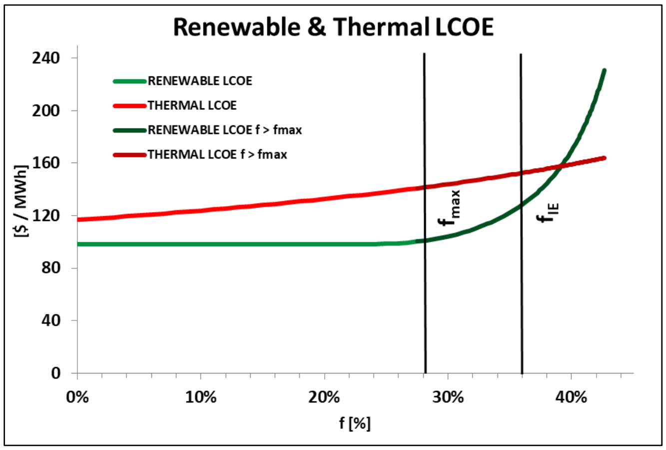

Figure 5: Renewable and thermal LCOE in the efficient scenario from the generator perspective.

The full cost of electricity, FCOE, is the sum of the renewable and thermal LCOEs weighted by their generation share. Thus, the weighted renewable LCOE rises from the beginning, increasingly gravitating toward the FCOE. The weighted thermal FCOE will fall slightly if the increase in fuel consumption is not able to cancel the effect of generation reduction (figure 6). This will be the case if combined cycle plants are mainly used to back up renewables.

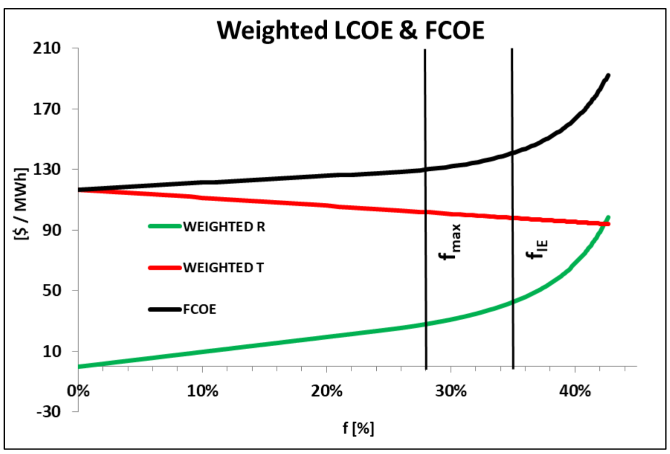

Figure 6: Weighted renewable and thermal LCOE, and the resulting FCOE in an efficient scenario.

Otherwise, this cost will increase, which is the case when a larger fraction of simple cycle plants or oil-fired plants are also used as backup (other generation technologies are not suitable to back up renewables because they are extremely slow to keep up with weather variability) (Figure 7). All in all, even if the weighted thermal cost drops, the increase in the weighted renewable cost inevitably causes the FCOE to increase, regardless of any improvements in renewables, such as a reduction in its investment costs or an increase in its capacity factor.

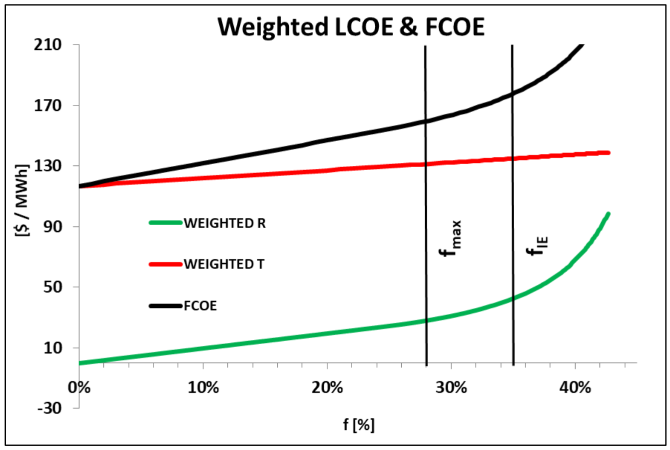

Figure 7: Weighted renewable and thermal LCOE, and FCOE in an inefficient scenario (not the case of Ireland).

It is remarkable how far above the limit renewable generation currently is in Ireland. For the Irish renewable mix, $f_{max} = 28\%$ (left vertical line), while its actual renewable generation fraction is $f_{IE} = 37\%$ (right vertical line), where f is the renewable generation fraction, *R* is the renewable LCOE, *T* is the thermal LCOE and subscript *IE* stands for Ireland.

3. The fundamental limit for renewables

The installed capacity required to generate the fraction *f* of the annual demand or generation is given by the following equation:

$$N = \frac{f\ D}{Z}$$

Where *N* is, for this matter, the renewable rated capacity, *f* is the renewable generation fraction in the grid, *D* is the hourly demand and *Z* is the renewable capacity factor.

The condition to be at a limit is when, operating at full load capacity, *N* is able to satisfy the entire demand *D*, i.e., when *N* = *D*. Therefore, above this limit, a greater installed capacity will be capable of generating more than the hourly demand, an excess that would be necessarily lost, meaning by lost that it will not be dispatched into the grid, whatever that loss is destined for, such as exporting it to the UK or France, charging batteries or producing green hydrogen. Then, replacing *N* = *D* in the above equation, it is directly obtained that the maximum renewable installed capacity or limit beyond which excess generation will be lost is:

$$f_{max} = Z$$

This doesn't mean that, above f_{max}, by adding more renewable capacity there will be no more electricity dispatched into the grid. There will be, but following an exponential decay (or logarithmic increase), while the excess renewable generation capacity will follow an exponential increase.

Schematically, this can be explained with a sine curve (figure 8). Below f_{max}, all generation will be dispatched into the grid, added renewable capacity will be achievable and there will be no losses since, even operating at full load, its capacity will not be enough to reach the hourly demand. In theory, China has reached this limit; however, this is not the case for Ireland.

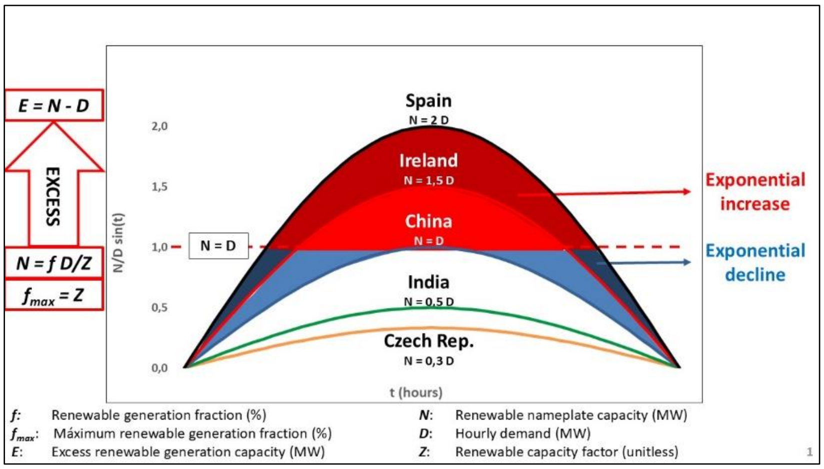

Figure 8: Excess and slack in renewable generation. India and Czech Republic may continue increasing their renewable capacity without losses, while China, Ireland and Spain, not any longer.

The exponential decay past f_{max} can be seen comparing Ireland's light blue area with Spain's dark blue area: the more the rated capacity, the more generation capacity is lost and the less renewable electricity is dispatched into the grid. This can also be explained in figure 9.

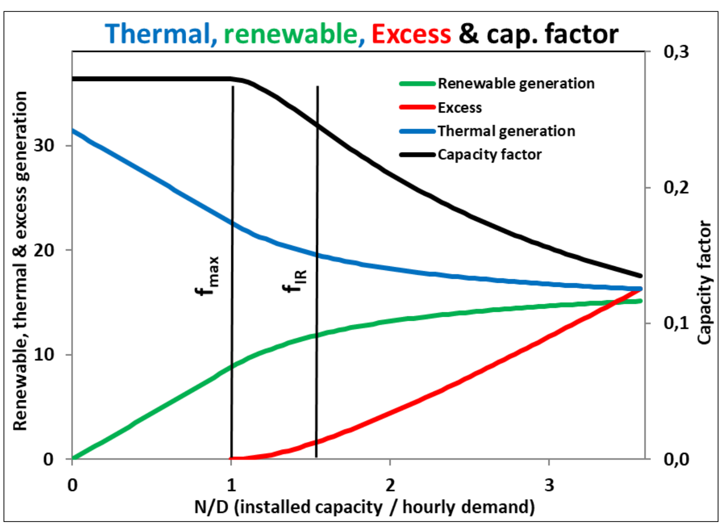

Figure 9: N/D = 1 is the limit for renewable generation above which it follows a logarithmic increase, while both thermal generation and the renewable capacity factor, follow an exponential decay, whereby the excess renewable generation starts increasing exponentially.

N/D = 1, i.e., *N = D*, is the point at f_{max}. Below f_{max}, renewable and thermal generation, respectively, increase and decrease linearly. Above this limit, thermal generation decays exponentially, renewable generation increases logarithmically, while the excess renewable generation starts increasing exponentially. The above is equivalent to an exponential decline in the renewable capacity factor, which remains constant below f_{max}. Ireland has already reached *N/D = 1.49* with *Z = 0.25*.

IV. CO_2 emissions: background

The analysis for CO_2 emissions is similar to that of the operating heat rate. As renewable generation increases, proportionally replacing thermal generation, more of the remaining thermal generation will have to operate as non-baseload or inefficiently to be used as backup. This causes the CO_2 output emission rate (Ton/MWh) to rise.

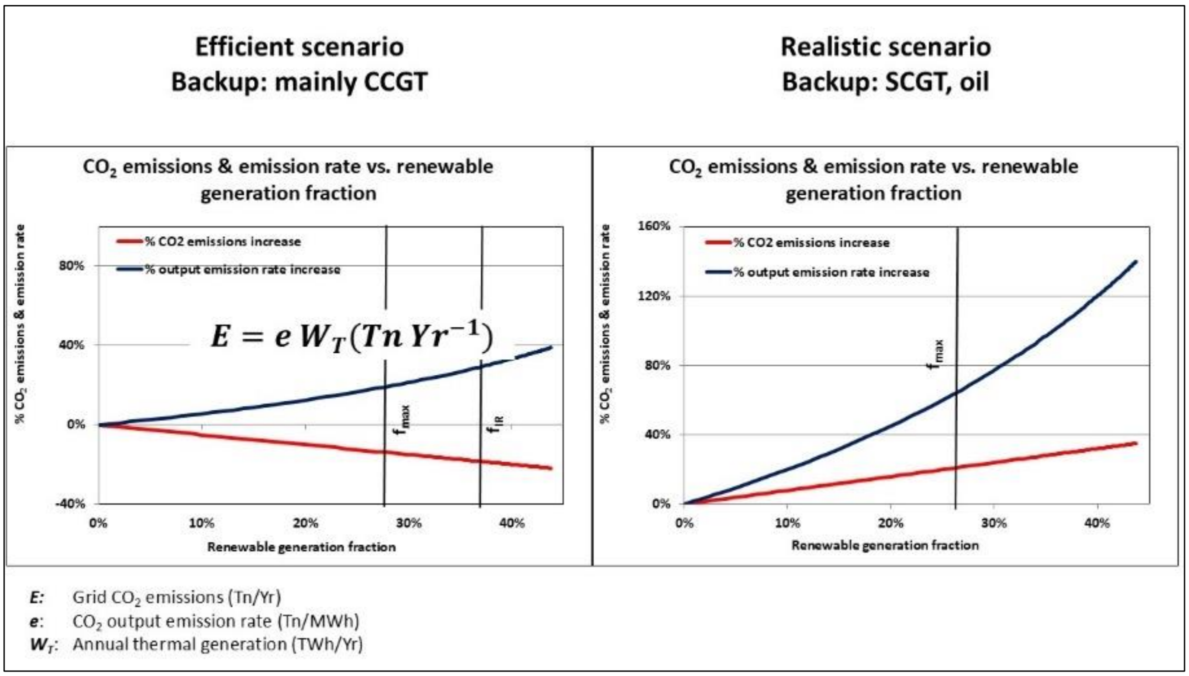

Figure 10: CO_2 emissions (E) and CO_2 output emission rates (e) under efficient and inefficient scenarios. In the equation, W_T is the thermal generation.

As shown in figure 10, in ideal (most efficient) grids, where only natural gas generation mainly in combined cycle gas turbines (CCGT) is used as backup, only a slight reduction in CO_2 emissions will be attainable, making renewables economically ineffective for this purpose. Yet, in real-world grids where simple-cycle gas turbines (SCGT) as well as oil are also used to back up renewables, the much higher thermal CO_2 output emission rates will cancel the effect of thermal generation reduction, causing total CO_2 emissions to rise significantly, hence, making renewable technologies an irrational solution for the same purpose since they were meant to reduce CO_2 emissions.

V. Cost of electricity under Ireland's Climate Action Plan

Changes in LCOE and FCOE derived from the increase in renewable infrastructure and generation planned for 2030, according to the Climate Action Plan 2025 - 2030, are presented next. For this matter, two scenarios have been established: the ideal or most efficient, where mainly CCGT are used to back up renewables and the realistic, where a larger fraction of SCGT and oil generation are used for the same purpose. In the ideal scenario, the fuel cost is less affected by the increase in non-baseload generation needed for backup than in the realistic one, both in respect of the operating heat rate as well as in the CO_2 output emission rate.

The operating heat rates and CO_2 output emission rates used in this analysis have been calculated based on the 2022 generation data of the United States [9]. In addition to the fact that the US can be considered one of the world's most efficient countries in thermal electricity generation, it is also the only one that provides the data necessary to allow establishing a relationship between the increase in renewable generation and fuel consumption, thus, allowing estimation of how electricity costs evolve, both at the generator and grid level, when expanding the renewable penetration.

1. Assumptions and parameters

The analysis is based on the following assumptions:

a) Stability and security of electricity supply at all times.
b) Demand or generation: CAP24 projects a 25% increase in generation by 2030. However, over the past seven years, Ireland's generation has remained almost constant and it is not clear that electricity demand will increase in the near future given that prices are already extremely high and will undoubtedly continue to rise if CAP24 is implemented. Therefore, electricity generation will be first assumed constant for the 2025 – 2030 period.
c) LCOE variables: realistic values for capital costs derived from investment costs, for renewable capacity factors and for project lifetime will be considered rather than the standard values used by IRENA and EIA.
d) Battery and hydrogen technologies are neither affordable nor technically feasible for large scale storage of energy for more than a few hours, hence, for backup purposes, they are not considered in this assessment.

The following Table is the parameter set required to calculate the renewable and thermal LCOE and FCOE for years 2025 and 2030, and for both scenarios (for values of natural gas unit energy cost, coal fuel LCOE and oil fuel LCOE, see source in references [10]).

Parameter	2025	2030
Capacity wind onshore (GW)	4,78	9,00
Capacity wind offshore (GW)	0,025	5,00
Capacity solar PV (GW)	0,54	8,00
Total renewable cacacity GW)	5,34	22,00
Investment cost wind onshore (USD/MW)	1.430.000	
Investment cost wind offshore (USD/MW)	3.500.000	
Investment cost solar PV (USD/MW)	1.070.000	
Weighted investment cost renwables (USD/MW)	1.403.440	1.769.545
Thermal - Renewables project lifespan (Yr)	25 - 15	25 - 15
WACC (weighted average capital cost)	5,5%	5,5%
Wind onshore capacity factor (unitless)	0,30	
Wind offshore capacity factor (unitless)	0,35	
Solar PV capacity factor (unitless)	0,11	
Weighted Renewable capacity factor (unitless)	0,28	0,24
Natural gas unit energy cost (USD/MBTU)	17,61	17,61
Coal fuel LCOE (USD/MWh)	62,05	62,05
Oil fuel LCOE (USD/MWh)	140,65	140,65
Ideal operating heat rate (Mbtu/MWh)	7,58	8,17
Realistic operating heat rate (Mbtu/MWh)	9,13	10,24
Total generation (imports excluded) (GWh)	31.430	31.430

Table 1: Parameter set used to obtain the LCOE for thermal and renewable generation for different generation fractions.

The drop in the weighted renewable capacity factor is remarkable. This is due to the sharp increase in Ireland's most unfavorable renewable generation technology, PV solar panels, which has only exhibited a capacity factor between 0.09 and 0.11 since 2017.

NOTE: All tables in this document use a comma for decimals and a dot for units of thousands.

2. LCOE and FCOE 2025 – 2030

The following two tables show the LCOE, weighted LCOE and FCOE for all generation sources, for 2023 and 2030, and for both scenarios, including generation, and generation fraction in the grid.

Source	Generation 2023 (GWh)	Share 2023	LCOE 2023 (USD/MWh)	Weighted LCOE & FCOE 2023 (USD/MWh)	Generation 2030 (GWh)	Share 2030	LCOE 2030 (USD/MWh)	Weighted LCOE & FCOE 2030 (USD/MWh)	LCOE & FCOE increase (%)
Renewables	11.780,0	37,5%	80,77	30,27	14.011,9	44,58%	358,98	160,04	344,4%
Gas	15.710,0	50,0%	154,8	77,37	15.468,1	49,2%	167,28	82,33	8,1%
Coal	1.140,0	3,6%	120,99	4,39	0,0	0,0%	120,99	0,00	0,0%
Hydro	940,0	3,0%	64,27	1,92	940,0	3,0%	64,27	1,92	0,0%
Oil	850,0	2,7%	152,83	4,13	0,0	0,0%	152,83	0,00	0,0%
Biomass	1.010,0	3,2%	90,16	2,90	1.010,0	3,2%	90,16	2,90	0,0%
Total	**31.430,0**	**100,0%**		**121,0**	**31.430,0**	**100,0%**		**247,2**	**104,3%**

Table 2: Ideal scenario. LCOE and FCOE for Irish generation sources based on the Climate Action Plan 2025 – 2030.

Source	Generation 2023 (GWh)	Share 2023	LCOE 2023 (USD/MWh)	Weighted LCOE & FCOE 2023 (USD/MWh)	Generation 2030 (GWh)	Share 2030	LCOE 2030 (USD/MWh)	Weighted LCOE & FCOE 2030 (USD/MWh)	LCOE & FCOE increase (%)
Renewables	11.780,0	37,5%	80,77	30,27	14.011,9	44,58%	358,98	160,04	344,4%
Gas	15.710,0	50,0%	182,1	91,00	15.468,1	49,2%	203,86	100,33	12,0%
Coal	1.140,0	3,6%	120,99	4,39	0,0	0,0%	120,99	0,00	0,0%
Hydro	940,0	3,0%	64,27	1,92	940,0	3,0%	64,27	1,92	0,0%
Oil	850,0	2,7%	152,83	4,13	0,0	0,0%	152,83	0,00	0,0%
Biomass	1.010,0	3,2%	90,16	2,90	1.010,0	3,2%	90,16	2,90	0,0%
Total	**31.430,0**	**100,0%**		**134,6**	**31.430,0**	**100,0%**		**265,2**	**97,0%**

Table 3: Realistic scenario. LCOE and FCOE for Irish generation sources based on the Climate Action Plan 2025 – 2030.

The increase in FCOE in Table 3 is lower than in Table 2 because the incidence of eliminating coal and oil generation is higher as the operating heat rate of natural gas is lower, as is the case in the ideal scenario.

The next three tables show the LCOE by cost variable for renewables, natural gas and other generation sources.

Renewables	2023 (USD/MWh)		2030 (USD/MWh)	
	Ideal	Real	Ideal	Real
Capital cost	63,45	63,45	276,80	276,80
Fuel	0,00	0,00	0,00	0,00
O&M	12,65	12,65	63,56	63,56
Transmission	4,67	4,67	18,62	18,62
LCOE	**80,8**	**80,8**	**359,0**	**359,0**

Table 4: LCOE for Irish renewable generation based on the Climate Action Plan 2025 – 2030.

Natural gas	2023 (USD/MWh)		2030 (USD/MWh)	
	Ideal	Real	Ideal	Real
Capital cost	16,76	16,76	18,91	18,91
Fuel	133,53	160,78	143,77	180,36
O&M	2,69	2,69	3,03	3,03
Transmission	1,82	1,82	1,56	1,56
LCOE	**154,8**	**182,1**	**167,3**	**203,9**

Table 5: LCOE for Irish natural gas generation based on the Climate Action Plan 2025 – 2030.

LCOE item	Other generationsources (USD/MWh)			
	Coal	Hydro	Oil	Biomass
Capital cost	52,11	46,58	9,36	40,80
Fuel	62,05	4,13	140,65	30,07
O&M	5,71	11,48	1,68	18,10
Transmission	1,12	2,08	1,14	1,19
LCOE	**121,0**	**64,3**	**152,8**	**90,2**

Table 6: LCOE for Irish generation of other sources based on the Climate Action Plan 2025 – 2030.

Finally, a summary of tables 2 to 6 is shown in tables 7 and 8 below, for both, LCOE and FCOE.

LCOE (USD/MWh)				
Source	**Scenario**	**2023**	**2030**	**Δ%**
Natural gas	**Ideal**	154,8	167,3	8,1%
	Realistic	182,1	203,9	12,0%
Renewables	**Ideal**	80,8	359,0	344,4%
	Realistic	80,8	359,0	344,4%

Table 7: LCOE summary for natural gas and renewables.

FCOE (USD/MWh)			
Scenario	**2023**	**2030**	**Δ%**
Ideal	121,0	247,2	104,3%
Realistic	134,6	265,2	97,0%

Table 8: FCOE summary for two scenarios.

3. Constraint, curtailment and capacity payments

Curtailment and/or constraint orders are based on the excess generation capacity of renewable facilities once they have exceeded the grid mean hourly demand and where a fee is paid for that energy not dispatched into the grid, thus avoiding bankruptcies in these renewable sources.

On the other hand, the capacity payment is an expense incurred by the system to cover the inefficiencies that arise when thermal sources have to back up renewables, forcing power plants to operate at spinning reserve for a long period without generating electricity and, therefore, without earning income, besides having to ramp up and slow down their load causing the fuel consumption to increase.

The analysis presented here is based on the payments that the UK has made to renewable facilities for constraints and curtailment orders, while capacity payments are based on Ireland's 2026/2027 T-4 Capacity Auction, The analysis aims to estimate the additional impact that these items would have on Irish electricity costs, noting that for year 2030, renewable generation losses are estimated at 70%, compared to the current loss of around 11%.

Table 9 shows the set of parameters for calculating the loss of renewable generation capacity, both currently and in 2030.

Scenario	Year	Capacity factor Z	Total generation	Hourly demand D	Nameplate capacity N	q = N/D	Total generation capacity	Renewable generation	Excess generation	% Excess generation
		(Unitless)	(GWh)	(GWh/h)	(GW)	(Unitless)	(GWh)	(GWh)	(GWh)	(%)
Ideal	2023	0,28	31.430	3,59	5,34	1,490	13.205	11.778	1.427	10,8%
	2030	0,24	31.430	3,59	22	6,132	46.772	14.012	32.761	70,0%
Real	2023	0,28	31.430	3,59	5,34	1,490	13.205	11.778	1.427	10,8%
	2030	0,24	31.430	3,59	22	6,132	46.772	14.012	32.761	70,0%

Table 9: Excess renewable generation capacity, current and in 2030.

NOTE: The reason why figures in Table 9 are identical in both scenarios is because renewables are affected in their generation in different years and not in different scenarios. Instead, fuel consumption in thermal generation, as well as CO_2 emissions, are affected in different scenarios (this is also valid for Table 16 below).

Table 10 calculates the amount of money that the Irish system would pay to renewable facilities if using the same rates of the UK for constraint and curtailment orders, and capacity payments of Ireland's 2026/2027 T-4 Capacity Auction, as well as the increase in the FCOE, both for the current excess generation capacity and for the estimated 70% loss towards 2030.

Scenario	Year	Constraint payments	Unit constraint payments	Capacity payments	Unit capacity payments	FCOE	TOTAL FCOE	Increase in FCOE
		(BUSD)	(USD/MWh)	(BUSD)	(USD/MWh)	(USD/MWh)	(USD/MWh)	(USD/MWh)
Ideal	2023	0,53	16,75	0,46	14,71	121,0	152,5	26%
	2030	12,09	384,62	1,90	60,55	247,2	692,4	472%
Real	2023	0,53	16,75	0,46	14,71	134,6	166,1	23%
	2030	12,09	384,62	1,90	60,55	265,2	710,4	428%

Table 10: Constraint and curtailment payments (UK rates) and capacity payments (Ireland's 2026/2027 T-4 Capacity Auction) for renewable excess generation capacity.

Finally, Table 11 shows the rates paid by the UK for constraint and curtailment order, and for capacity payments of Ireland's 2026/2027 T-4 Capacity Auction, including exchange rates.

BBN Bloomberg				Eirgrid-WEI_Report-23	
UK Constraint generation	UK Constraint payment	UK unit constraint payment	Exchange rate	Unit capacity payment	Exchange rate
(TWh)	(bn£)	(USD/MWh)	(£/USD)	(€/MW)	(€/USD)
5	1,5	369	1,23	83.050,0	0,96

Table 11: Constraint and curtailment payments (UK) and capacity payments (Ireland), 2023.

VI. CO_2 emissions abatement

The following two parameter sets are used to estimate CO_2 emissions reduction according to the Irish Climate Action Plan 2025 - 2030.

Parameter	Value	Unit	Description
W	29,5	TWh / Yr	Annual generation excluding biomass and hydro.
e_b	0,353	Tn / MWh	Baseload generation CO_2 output emission rate for natural gas.
e_c	1,052	Tn / MWh	Coal generation CO_2 output emissions rate.
e_o	1,089	Tn / MWh	Oil generation CO_2 output emissions rate.
k (ideal)	1,482	Unitless	Inefficency factor for the ideal scenario.
k (real)	1,922	Unitless	Inefficency factor the realistic scenario.

Table 12: Parameter set to calculate CO2 emissions reduction according to the Irish Climate Action Plan 2025 – 2030.

Biomass and hydro generation have been excluded because they are assumed not to vary with the climate plan. Factor *k* (ideal) and *k* (real) represent the inefficiency factors which account for the use mainly of CCGT plants to back up renewables (ideal) and the use, in addition, of a larger fraction of SCGT plants and oil, respectively, and is obtained by the following equation:

$$\boldsymbol{k = \frac{e_n + g_0 e_0}{e_b}}$$

Where:

- e_n is the overall non-baseload CO_2 output emission rate. In the ideal scenario, it would be the non-baseload CO_2 output emission rate of natural gas generation. In the realistic scenario, it would be the non-baseload CO_2 output emission rate of all fuels and technologies used to back up renewables.
- e_b is the baseload CO_2 output emission rate for a CCGT operating a 95% of full load capacity or with an efficiency of 58% and is equal to 0.353 tons/MWh.
- g_0 is the fraction of the full load capacity of a simple cycle gas turbine operating at idle (spinning reserve), i.e., without generating electricity yet burning fuel, and it ranges between 5% and 7%. The use of g_0 in SCGT is because, below 50% of full load, a CCGT leaves its steam booster aside and starts behaving as a SCGT.
- e_0 is the CO_2 output emission rate of a SCGT generating at full load.

Table 13 shows the generation of the Irish grid by generation source for years 2023 and 2030, assuming coal and oil generation decommissioned by 2030 and biomass and that hydro generation remains constant.

Demand				
Source	**2023**	**2030**	**Unit**	**Description**
W_R	11,78	14,01	TWh / Yr	Annual renewable generation.
W_{gas}	15,71	15,47	TWh / Yr	Annual natural gas generation.
W_{coal}	1,14	0,00	TWh / Yr	Annual coal generation.
W_{oil}	0,85	0,00	TWh / Yr	Annual oil generation.
W	29,48	29,48	TWh / Yr	Total annual generation.

Table 13: Generation by source for 2023 and 2030.

CO_2 emissions E is the product of the CO_2 output emission rate e and the thermal generation W_i:

$$E[MMTn\,Yr^{-1}] = e[Tn\,MWh^{-1}]\,10^{-6}\;W_i[MWh\,Yr^{-1}]$$

Subscript i stands for gas, coal or oil.

Table 14 below shows current emissions and emissions in 2030, according to the Irish Climate Action Plan 2025 – 2030. It is here assumed that coal and oil-based generation will have been fully phased out towards 2030.

Scenario	E_{coal} 2023 (MMTon/yr)	E_{oil} 2023 (MMTon/yr)	E_{gas} 2023 (MMTon/yr)	E_{gas} 2030 (MMTon/yr)	E 2023 (MMTon/yr)	E 2030 (MMTon/yr)	ΔCO_2 (MMTon/yr)
Ideal	1,199	0,925	8,598	8,368	10,723	8,368	-2,355
Real	1,199	0,925	11,377	11,015	13,501	11,015	-2,486

Table 14: CO_2 emissions reduction towards 2030 compared to current emissions. Coal and oil-based generation have been assumed decommissioned by 2030.

Finally, Table 15 shows the Irish CO_2 emissions achievements if it were to fulfill the Climate Action Plan 2025 – 2030. In reality it will fall far short of the 2030 ambitions.

CO_2 emissions source	Million tons	Reduction (%)
CAP CO_2 emissions abatement target	10,0	25,0%
CAP CO_2 emissions abatement	2,5	
Ireland's CO_2 emissions 2023	36,4	6,9%
Global emissions 2023	40.417,9	0,0%

Table 15: CO_2 emissions reduction based on the Irish Climate Action Plan 2025 – 2030 with respect to CAP target emissions, Ireland emissions and global emissions.

VII. A sensitivity analysis for 25% load increase by 2030

Probably because of the law of supply and demand, over the past seven years (2017 – 2023), electricity generation has declined, among other countries, in Germany, France, the UK, Spain, Italy, Japan and Canada, due to sustained electricity fare hikes. According to CAP24, Ireland would increase its generation by 25% towards 2030, despite the foreseeable increase in electricity costs. The following sensitivity analysis shows the comparison in costs and in CO_2 emissions, between "Constant" demand and a "25% increase" in demand, if such an increase in generation were to occur.

Scenario	Renewable generation (GWh)		Excess renewable generation (%)		Renewable generation fraction (5)		Natural gas generation (GWh)		Natural gas generation fraction (%)	
	Constant	25% increase	Constant	25% increase	Constant	25% increase	Constant	25% increase	Constant	25% increase
Ideal	14.012	17.126	70,0%	63,4%	44,6%	43,6%	15.468	20.211	49,2%	51,4%
Real	14.012	17.126			44,6%	43,6%	15.468	20.211	49,2%	51,4%

Table 16: Difference in renewable and natural gas generation and generation fraction between increasing Ireland's total generation by 25% (field "25% increase") or leaving it constant (field "constant").

Given the increase in mean hourly demand from 3.6 to 4.5 GWh/h as generation increases by 25%, there would be room for more renewable energy on the grid and therefore less excess. However, natural gas generation would need to increase significantly to cover what the 22 GW of renewable capacity could not, making the renewable generation fraction to drop slightly and fossil-fuel based generation to increase by 14% even after having decommissioned coal and oil-fired generation.

In terms of costs, the FCOE would decrease significantly in both ideal and realistic scenarios. Still, the increase in this cost (including curtailment, constraint and capacity payments) would be overwhelming. Finally, due to the considerable increase in natural gas generation, CO_2 emissions would, in this scenario, increase (shown in red in Table 17 below).

Scenario	FCOE increase w/o CCC (%)		FCOE increase w/ CCC (%)		CO_2 emissions reduction (Million tons)	
	Constant	25% increase	Constant	25% increase	Constant	25% increase
Ideal	104,3%	79,4%	472%	350%	-2,35	**0,47**
Real	97,0%	74,7%	428%	317%	-2,49	**1,39**

Table 17: Difference in FCOE increase both with CCC (curtailment, constraint and capacity payments) and without, and in CO_2 emissions between increasing total Ireland's generation by 25% (field "25% increase") or leaving it constant (field "constant"). Red cells mean CO_2 emissions increase.

VIII. Ireland's path to net-zero, the impact on global warming and the associated cost

Ireland's Climate Action Plan 2025 - 2030 is framed within the net-zero emissions goal towards 2050. An important question should arise regarding this initiative: *How much global warming would be averted by Ireland if achieving its Climate Action Plan?*

To answer this question, official figures from the UN's Intergovernmental Panel on Climate Change, IPCC, NOAA and UAH (University of Alabama in Huntsville) will be used. Table 16 shows the parameters to convert the radiative forcing from anthropogenic emissions of greenhouse gases (GHG) into temperature increase [11].

Variable	Value	Unit
Radiative forcing by doubling CO_2 (IPCC AR6-2021)	3,93	$W M^{-2}$
Temperature increase by doubling CO_2 (IPCC AR6-2021)	1,8	°K
Anthropogenic decadal radiative forcing (NOAA 2024)	0,33	$W M^{-2}$ $decade^{-1}$
Radiative forcing 25 years	0,825	$W M^{-2}$
Decadal temperature increase (IPCC AR1-1990)	0,3	°K
Decadal temperature increase (UAH 1979-2023)	0,156	°K

Table 18: IPCC, NOAA and UAH figures for estimating temperature increase according to human GHG emissions.

The equation below shows how much global warming would be prevented if the entire world would go to net-zero by 2050. The IPCC's estimated 0.3°K decadal temperature increase has been corrected based on actual UAH observations.

$$\mathbf{0.5\ x 0.33 x \frac{25}{10} x \frac{1.8}{3.93} x \frac{0.156}{0.3} = 0.098 \approx 0.1\ ^{\circ}C}$$

Extrapolating linearly from the above equation and Table 15, if Ireland were to achieve net-zero emissions by 2050, it would prevent global warming by 0.00009 °C and only by 0.000006 °C with the Climate Action Plan 2025 - 2030 contribution.

Other studies conclude with even smaller numbers, such as the peer reviewed paper by R. Lindzen, W. Happer and W. A. van Wijngaarden, "*Net Zero Averted Temperature Increase* [12]", that estimate that, without accounting for the IPCC's positive feedbacks that quadruples the radiative effect of CO_2, the averted temperature increase would be 0.07 °C if the entire world were to go net-zero by 2050.

One of the most realistic cost assessments of driving a national grid to net-zero towards 2050 is from the UK (National Grid 2022). According to that study, British net-zero would cost US 3.8 trillion dollars. By making a direct linear extrapolation, where emissions from the British grid represent 25% of national emissions (DESNZ 2024) and, in turn, accounts for 0.8% of global emissions, it can be obtained that net-zeroing the entire world would roughly cost US 2 quadrillion dollars (2.000 US trillion dollars), that is to say, 20 times global GDP.

IX. Conclusions

The following conclusions can be drawn from this paper on Ireland's Renewable Energy Ambitions based on its Climate Action Plan 2025 - 2030.

1. Regarding the cost of electricity

a) The cost of electricity inevitably increases regardless of any improvements from renewables, such as a reduction in their investment costs or an increase in their capacity factors. Typically, the only way to reduce the cost of electricity is for the fuel cost to drop and/or going to coal generation, like in China and India. In the case of Ireland, if CAP24 were carried out, the increase in the cost of electricity would be so high that it could deeply harm its economy.

b) The cost increase here analyzed would be further aggravated by the introduction of costly market mechanisms, such as curtailment or constraint generation orders and capacity payments that have the effect of subsidizing wind and solar generators for an ever-increasing curtailed power supply. In the case of Ireland, given the magnitude of renewable generation capacity that would be lost, in addition to the direct cost increase derived from the CAP24 expansion in renewable installed capacity, the cost of electricity could soar by 430% in a realistic scenario.

2. Regarding CO_2 emissions

a) Even if renewables didn't bring about a huge increase in electricity prices, they would still be economically ineffective in reducing CO_2 emissions because only in ideal grids can a meager reduction be achieved. Ireland would attain a 6.8% CO_2 emissions reduction but mainly because it assumes a full decommissioning of coal and oil-based generation, at a cost of more than 30 billion dollars and an increase in the cost of electricity of about 430%. In real-world grids, renewables cause emissions to rise significantly, making wind and solar an irrational solution for this purpose. In addition, high renewable penetration brings potential drawbacks, such as grid instability, leading to a loss of competitiveness and a subsequent decline in economic growth.

b) Typically, the efficient way to reduce CO_2 emissions is by replacing coal directly with natural gas generation. Renewables hinder such reduction. Ireland has very little room left to further reduce CO_2 emissions by replacing coal-fired generation, so the next target could likely be reducing natural gas-fired generation, the only stable and potentially inexpensive source still available, so no further socially acceptable options exist.

3. Regarding the fundamental limit for renewables

When wind and solar nameplate capacity exceeds the mean hourly demand limit (as has already happened in Ireland), renewable generation follows an exponential decline while electricity loss incurs an exponential increase. Above this limit, both new and existing renewable generators will receive less money per MW of installed capacity and this is the point above which pressure for curtailment and capacity payments begins. The estimated *non-dispatched-into-grid* 70% of renewable generation capacity, if CAP24 were to take place in Ireland, would imply an increase in electricity costs close to 170% on top of the direct increase caused by the expected renewable expansion. In short, the very high level of renewables envisaged in CAP24, with its associated capital and operating costs, will lead to even more unaffordable electricity prices, in turn, leading to a national economic downturn. Neither will there be any further reduction in gas imports, nor will the desired 2030 reduction in CO_2 emissions be met

4. After the Reality Check, the best way forward

Contrary to current policy, to ensure the most competitive and reliable electricity supply into the future, Ireland should actually be adding new gas-fired power stations rather than any further renewables. A corollary is that the imported gas supply to Ireland must be competitive and secure (as its indigenous Corrib field is in rapid decline). Therefore, in addition to its two existing import pipelines from the UK, Ireland should invest in an LNG import facility both from competitive and security of supply considerations.

X. References

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