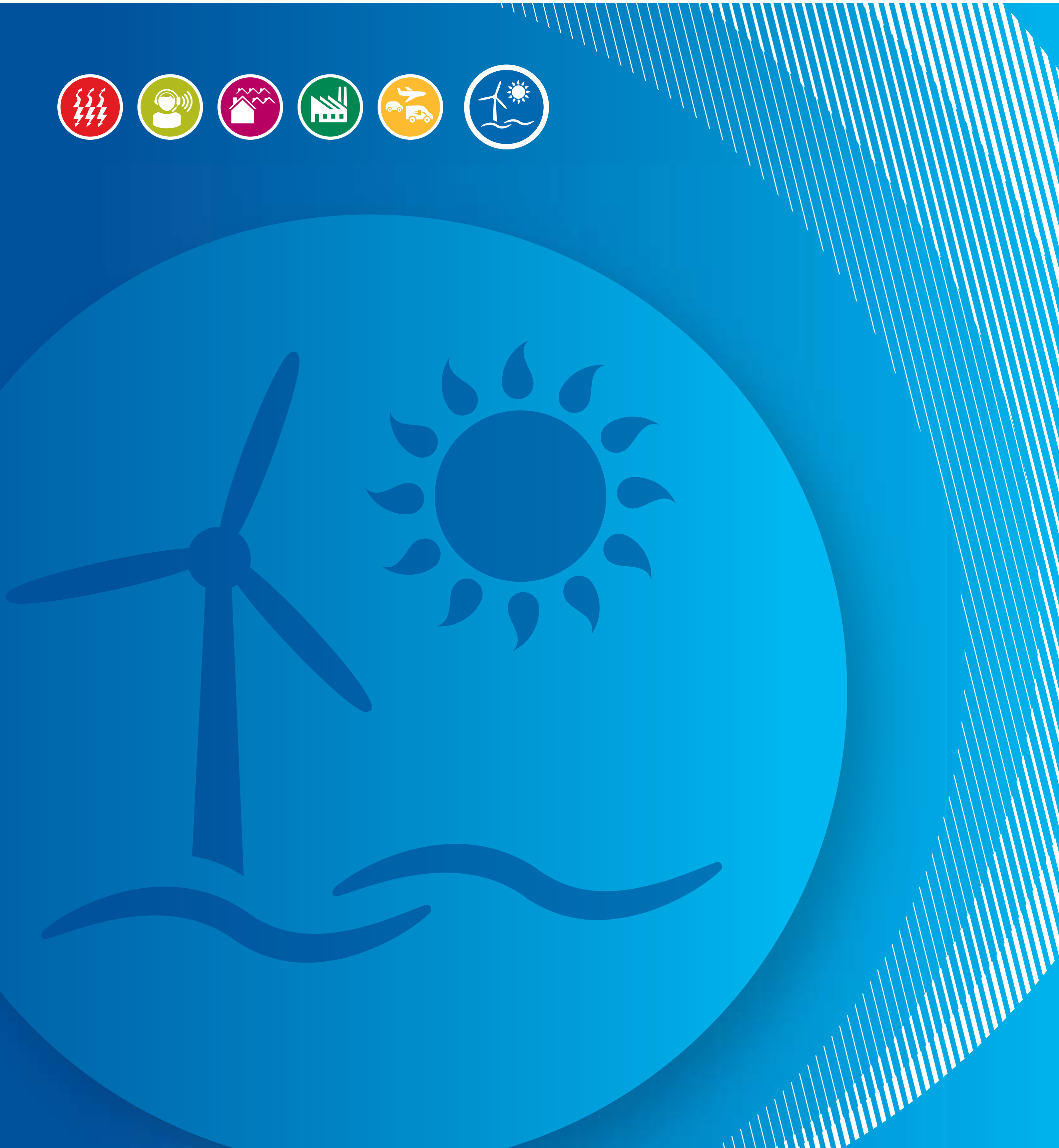
SUSTAINABLE ENERGY AUTHORITY OF IRELAND

Renewable Electricity in Ireland 2015

2016 Report



Renewable Electricity in Ireland 2015

2016 Report

Report prepared by
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Energy Policy Statistical Support Unit

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Sustainable Energy Authority of Ireland

The Sustainable Energy Authority of Ireland (SEAI) has a mission to play a leading role in transforming Ireland into a society based on sustainable energy structures, technologies and practices. To fulfil this mission SEAI aims to provide well-timed and informed advice to Government, and to deliver a range of programmes efficiently and effectively, while engaging and motivating a wide range of stakeholders and showing continuing flexibility and innovation in all activities. SEAI's actions will help advance Ireland to the vanguard of the global green technology movement, so that Ireland is recognised as a pioneer in the move to decarbonised energy systems.

Energy Policy Statistical Support Unit (EPSSU)

SEAI has a lead role in developing and maintaining comprehensive national and sectoral statistics for energy production, transformation and end use. These data are a vital input in meeting international reporting obligations, for advising policy makers and informing investment decisions. Based in Cork, EPSSU is SEAI's specialist statistics team. Its core functions are to:

- Collect, process and publish energy statistics to support policy analysis and development in line with national needs and international obligations;
- Conduct statistical and economic analyses of energy services sectors and sustainable energy options;
- Contribute to the development and promulgation of appropriate sustainability indicators.

Acknowledgements

SEAI gratefully acknowledges the co-operation of the all the organisations, agencies, energy suppliers and distributors that provided data and responded to questionnaires throughout the year.

Highlights

Progress towards targets

- Renewable energy contributed 9.1% of Gross Final Energy Consumption in 2015. This compares with a target of 16% to be reached by 2020.
- The share of electricity from renewable energy was 25.3% (normalised) in 2015, over half way to the RES-E target of 40% in 2020.

Renewable Electricity (RES-E)

- Electricity from renewable energy sources more than quadrupled its share of gross electricity generation since 1990 going from 4.9% in 1990 to 27.3% (non-normalised) in 2015. During this time the absolute amount of electricity from renewables increased elevenfold from 697 GWh to GWh in 1990 to 7,857 GWh in 2015.
- Use of renewables in fuels used for electricity generation increased by 18.8% in 2015. The largest increase was in wind, with an increase of 27.9%, accounting for 12.6% or approximately one eighth of fuels used.
- Electricity generated from wind and hydro (normalised) in 2015 accounted for 21.1% and 2.5%, respectively, of Ireland's gross electrical consumption. Biomass and renewable waste accounted for 1.0%, landfill gas for 0.6%, biogas for 1.0% and 0.01% from solar.
- Over 80% of renewable electricity generated came from wind power, with installed generating capacity reaching 2,440 MW.

CO_2 Intensity and Avoided Emissions

- The carbon intensity of electricity increased by 2.5% to 467.5 CO_2/kWh in 2015 mostly due to increased use of coal for electricity generation.
- Renewable energy in electricity generation is estimated to have avoided greenhouse gas emissions of 3,188 ktCO_2 in 2015.
- It is estimated that wind energy avoided 2,436 ktCO_2, followed by hydro at 323 ktCO_2 and solid biomass at 203 ktCO_2 in 2015.

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1 Introduction

Developing renewable energy is an integral part of Ireland's sustainable energy objectives and climate change strategy. Renewable energy contributes to meeting all three energy policy goals, namely: energy security, cost competitiveness and protection of the environment through the reduction of greenhouse gas (GHG) emissions. With lower or no net emissions from renewable energy sources compared with fossil fuels, renewable energy sources contribute to the decarbonisation of energy supply and reduction in GHG emissions. They also contribute to energy security, being, for the most part, indigenous energy sources. In a period of volatile energy costs, renewables can also contribute to cost competitiveness by reducing dependence on imported fossil fuels and hedging against further fossil fuel price volatility. There is the potential, in the case of some renewable sources, for Ireland to become a net exporter of renewable energy and technology.

The European Renewable Energy Directive 2009/28/EC sets a mandatory target for Ireland of 16% of gross final energy consumption to come from renewable energy sources by 2020 and a minimum 10% target for the contribution of renewable energy in transport. In response, Ireland's National Renewable Energy Action Plan (NREAP) set out targets of 40% 12% and 10% for the contributions of renewable energy to electricity generation, heating and transport respectively.

This report examines the contribution made by renewables to Ireland's electricity requirements for the period 1990 to 2015, with a particular focus on production data in 2015. This is the eighth in an ongoing series of renewable energy reports and follows Renewable Energy in Ireland 2014[1]. For further details on the policy context and methodology, please see the 2014 report.

Progress towards our heating, transport and overall targets in 2015 will be reported in the Energy Ireland 2016 Report which is due to be published later in 2016.

The 2015 Government White Paper on Energy, *Ireland's Transition to a Low Carbon Energy Future 2015 – 2030*[2], details a vision for a low carbon future which includes generating our electricity from renewable sources of which we have a plentiful indigenous supply. To ensure that the 40% renewable electricity target is achieved by 2020, and to prepare for more renewable electricity deployment in the period to 2030, Government will:

- Introduce a new renewable electricity support scheme for a range of RES-E technologies from 2016;
- Update the existing support schemes so that they are compatible with the wholesale electricity market reform;
- Ensure that grid connection policy will have due regard to current and future renewable energy policy, including in relation to community renewable energy projects; this policy, will be defined using criteria such as scheme size and degree of community ownership;
- Publish a Renewable Electricity Policy and Development Framework (with a spatial dimension) to underpin the proper planning and development of larger scale renewable electricity generation development on land. This plan will give guidance to those seeking development consent in relation to larger-scale onshore renewable electricity projects, and to planning authorities, statutory authorities and citizens;
- Develop a policy framework to encourage the development of CHP, taking account of the findings and recommendations of the comprehensive assessment required by the European Union (Energy Efficiency) Regulations 2014.

The national energy balance data presented in this report are the most up-to-date at the time of writing. Balance data are updated whenever more accurate information is known. The most up-to-date balance figures are available in the statistics publications section of the Sustainable Energy Authority of Ireland's website[3]. An energy data portal is available at http://www.seai.ie/Energy-Data-Portal/. The 2015 national energy balance data underpins this report. This was published by SEAI in August 2016.

Feedback and comment on the report are welcome and should be addressed by post to the address on the back cover or by email to epssu@seai.ie.

1 Available from http://www.seai.ie/Publications/Statistics_Publications/Renewable_Energy_in_Ireland/
2 DCCAE, 2015, *Ireland's Transition to a Low Carbon Energy Future 2015 – 2030* , Available from http://www.dccae.gov.ie/
3 Available from http://www.seai.ie/Energy-Data-Portal/Energy%20Data%20Publications/

2 Context for Renewable Energy Deployment

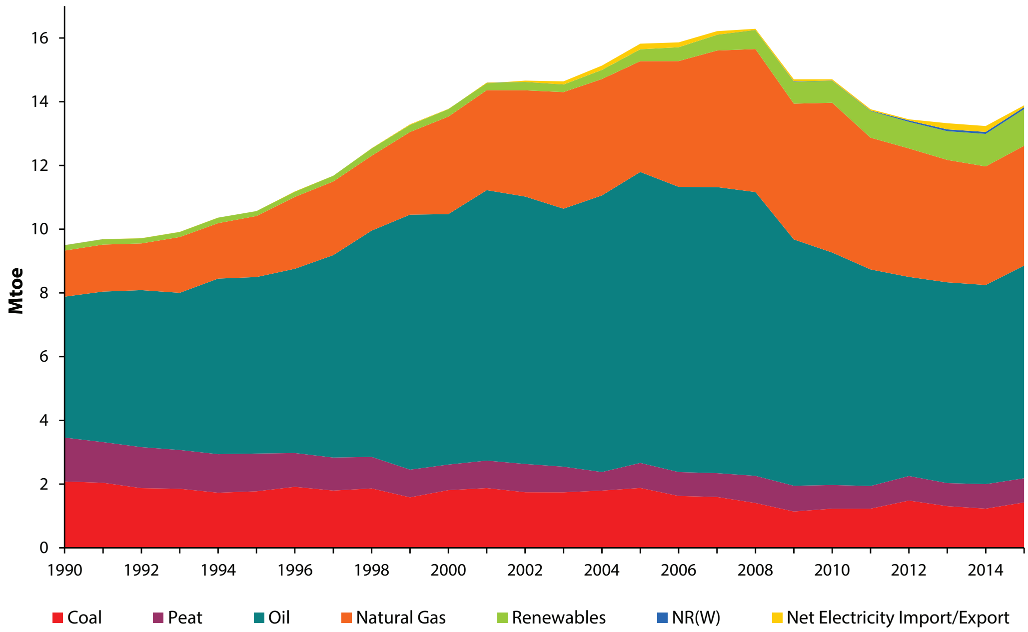
2.1 Primary Energy

Ireland's overall energy supply is discussed in terms of changes to the total primary energy requirement (TPER). TPER is defined as the total amount of energy used within Ireland in any given year. This includes the energy requirements for the conversion of primary sources of energy into forms that are useful for the final consumer, for example electricity generation and oil refining. These conversion activities are not all directly related to the level of economic activity that drives energy use but are dependent to a large extent, as in the case of electricity, on the efficiency of the transformation process and the technologies involved.

Figure 1 illustrates the trend in energy supply over the period 1990 to 2015, emphasising changes in the fuel mix. Primary energy requirement in Ireland in 2015 was 13.9 million tonnes of oil equivalent (Mtoe). Over the period 1990 to 2015 Ireland's total annual primary energy requirement grew in absolute terms by 46% (average annual growth rate of 1.5%). The individual fuel growth rates and shares are shown in Table 1. A more detailed discussion on the trends in TPER between 1990 and 2015 will be contained in SEAI's Energy in Ireland 2016 report which is due to be published later in 2016.

The 2015 data show a growth of 4.9% in primary energy requirement relative to 2014. Oil increased 6.8% due to growth in the transport sector, while coal consumption increased by 15.7% due to increased use in electricity generation.

Figure 1 *Total Primary Energy Requirement 1990 – 2015*



Source: SEAI

Figure 1 shows the significant increase in overall TPER over the period 1990 to 2015 and also the considerable growth in renewable energy since 2000. Total renewable energy grew from 168 ktoe to 1,150 ktoe between 1990 and 2015, an increase of 586% (8.0% per annum on average) and an almost sevenfold increase, over the period. The latest 2015 figures show a 12.8% increase compared with 2014 in terms of the contribution of renewables to the TPER.

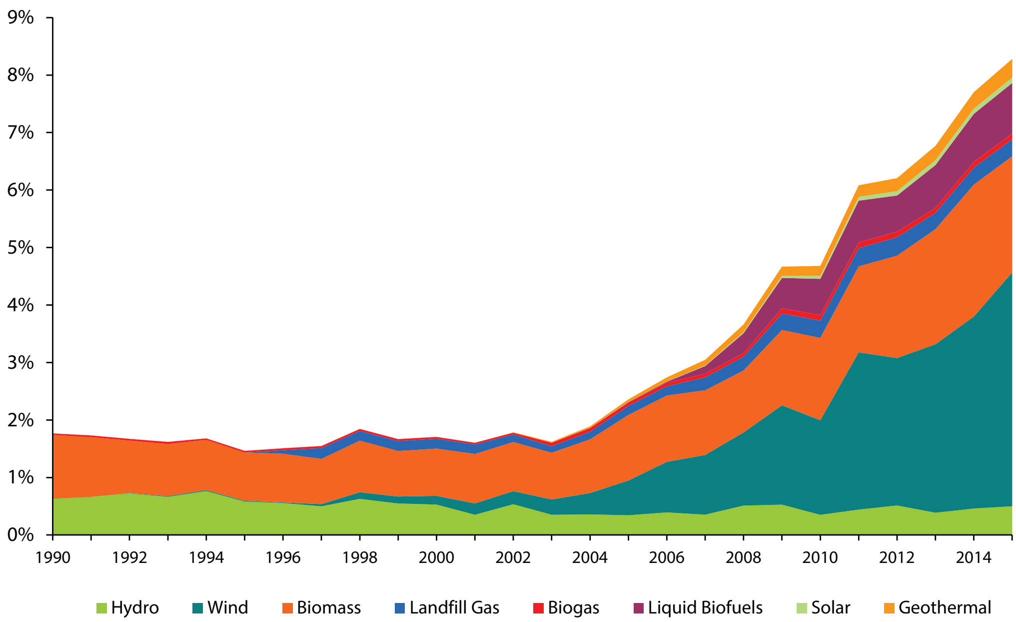
Table 1 *Growth Rates and Shares of TPER Fuels 1990 – 2015*

	Growth %	Average annual growth rates %					Quantity (ktoe)		Shares %	
	1990 – 2015	'90 – '15	'00 – '05	'05 – '10	'10 – '15	2015	1990	2015	1990	2015
Fossil Fuels (Total)	35.2	1.2	2.4	-1.8	-2.0	5.4	9,330	12,618	98.2	90.9
Coal	-31.6	-1.5	0.7	-8.1	3.0	15.7	2,085	1,426	22.0	10.3
Peat	-44.9	-2.4	-0.4	-1.1	0.4	-1.2	1,377	759	14.5	5.5
Oil	50.9	1.7	3.0	-4.4	-1.8	6.8	4,422	6,672	46.6	48.0
Natural Gas	160.0	3.9	2.6	6.2	-4.4	1.0	1,446	3,761	15.2	27.1
Renewables (Total)	585.6	8.0	9.7	13.0	10.8	12.8	168	1,150	1.8	8.3
Hydro	15.7	0.6	-5.7	-1.0	6.1	13.8	60	69	0.6	0.5
Wind	-	-	35.4	20.4	18.5	27.9	0	565	-	4.1
Biomass	166.0	4.0	9.8	3.1	5.9	-7.7	105	281	1.1	2.0
Other Renewables	9852.4	20.2	8.9	33.7	5.0	10.5	2	235	0.0	1.7
Non-Renewable (Wastes)	-	-	-	-	48.6	-1.6	-	62	-	0.4
Electricity Imports	-	-	83.6	-25.5	7.4	-68.7	-	58	-	0.4
Total	**46.2**	**1.5**	**2.8**	**-1.5**	**-1.1**	**4.9**	**9,497**	**13,889**		

Source: SEAI

Figure 2 shows that renewable energy had been contributing nearly 2% of Ireland's TPER between 1990 and 2004. In 2004 the contribution stood at 1.8% and this increased to 8.3% in 2015.

Figure 2 *Renewable Energy Contribution to TPER 1990 – 2015*



Source: SEAI

3 Renewable Generated Electricity (RES-E)

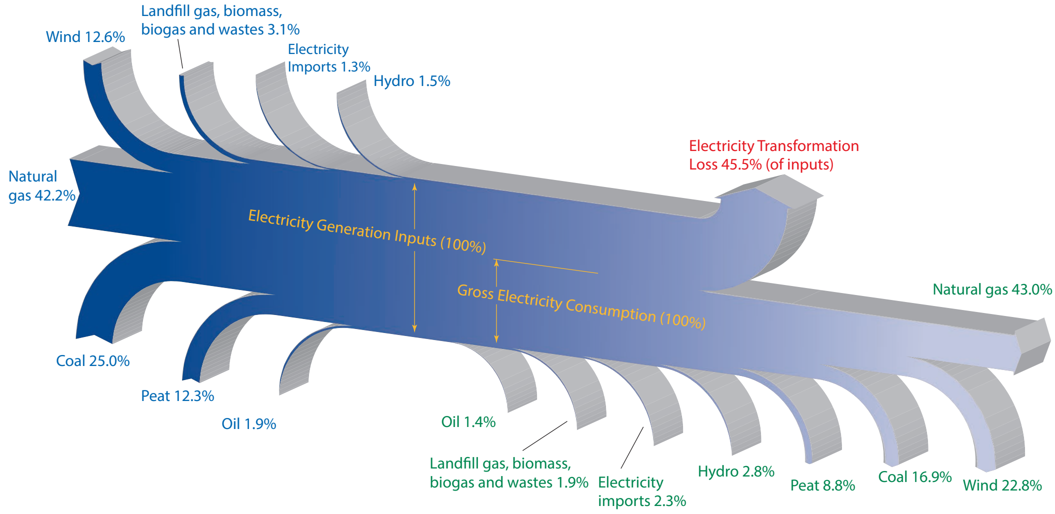
3.1 Fuel Inputs to Electricity Generation

Fuel inputs to electricity generation are responsible for approximately one third of the total primary energy demand in Ireland (4.5 Mtoe in 2015 out of a total of 13.9 Mtoe). The upstream energy use and related emissions from electricity use in the residential, industry and services sectors are significant in terms of understanding sectoral primary energy use and CO_2 emissions in Ireland.

There are two broad categories of renewable electricity sources: combustible and non-combustible. Non-combustible sources of renewable electricity contribute to an overall reduction in primary energy demand as they do not have the transformation losses associated with fuel combustion for electricity generation. In relation to combustible sources, solid biomass - primarily wood, wood wastes (e.g. firewood, wood chips, barks, sawdust, shavings, chips, black liquor) and other solid wastes (straw, oat hulls, nut shells, tallow, meat and bone meal etc.) – is used. Biomass is primarily used in co-firing with peat in existing power plants, with a small amount also used in Combined Heat and Power (CHP) plants.

Figure 3 shows a Sankey diagram for electricity generation in 2015. On the left hand side are shares of primary energy inputs to electricity generation by fuel type. On the right hand side are the shares of gross electricity consumption generated by each fuel type. The difference in shares between the two sides is due to the different conversion efficiencies for different fuel types. The scale of transformation losses from the conversion of combustible fuels to electricity accounted for 46% of the primary energy input.

Figure 3 *Flow of Energy in Electricity Generation 2015– Inputs and Outputs by Fuel*



Note: Some statistical differences and rounding errors exist between inputs and outputs.
Percentages of inputs on the left refer to percentages of total inputs.
Percentages of output, with the exception of electricity transformation loss, refer to percentages of gross electricity generated.

Renewables as % of gross electricity consumption = 27.3%
Renewables as % of gross electricity consumption (normalised) = 25.3%
CHP as % of total electricity generation = 7.5%

Source: SEAI

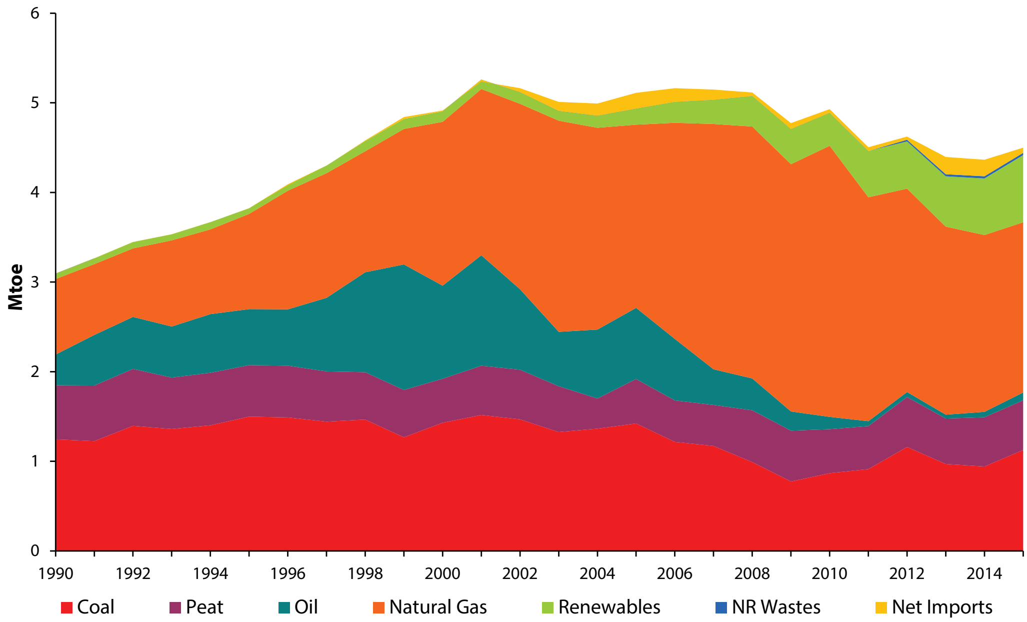
The fuel inputs to electricity generation from 1990 to 2015 are shown in Figure 4. Fuel inputs increased steadily between 1990 and 2001. However, following a peak in 2001, there was a switch away from oil to more efficient natural gas generation which resulted in a reduction in fossil fuel inputs and from 2004 onwards increasing amounts of renewable energy, mainly wind. Overall energy inputs to electricity generation have decreased over the last decade and more recently the fossil fuel inputs have fallen due to the growing contribution of renewables.

Table 2 shows the growth rates, quantities and shares of the primary fuel mix for electricity generation over the period 1990 – 2015. The primary fuel requirement for electricity generation grew by 69%, from 3,094 ktoe in 1990, to a high of 5,237 ktoe in 2001. Between 2001 and 2004 the primary fuel requirement reduced by 4.7%, while at the same time the final consumption of electricity increased by 10%. This decoupling was driven by new gas efficient generation and increased wind generation. Some key insights related to electricity generation in 2015 are:

- In 2015, 4,500 ktoe of energy was used to generate electricity, 3.1% more than in 2014 and 14% lower than peak levels in 2001;
- The fuel inputs to electricity generation were almost one third (32%) of the total primary energy requirement in 2015;

- Coal use increased by 19.6%, with a share of 25% of the total electricity fuel mix. This compares to a 40% share in 1990;
- Oil used increased by 45% but only accounted for 1.9% of the total fuel inputs;
- Natural gas remains the dominant fuel with a share of 42% although use fell by 3.7% in 2015 to 1,899 ktoe. Use of natural gas in electricity generation peaked in 2010 with a share of 61% or 3,025 ktoe;
- Use of renewables in electricity generation increased by 18.8%, with a total share of 16.7% compared to a share of just 1.9% in 1990. The largest increase was in wind, with an increase of 27.9%, accounting for 12.6% or approximately one eighth of the energy input to electricity generation;
- Net electricity imports fell by 69% to 58 ktoe, with a share of 1.3% of the electricity generation fuel mix.

Figure 4 *Inputs to Electricity Generation by Fuel Source 1990 – 2015*



Source: SEAI

Table 2 *Growth Rates, Quantities and Shares of Electricity Generation Fuel Mix (primary fuel inputs)*

	Growth %	Average annual growth rates %					Quantity (ktoe)		Shares %	
	1990 – 2015	'90 – '15	'00 – '05	'05 – '10	'10 – '15	2015	1990	2015	1990	2015
Fossil Fuels (Total)	20.9	0.8	-0.1	-1.0	-4.1	4.0	3,034	3,667	98.1	81.5
Coal	-9.5	-0.4	-0.1	-9.4	5.4	19.6	1,245	1,127	40.2	25.0
Peat	-8.2	-0.3	0.2	-0.2	2.4	0.8	604	554	19.5	12.3
Oil	-74.5	-5.3	-5.2	-29.6	-8.7	44.7	343	87	11.1	1.9
Gas	125.3	3.3	2.3	8.2	-8.9	-3.7	843	1,899	27.2	42.2
Renewables (Total)	1150.3	10.6	8.9	15.4	15.3	18.8	60	749	1.9	16.7
Hydro	15.7	0.6	-5.7	-1.0	6.1	13.8	60	69	1.9	1.5
Wind	-	-	35.4	20.4	18.5	27.9	-	565	-	12.6
Other Renewables	-	-	4.8	20.1	9.1	-10.2	-	115	-	2.6
Non-Renewable (Wastes)	-	-	-	-	-	1.2	-	25	-	0.6
Combustible Fuels (Total)	25.5	0.9	-0.1	-0.8	-3.7	3.5	3,034	3,807	98.1	84.6
Electricity Imports (net)	-	-	83.6	-25.5	7.4	-68.7	-	58	-	1.3
Total	45.4	1.5	0.8	-0.7	**-1.8**	**3.1**	**3,094**	**4,500**		

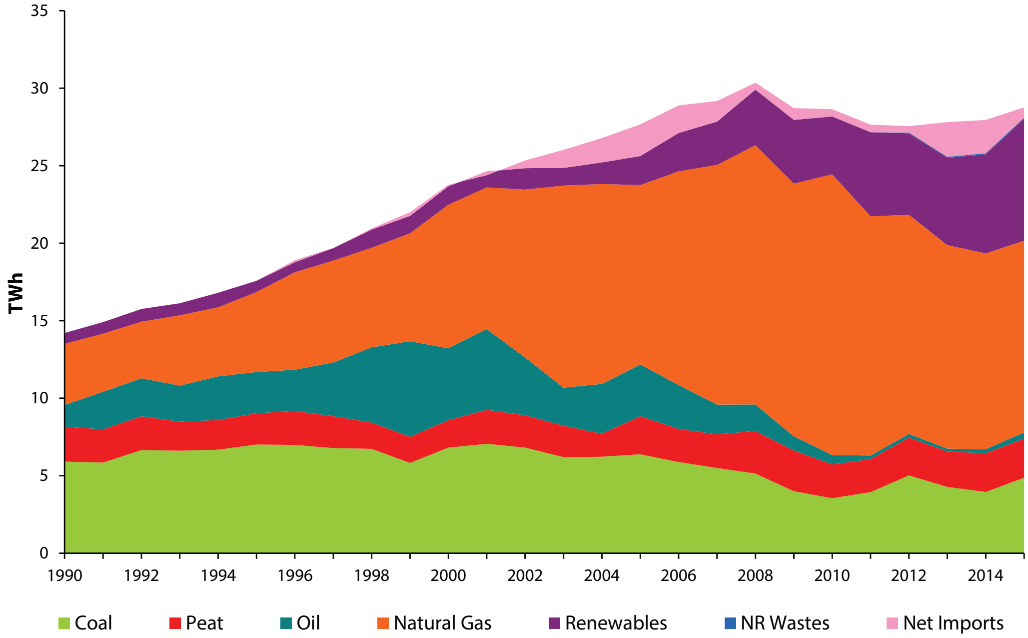
Source: SEAI

3.1.1 Gross Final Consumption (GFC)

The trend in Gross Final Consumption (GFC)[4] of electricity for Ireland over the period 1990 – 2015 is shown in Figure 5. The doubling of gross electricity consumption over the period 1990 to 2008 is striking, as is the growth in gas generated electricity. It is interesting to compare the inputs to electricity generation (Figure 4) with final electricity demand (Figure 5) which shows that even though demand continued to increase between 2001 and 2008 the inputs to electricity generation decreased. This is the result of higher efficiency electricity generation from natural gas Combined Cycle Gas Turbines (CCGT) and the increasing contribution from renewables.

A further factor in this decoupling of fuel input and demand is the development of increased interconnection between the Irish and UK electricity grids. The 500 MW Moyle Interconnector between Scotland and Northern Ireland became operational in 2002 and has been operating at a limited capacity of 250 MW. In addition, the 500 MW East West Interconnector between Wales and the Republic of Ireland became operational in late 2012 with 2013 being its first full year of operation. This lead to an increase in electricity imports of over 400% in 2013, albeit from a low base.

Figure 5 *Gross Electricity Consumption by Fuel Source 1990 – 2015*



Source: SEAI

Due to the impact of the economic recession there was a 9.2% reduction in gross electricity consumption between 2008 and 2012, as shown in Figure 5. Gross electricity consumption has grown since then with 2015 levels 4.4% above 2012. As detailed in Table 3, the share of gas generation increased from 28% in 1990 to 63% in 2010 but fell back to 43% in 2015. Gas-generated electricity grew by 214% over the period 1990 to 2015, an annual average growth rate of 4.7% per annum. In contrast, oil generated electricity has almost been eliminated, falling from a 10% share of all generation in 1990 to 1.4% in 2015. GFC of electricity was 28.8 TWh in 2015. These changes provide a context against which the growth in RES-E can be assessed.

Electricity from renewable energy sources more than quadrupled its share of gross electricity generation over the period, going from 4.9% in 1990 to 27.3% (non-normalised) in 2015. During this time the absolute amount of electricity from renewables increased elevenfold from 697 GWh to 7,857 GWh. Renewable energy was the second largest source of electricity produced in 2015. Indeed, wind on its own, was the second largest share of electricity generated in 2015 at 22.8% (non-normalised) behind gas at 43% and ahead of coal at 16.9%.

4 The Renewable Energy Directive (2008/28/EC) defines gross final consumption of energy as the energy commodities delivered for energy purposes to manufacturing industry, transport, households, services, agriculture, forestry and fisheries, including the consumption of electricity and heat by the energy branch for electricity and heat production and including losses of electricity and heat in distribution.

Table 3 *Gross Electricity Consumption Percentage by Fuel Source 1990 – 2015*

% of Gross	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Coal	41.6	39.9	28.7	23.1	12.4	14.3	18.2	15.4	14.2	16.9
Peat	15.8	11.5	7.4	8.9	7.6	7.7	8.8	8.2	8.9	8.8
Oil	9.9	15.1	19.5	12.1	2.1	0.8	0.9	0.7	0.9	1.4
Gas	27.7	29.4	39.0	41.8	63.2	55.8	51.3	47.2	45.2	43.0
Renewables (Total)	4.9	4.1	5.0	6.8	13.0	19.6	19.1	20.2	22.9	27.3
Hydro	4.9	4.1	3.6	2.3	2.1	2.6	2.9	2.2	2.5	2.8
Wind	0.0	0.1	1.0	4.0	9.8	15.8	14.6	16.3	18.4	22.8
Other Renewables	-	-	0.4	0.5	1.1	1.2	1.6	1.8	1.9	1.7
Non-Renewable Wastes	-	-	-	-	-	-	0.2	0.2	0.2	0.3
Net Imports	0.0	-0.1	0.4	7.4	1.6	1.8	1.5	8.1	7.7	2.3

Source: SEAI

3.2 Contribution of Renewable Electricity Sources

The contribution of all renewables as a percentage of gross consumption, with wind and hydro normalised as per Directive 2009/29/EC are shown in Figure 6 and Table 4. Up until 2003, hydro was the largest contributor to renewable electricity in Ireland. While the contribution from hydro has declined in percentage terms since 1990, electricity production from wind energy has increased to the point where it accounted for 84% of the renewable electricity generated in 2015. Normalised wind and hydro energy in 2015 accounted for 21.1% (18.4% in 2014) and 2.5% (2.6% in 2014), respectively, of Ireland's gross electrical consumption.

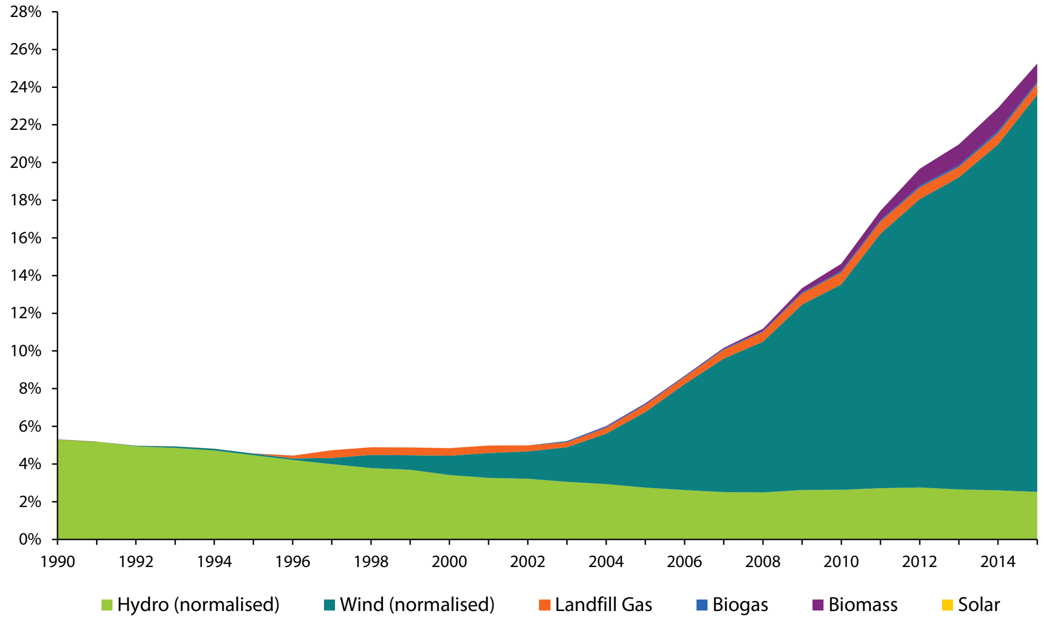
In 2015, biomass and renewable waste, which includes a small contribution of solid biomass CHP since 2004, was responsible for 1.0% (1.2% in 2014). Landfill gas was responsible for 0.6% in 2015. Biogas accounted for 1.0% of Ireland's gross electrical consumption and the remaining 0.01% was from solar.

Table 4 *Renewable Electricity (Normalised) as Percentage of Gross Electricity Consumption 1990 – 2015*

% of Gross Electricity	1990	2000	2005	2010	2011	2012	2013	2014	2015
Renewables % of Gross Electricity	5.3	4.8	7.2	14.6	17.4	19.7	21.0	22.9	25.3
Hydro (normalised)	5.3	3.4	2.7	2.6	2.7	2.8	2.7	2.6	2.5
Wind (normalised)	-	1.0	4.0	10.9	13.5	15.3	16.6	18.4	21.1
Biomass & Renewable Waste	-	-	-	0.4	0.5	0.9	1.1	1.2	1.0
Landfill gas	-	0.4	0.4	0.6	0.6	0.6	0.6	0.6	0.6
Biogas	-	-	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Solar	-	-	-	0.0	0.0	0.0	0.0	0.0	0.0

Source: SEAI

Figure 6 *Renewable Energy (Normalised) Contribution (%) to Gross Electricity Consumption by Source 1990 – 2015*

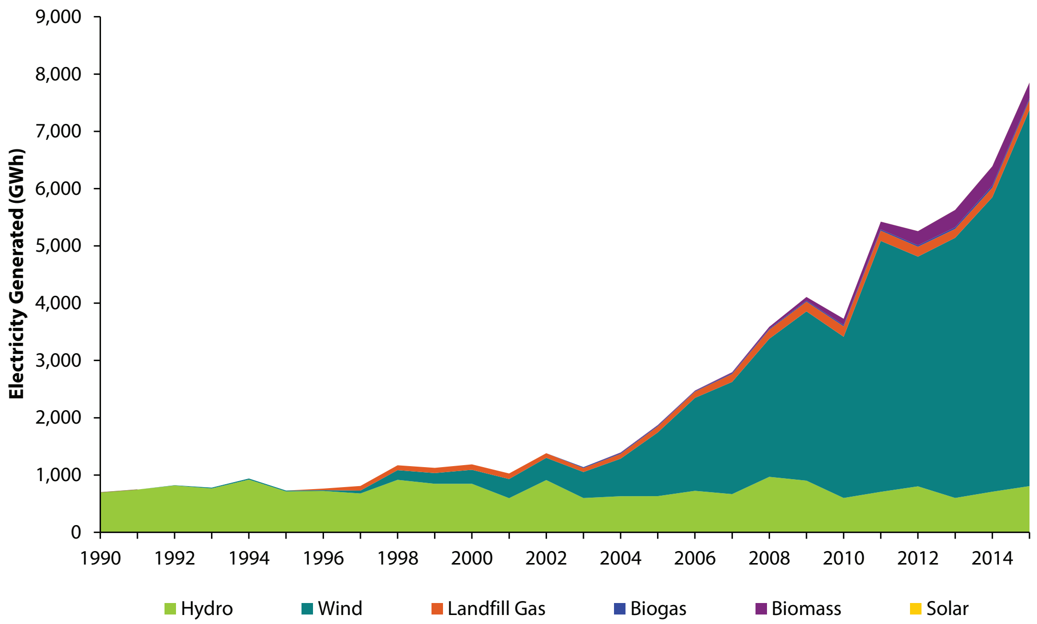


Source: SEAI and EirGrid

The overall share of electricity from renewables increased almost fivefold in the period 1990 to 2015, from 5.3% to 25.3% (normalised). As a result of this growth, since 2009, renewables have been the second largest source of electricity generated in Ireland after gas, contributing more than coal which had a share of 16.9% in 2015.

Figure 7 shows the contribution from each renewable energy source to the overall RES-E mix in GWh before the normalisation rules are applied. Estimates for solar PV have been included from 2009. The elevenfold increase in electricity generation from renewable energy between 1990 and 2015 is clearly visible in Figure 7, driven predominantly by the growth in wind energy. The total electricity generated from renewable energy reached 7,857 GWh in 2015, an increase of 23% from 2014.

Figure 7 *Renewable Energy Contribution (GWh) to Gross Electricity Consumption by Source 1990 – 2015*



Source: SEAI and EirGrid

Table 5 shows the sources of renewable electricity by technology and their installed capacity and contribution to gross electricity consumption in 2015. This is followed by a more detailed look at each of the individual technologies.

Wind is the most significant technology with an installed capacity of 2,440 MW, followed by hydro at 238 MW. It should be noted that the installed capacity for biomass of 49 MW includes solid biomass CHP, 30% of the total capacity of the Edenderry peat-fired power station which co-fires biomass and 50% of the capacity of the Meath waste-to-energy plant.

Table 5 *Renewable Electricity Sources by Technology in 2015*

Renewable Technology	Installed Capacity MW	Electricity Generated GWh	% of Gross Electricity (actual)	% of Gross Electricity (normalised)
Hydro	238	806	2.8	2.5
Wind	2,440	6,573	22.8	21.1
Biomass & Renewable Waste	49	275	1.0	1.0
Landfill Gas	49	172	0.6	0.6
Biogas	9	30	0.1	01
Solar	2	2	0.01	0.01
Total	**2,787**	**7,857**	**27.3**	**25.3**

Source: SEAI

3.2.1 Hydro Energy

There are 15 hydroelectric[5] generators connected to the power transmission system, 14 of which have a maximum export capacity (MEC) of over 4 MW. The total hydro connected to the transmission system is 212 MW. This is 2.9% of the total connected generation capacity. There are a further 59[6] hydroelectric generators connected to the distribution system, with an installed capacity of 26 MW. There are eight micro-generation projects contracted for power distribution system connections.

In 2015 hydropower generated 806 GWh of electricity (2.8% of gross electricity) which equates to 725 GWh when normalised (2.5% of gross electricity).

3.2.1.1 Pumped Hydro Storage

Electricity produced by pumped storage from water that has previously been pumped uphill is not classified as being from a renewable energy source and is not included in either the numerator or the denominator of the renewable electricity (RES-E) calculation. While it is not a renewable electricity source, pumped hydro storage has attributes relevant to renewable energy deployment such as load balancing in an electricity system. Significantly for renewables deployment, pumped hydro storage can also be used to facilitate wind energy integration on the electricity grid.

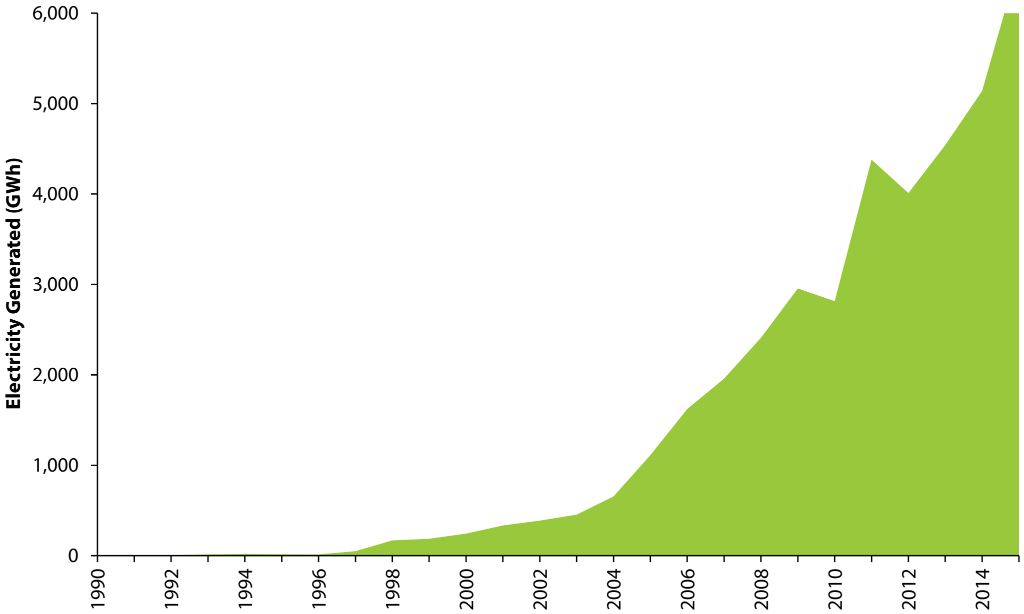
There is currently only one pumped hydro station in Ireland, at Turlough hill. The station comprises four 73 MW generators giving a total capacity of 292 MW. All of the electricity produced from this station is from water that has previously been pumped uphill using electricity and is therefore not classed as renewable. It was not in operation from August 2010 to February 2012 due to scheduled maintenance works. There are also two pumped storage projects with a total capacity of 740 MW in the grid connection application queue[7]. In 2015 288 GWh of electricity was generated at Turlough hill.

3.2.2 Wind Energy

There has been a significant increase in the electricity generated from wind (see Figure 8 and Table 6) since 1997 when the first wind farms were supported by the Alternative Energy Requirement (AER) programme. Total electrical output from wind in 2015 was 6,573[8] GWh representing an increase of 27.9% on 2014. Wind was responsible for 22.8% of gross electrical consumption in 2015 or 21.1% on a normalised basis. The peak recorded wind power output in 2015 was 2,037 MW, delivered on 19th December. At the time of writing the historic peak recorded wind power output[9] was 2,132 MW, delivered on Thursday, 28th January 2016 at which point wind contributed 59% to the instantaneous system demand.

5 EirGrid, *Connected TSO (Non-Wind) Generators*. http://www.eirgridgroup.com/customer-and-industry/general-customer-information/gate-3/
6 ESB Networks, *Distribution Energised Connected Non-Wind*. https://www.esbnetworks.ie/new-connections/generator-connections/generator-connection-statistics
7 See http://www.eirgridgroup.com/customer-and-industry/general-customer-information/connections-and-contracts/
8 Output from both grid-connected wind farms and large auto-producer turbines.
9 System records are updated on the EirGrid website, as well as 15 minute average data on wind power, http://www.eirgridgroup.com/how-the-grid-works/system-information/

Figure 8 *Electricity Generated by Wind (GWh) 1990 – 2015*



Source: EirGrid

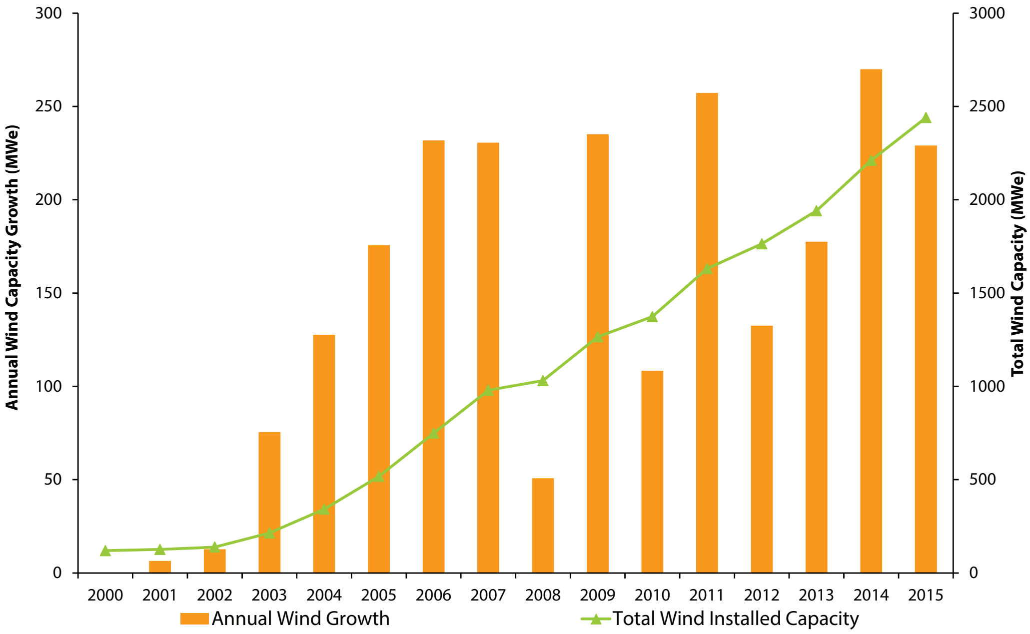
Table 6 *Renewable Electricity Production from Wind*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Wind (GWh)	0	16	244	1,112	2,815	4,380	4,010	4,542	5,140	6,570

Source: EirGrid

Figure 9 traces the evolution of installed wind capacity from 2000 to 2015 (the first wind farms came on line in 1992). It shows the annual incremental capacity added and the cumulative capacity on the Irish transmission and distribution networks.

Figure 9 *Installed Wind Generating Capacity 2000 – 2015*



Source: EirGrid

There was a slowdown in wind farm development in 2008 due to a number of factors, including uncertainty regarding the renewable energy feed-in tariff (REFIT) scheme (which was waiting for EU approval until September 2007) and also in relation to uncertainty surrounding access to finance for wind farm development. The rate of development has varied since then with 229 MW added in 2015, bringing the total installed capacity of transmission and distribution system connected wind farms to 2,440 MW by the end of 2015. This compares to an average level of between 250 and 300 MW/annum (approximately 125 turbines) estimated to be required in 2020 to deliver 40% RES-E[10].

According to the latest contracted generators lists published by EirGrid and ESB Networks, approximately 2,200 MW of wind capacity is contracted to be added to the grid in the period 2016 - 2018..

The contribution of wind energy from small turbines for auto production in industry was 33.1 GWh or just 0.5% of all wind energy generated in 2015. A domestic micro-generation rate is available from Electric Ireland until the end of 2016, with this scheme closed to new entrants since 31st December 2014. Reliable data is not available on the contribution from grid-connected or non-grid-connected domestic turbines, however this is currently considered negligible.

3.2.2.1 Capacity Factors

The capacity factor of wind power is the ratio of average delivered power to theoretical maximum power. It can be computed for a single turbine, a wind farm consisting of dozens of turbines or at the national level consisting of hundreds of farms. At the national level, the rate of capacity increase over the course of the year can significantly impact on the annual capacity factor reported. For instance, if a significant amount of capacity is installed in the last months of the year, then the aggregated capacity factor for the year will appear low as this additional capacity only generated for a fraction of the year.

Estimates of the annual average capacity factor for installed wind capacity in Ireland since 2000 are shown in Table 7. In this calculation the total wind generated electricity produced per annum is divided by the mid-year installed capacity. However, as already mentioned, this method can underestimate the annual capacity factor if the bulk of new capacity is installed and becomes operational in the second half of the year.

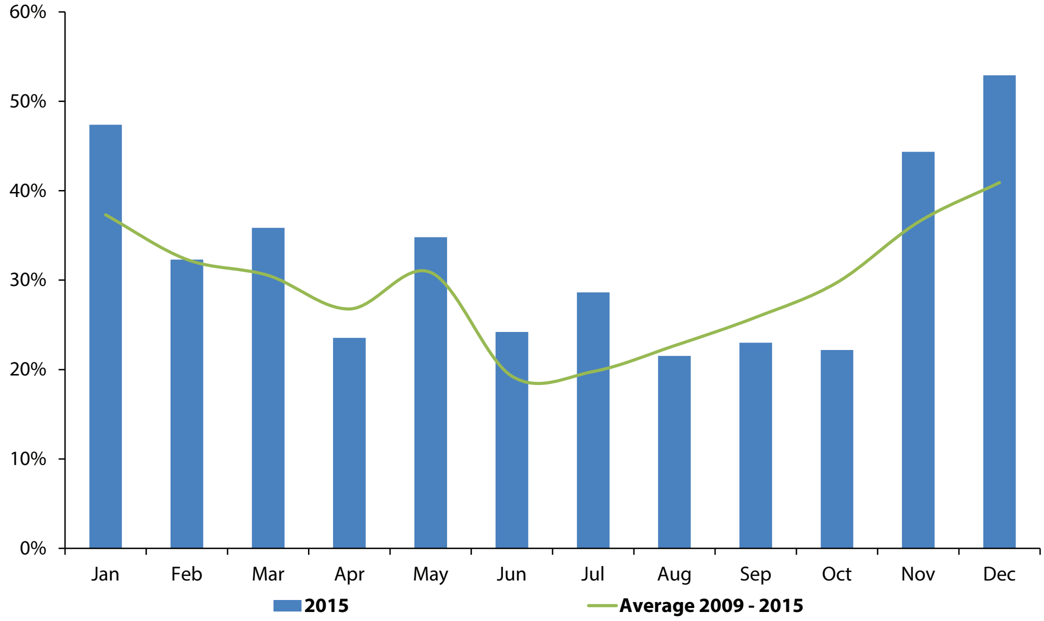
Table 7 *Annual Capacity Factor for Wind Power Generation in Ireland 2000 – 2015*

	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Capacity Factor	30%	30%	30%	28%	29%	29%	24%	33%	27%	28%	28%	32%

Source: EirGrid and SEAI

A more accurate calculation of the capacity factor for Ireland using monthly installed capacities and wind generated electricity was also calculated for 2015 and is shown in Figure 10 alongside the average for 2009 to 2015. The average over the six year period shows a general tendency for the highest capacity factors to be at the start and end of the year, with lower wind generated outputs during the summer months. In 2015 December had the highest capacity factor at 53%, followed by January at 47%

Figure 10 *Wind Generation Capacity—Monthly Capacity Factors 2015*



Source: EirGrid & SEAI

10 SEAI, 2016, *Ireland's Energy Targets: Progress, Ambition & Impacts*, Available from http://www.seai.ie/

3.2.3 Normalisation of Hydro and Wind Energy

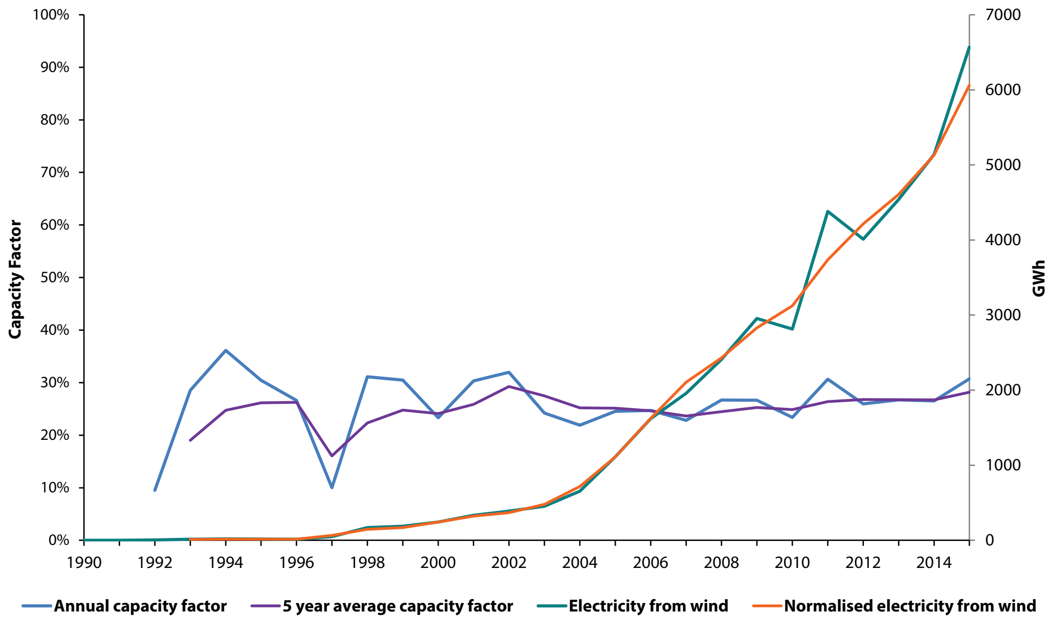
In calculating the contribution of hydro and wind energy for the purpose of the overall 16% target for renewable energy in Ireland by 2020 under the EU Renewable Energy Directive, the effects of climatic variation are smoothed through use of a normalisation rule. The normalisation rule for hydro uses the average capacity factor of the previous 15 years and the installed capacity of the reporting year to calculate the normalised hydro contribution towards the renewable energy targets. Figure 11 shows the individual and normalised data over the 24 years 1990 – 2015.

Figure 11 *Normalised Hydro Energy Contribution 1990 – 2015*

Source: SEAI and EirGrid

The normalisation rule for wind uses the average installed capacity of the reporting year and the previous year multiplied and the average capacity factor of the previous five years. The average five year capacity factor is shown in Figure 12.

Figure 12 *Normalised Wind Energy Contribution 1990 – 2015*



Source: SEAI and EirGrid

3.2.4 Combustible Renewables

3.2.4.1 Solid Biomass

Solid biomass covers organic, non-fossil material of biological origin which may be used as fuel for heat production or electricity generation. It is primarily wood, wood wastes (firewood, wood chips, barks, sawdust, shavings, chips, black liquor[11]) and other solid wastes (straw, oat hulls, nut shells, tallow, meat and bone meal). Most of the solid biomass used in Ireland is for thermal energy purposes where higher efficiencies, relative to power generation, makes the best use of this valuable resource. In electricity generation biomass is primarily used in co-firing with peat in existing power plants, with a small amount also used in Combined Heat and Power (CHP) plants. Edenderry peat-fired power station co-fires biomass, up to a level of 30% average co-firing, supported under REFIT. In 2015, 184 GWh of electricity was produced from the co-firing of biomass in conventional plant while a further 13 GWh of electricity was produced from biomass CHP.

The Government's 2015 White Paper states that future support for biomass will be decided in the context of new support schemes for renewable electricity and renewable heat that are currently under development..

3.2.4.2 Waste to Energy

There is currently one municipal waste-to-energy plant in Ireland which is operated by Indaver and is based in Duleek, Co. Meath. It became operational in 2011 and manages 200,000 tonnes of residual waste per annum with a capacity of 17 MW. There are currently plans for two further waste-to-energy plants to be developed, one in Ringaskiddy, Co. Cork and another in Poolbeg, Dublin. In 2015, 151 GWh of electricity was produced from waste incineration.

3.2.4.2.1 Renewable Municipal Solid Waste

The biodegradable part of municipal solid waste (MSW) produced by households, industry, hospitals and the tertiary sector is considered to be 'renewable biomass'.[12] The quantities used as fuel are reported on a net calorific value basis. If the renewable portion of MSW is not known then a default value of 50% is used. In 2015, 77 GWh of electricity was produced from the combustion of renewable wastes.

3.2.4.2.2 Non-Renewable Municipal Solid Waste

This covers the non-biodegradable part of MSW produced by households, industry, hospitals and the tertiary sector that is incinerated at specific locations. The quantities used as fuel are reported on a net calorific value basis. If the non-renewable portion of MSW is not known then a default value of 50% is used. In 2015, 74 GWh of electricity was produced from the combustion of non-renewable wastes.

3.2.4.3 Biogas

Biogas consists of landfill gas, sewage sludge gas and other biogas produced by anaerobic digestion. Landfill gas is reported separately to biogas in the Irish national energy balance.

In 2015 the biogas figure in the Irish national energy balance consisted largely of estimates of energy generated in waste-water treatment plants and other biogas installations in industry. It should be noted that these are estimates, due to poor response rates to the SEAI annual surveys.

3.2.4.3.1 Landfill Gas

Landfill gas is regarded as a renewable or sustainable energy source for the purposes of meeting targets set down under EU renewable energy targets. Landfill gas in Ireland is only used for electricity generation or is flared directly to the atmosphere. There are 24 landfill gas generators connected to the distribution grid with a Maximum Export Capacity (MEC) of 49 MW and a further 2 MW contracted for connection to the electricity grid.

In 2015, 172 GWh was produced from landfill gas, representing 0.6% of the gross electricity generated.

3.2.4.3.2 Sewage Sludge Gas

Sewage sludge gas is produced in sewage treatment facilities and used on site in CHP plants for own use electricity and for heat treatment of the sewage. In 2015, approximately 21 GWh of electricity was produced from sewage sludge gas in CHP units which equates to just 0.07% of gross electricity generated.

11 This is a recycled by-product formed during the pulping of wood in the paper-making industry.

12 Article 2 (e) of Directive 2009/28/EC.

3.2.4.3.3 Other Biogas

Biogas is produced from the anaerobic digestion of animal slurries, wastes in abattoirs, breweries and other agri-food industries.

There is currently 9 MW installed capacity connected to the electricity distribution network with a further 13 MW contracted or in the queue for connection. In 2015, approximately 8.8 GWh was generated from biogas, or 0.03% of total electricity generated in 2015.

3.2.5 Solar Electricity (Photovoltaic)

There are currently few grid-connected photovoltaic (PV) installations in Ireland although interest in the technology is growing. The cost of PV has been falling dramatically in recent years, with a recent report by the International Renewable Energy Agency (IRENA) noting that solar PV module prices in 2014 were around 75% lower than at the end of 2009[13,14]. For installations using certified products installed by competent personnel solar PV performs reliably to provide viable contributions to renewable electricity generation.

Official recognition that solar PV is a viable renewable energy generation option in Ireland has been demonstrated in the following ways:

- Over €2m of funding has been committed to solar projects since 2005 under the SEAI RD&D programme. This includes grants for research as well as larger demonstration projects, including a 300kW solar PV array, the largest installation in Ireland.
- The energy contribution of a solar PV array may be included in the calculation of the renewable energy contribution within a building to comply with Part L of the Building Regulations for new buildings. It is now generally recognised that solar PV may, in many cases, represent the least cost option for meeting the Part L renewable energy contribution requirement.
- The contribution of a solar PV array to reducing a building's annual electricity demand and CO_2 emissions is included in the Building Energy Rating and a calculation routine for the estimation of this is included within the associated DEAP software.
- Solar PV products meeting the required European and international standards are listed on the SEAI Triple E Register for accredited energy-efficient equipment. Listed solar PV products qualify for a favourable depreciation regime for corporation tax under the Accelerated Capital Allowances scheme and for VAT refunds when installed for agricultural use by farmers. Public bodies are also obliged to purchase Triple E listed products when procuring relevant equipment items.
- SEAI recommends solar PV panels as an option for consideration in its literature and publications on renewable energy and on low carbon buildings.
- SEAI formed a Standards Development Group to develop FETAC micro-generation award standards for installer training courses, including courses for solar PV installers. Final award specifications were provided to FETAC for training awards, which are now FETAC accredited, for the following courses.
  - Implementation of micro solar PV systems
  - Electrical Installation of micro-generators
- Solar technology is one of the technologies being considered in the context of the new support scheme for renewable electricity generation which will be available in 2017, as detailed in the 2015 Energy White Paper.

There is currently 24 MW solar PV contracted for connection to the electricity grid. A further 3GW in generation applications has been submitted to the distribution and transmission systems in 2015 and 2016.

A single electricity supplier, Electric Ireland, voluntarily offered a domestic micro-generation rate[15] of €0.09 per kWh for micro-generation exported to the grid, including domestic solar PV, until the end of 2016. This scheme has been closed to new entrants from 31st December 2014.

The total number of micro-generation grid-connected PV installations at the end of 2015 was 412, with a total installed capacity of 1,075 kW. Electricity generated from solar PV is included in the national energy balance from 2009 and includes estimates for stand-alone commercial installations. In 2015, 1.6 GWh was generated from solar, representing 0.01% of the gross electricity generated.

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13 Available from http://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Power_Costs_Summary.pdf

14 See also Bazillian et. al., 2012, Reconsidering the Economics of Photovoltaic Power. http://www.bnef.com/WhitePapers/download/82

15 Details available from https://www.electricireland.ie/ei/residential/price-plans/micro-generation-scheme.jsp

3.2.6 Ocean Energy

3.2.6.1 Tidal Energy

The accessible tidal resource in Ireland is determined by the availability of suitable sites with appropriate depth, tidal stream speeds and also by commercial constraints. A strategic environmental assessment, published as part of Ireland's Offshore Renewable Energy Development Plan (OREDP)[16] in 2014, indicates that there is potential for between 1,500 MW and 3,000 MW of tidal energy development to occur without significant effects on the environment. However, these levels of deployment were not assessed from a technical or commercial feasibility perspective.

An Irish company (OpenHydro) was the first company to install a tidal energy device in the European Marine Energy Centre (EMEC) off the Scottish coast in 2006. They have since progressed to installing two grid-connected 2 MW turbines as part of the Paimpol-Bréhat array in France in early 2016. Part of OpenHyrdo's future project portfolio includes a 100 MW development off Torr Head on the north coast of Antrim. Another Irish company DP Energy are also proposing to develop a 100 MW project near Fair Head, Co. Antrim.

3.2.6.2 Wave Energy

Ireland has one of the most energetic wave climates in the world. The OREDP indicates that there is potential for up to 17,500 MW of wave energy development to occur without significant effects on the environment. However, these levels were not assessed from a technical or commercial feasibility perspective.

The Government has an ambition for Ireland to be a world leader in the development of wave energy. A key attribute in the ongoing effort to realise these goals, is the presence, continued improvement and expansion of several outstanding test and demonstration facilities[17] covering each stage of offshore renewable energy technology development. These facilities include: the LIR National Ocean Test Facility (NOTF) in Ringaskiddy, Co. Cork; the ¼-scale Marine and Renewable Energy Test Site located within the confines of Galway Bay, and; the Atlantic Marine Energy Test Site (AMETS) off the coast of Belmullet, Co. Mayo.

While there are several different wave energy device prototypes in development, a commercial wave energy device does not yet exist. According to the 2015 Energy White Paper, given the current state of readiness of these technologies, it is not anticipated that wave and tidal will make a large contribution in the short term. Significant steps are being taken at the early stage of R&D however, and SEAI has supported over 80 early stage ocean energy projects through its Prototype Development Fund[18] since 2009.

16 DCCAE, 2014, Offshore Renewable Energy Development Plan. http://www.dccae.gov.ie/energy/SiteCollectionDocuments/Renewable-Energy/20140204%20DCENR%20-%20Offshore%20Renewable%20Energy%20Development%20Plan.pdf

17 For more information see http://www.seai.ie/Renewables/Ocean-Energy/Ocean-Energy-Test-Sites-in-Ireland/

18 For more information see http://www.seai.ie/Renewables/Ocean-Energy/Prototype-Development-Fund/

4 Progress Towards Targets

The EU Renewable Energy Directive sets out two mandatory targets for renewable energy in Ireland to be met by 2020, as follows:

- at least 16% of Ireland's gross final energy consumption to come from renewable sources;
- at least 10% of energy consumed in road and rail transport to come from renewable sources.

In addition to these EU mandatory targets, Ireland has national targets for 2020 for electricity and heat, as follows:

- RES-E—40% of gross electricity consumption to come from renewable sources;
- RES-H—12% of thermal energy to come from renewable sources.

Table 8 tabulates progress towards the RES-E target and to the overall EU Renewable Energy Directive target for the period 1990 to 2015. Here the percentages in RES-E relate to the specific modal target and the percentages in the final row relate to the overall target, using the definition in the EU Renewable Energy Directive. Looking at the contribution of renewables in 2015 it can be seen that for both electricity generation (RES-E) and the overall renewables targets, Ireland is over half way towards meeting the 2020 targets.

Table 8 *Renewable Energy Progress to Targets 1990 – 2015*

% of each target	1990	2000	2005	2010	2011	2012	2013	2014	2015
RES-E (normalised)	5.3	4.8	7.2	14.6	17.4	19.7	21.0	22.9	25.3
Overall RED	2.3	2.0	2.8	5.6	6.5	7.1	7.6	8.6	9.1

Source: SEAI

In 2015 the overall renewable energy contribution to gross final consumption was 9.1%. The RED target is 16% in 2020.

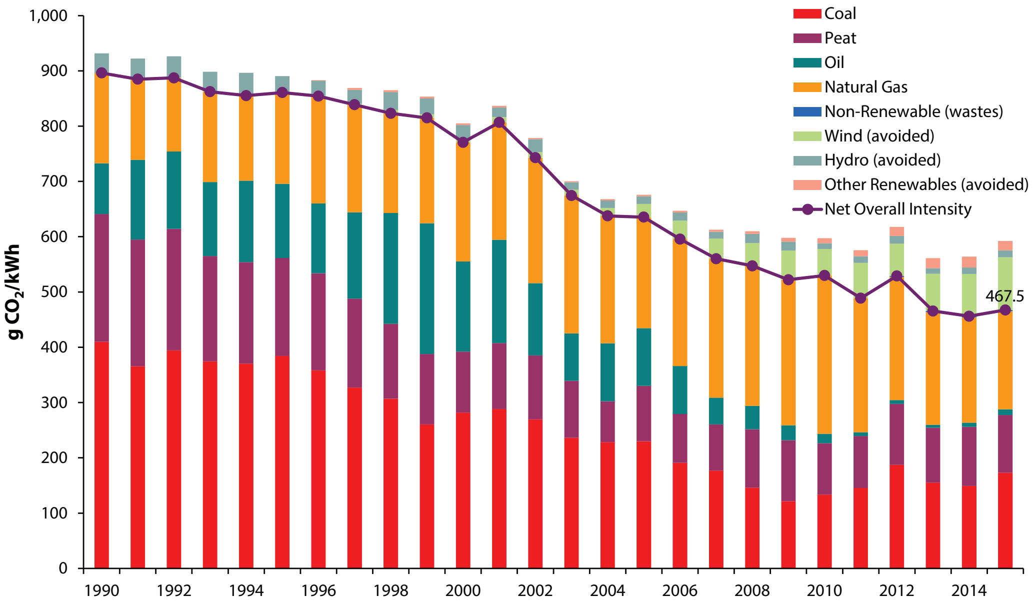
The share of electricity from renewable energy was 25.3% (normalised) in 2015. The RES-E target is 40% in 2020.

5 CO_2 Intensity and Avoided Emissions

Shifts in electricity generating technology in recent years and fuel mix have resulted in changes in the CO_2 emissions per kWh of electricity supplied, as illustrated in *Figure 13*.

Figure 13 shows as stacked bars the shares of the various fuels contributing to the overall emissions intensity of electricity generation from 1990 to 2015 as well as the reduction in intensity as a result of emissions avoided by renewable generation from wind, hydro and other renewables. It is important to note that this graph represents the shares of the fuels to the overall intensity and not the intensity of the generation by the individual fuels themselves. The net overall intensity is shown as a line graph in *Figure 13.*

Figure 13 *CO_2 Emissions per kWh of Electricity Supplied; with Contributions by Fuel*



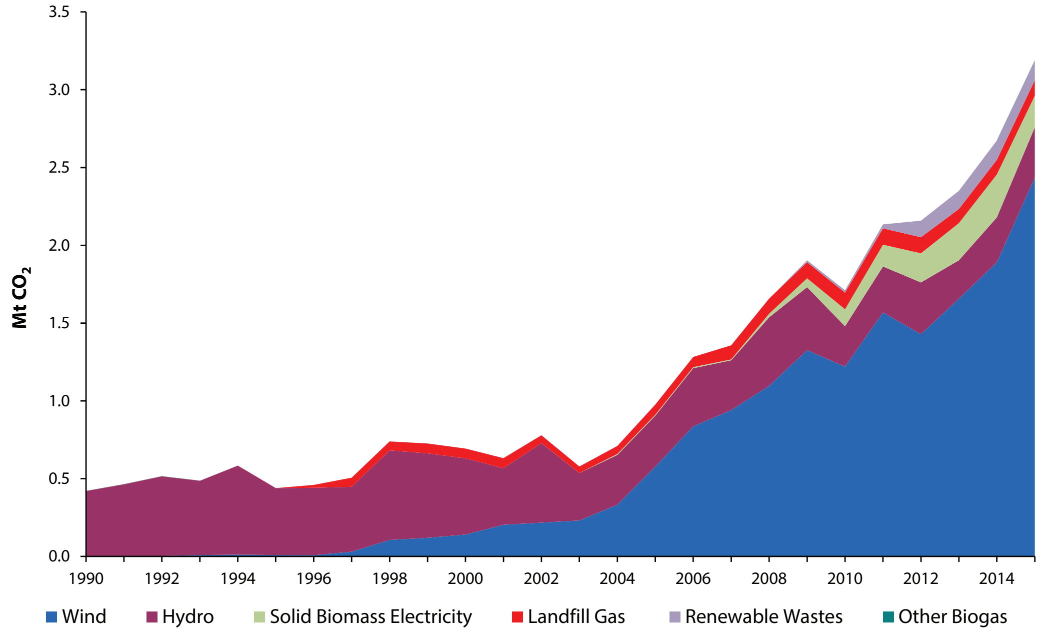
Since 1990 the share of high carbon content fuels, such as coal and oil, has been reducing with a corresponding rise in the relatively lower carbon natural gas and zero carbon renewables. Imported electricity is also considered zero carbon in terms of reporting national greenhouse gas emissions under IPCC and EU legal reporting obligations. This resulted in the carbon intensity of electricity dropping by 49%, from 896 g CO_2/kWh in 1990, to a new low of 456 g CO_2/kWh in 2014. However, this increased by 2.5% in 2015 to 467.5 CO_2/kWh mostly due to increased use of coal for electricity generation which grew by 19.6% in 2015.

The avoided carbon emissions by renewable energy generation are estimated using the Primary Energy Equivalent approach. The methodology used to calculate the PEE is included in Appendix 1. The results obtained using the PEE methodology have been further refined, using the results of a more detailed dispatch model of the entire all-Island electricity system, developed by SEAI for the year 2012[19], so that the effects of ramping and cycling of fossil fuel plant, though small, are accounted for.

Figure 14 shows the trend in avoided CO_2 emissions from renewable energy in electricity generation for the period 1990 – 2015. Renewable energy in electricity generation is estimated to have avoided greenhouse gas emissions of 3,188 ktCO_2 in 2015, as illustrated in Figure 14. The emissions avoided from wind energy deployment have increased considerably since 2004. It is estimated that in 2015 emissions avoided by wind energy was most significant at 2,436 ktCO_2, followed by hydro at 323 ktCO_2, solid biomass at 203 ktCO_2.

19 See the SEAI report *Quantifying Ireland's Fuel and CO_2 Emissions Savings from Renewable Electricity in 2012* for further details on the methodologies used to calculate the avoided emissions, http://www.seai.ie/Publications/Statistics_Publications/Energy_Modelling_Group_Publications/Quantifying-Ireland%E2%80%99s-Fuel-and-CO2-Emissions-Savings-from-Renewable-Electricity-in-2012.pdf

Figure 14 *Avoided CO_2 from Renewable Energy in Electricity Generation 1990 – 2015*



Source: SEAI

Glossary of Terms

Biogas: A gas composed principally of methane and carbon dioxide produced by anaerobic digestion of biomass, comprising: sewage sludge gas, produced from the anaerobic fermentation of sewage sludge, and other biogas, such as biogas produced from the anaerobic fermentation of animal slurries and of wastes in abattoirs, breweries and other agri-food industries.

Biomass: The biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste.

Carbon Dioxide (CO_2): A compound of carbon and oxygen formed when carbon is burned. Carbon dioxide is one of the main greenhouse gases. Units used in this report are t CO_2 (tonnes of CO_2), kt CO_2 (kilo-tonnes of CO_2 {10^3 tonnes}) and MtCO_2 (mega-tonnes of CO_2 {10^6 tonnes}).

Combined Heat and Power (CHP) Plants: Combined heat and power (CHP) refers to plants which are designed to produce both heat and electricity. CHP plants may be autoproducer (generating for own use only) or third-party owned selling electricity and heat on-site as well as exporting electricity to the grid.

Gross Final Consumption (GFC): The Renewable Energy Directive (2008/28/EC) defines gross final consumption of energy as the energy commodities delivered for energy purposes to manufacturing industry, transport, households, services, agriculture, forestry and fisheries, including the consumption of electricity and heat by the energy branch for electricity and heat production and including losses of electricity and heat in distribution.

Gross Electrical Consumption: Gross electricity production is measured at the terminals of all alternator sets in a station; it therefore includes the energy taken by station auxiliaries and losses in transformers that are considered integral parts of the station. The difference between gross and net production is the amount of own use of electricity in the generation plants.

Hydropower: Potential and kinetic energy of water converted into electricity in hydroelectric plants. Pumped storage is treated separately in the national energy balance. The Renewable Energy Directive 2009/28/EC states that electricity produced in pumped storage units from water that has previously been pumped uphill should not be considered to be electricity produced from renewable energy sources.

Kilowatt Hour (kWh): The conventional unit of energy whereby electricity is measured and charged for commercially. Related units are megawatt hour (MWh) and gigawatt hour (GWh) which are one thousand and one million kWhs respectively.

Landfill Gas (LFG): A gas composed principally of methane and carbon dioxide produced by anaerobic digestion landfill wastes.

Meat and Bone meal: Produced when offal, carcasses and butchers' wastes are processed at rendering plants.

Microgeneration: A microgenerator might use any one of the following technologies to generate electricity: wind turbine, photovoltaic panels (also known as solar electric panels), micro-hydro (scaled down version of hydro-electricity station), micro-CHP (fuelled by bio or fossil fuels). In Ireland microgeneration is classified by ESB Networks as grid-connected electricity generation up to a maximum rating of 11 kW when connected to the three-phase grid (400 V). The vast majority of domestic and agricultural customers are connected at single phase (230V) and for these customers to be classified as microgenerators the maximum rating permitted is 5.75 kW. These ratings are in line with Irish conditions prescribed in European standard EN50438.

Photovoltaic Energy (PV): Energy from solar electric panels. Solar radiation is exploited for electricity generation by photovoltaic cells which convert the solar radiation into DC current.

RES-E: Renewable energy sources in electricity.

RES-H : Renewable energy sources of heat/thermal energy.

RES-T: Renewable energy sources used for transportation.

Solar PV: See Photovoltaic Energy

Solid Biomass: Covers organic, non-fossil material of biological origin which may be used as fuel for heat production or electricity generation. It comprises: (a) charcoal, covering the solid residue of the destructive distillation and pyrolysis of wood and other vegetal material and (b) wood, wood wastes and other solid wastes, covering purpose-grown energy crops (poplar, willow etc.), a multitude of woody materials generated by an industrial process (wood/paper industry in particular) or provided directly by forestry and agriculture (firewood, wood chips, bark, sawdust, shavings, chips, black liquor etc.) as well as (c) wastes such as tallow, straw, rice husks, nut shells, poultry litter, crushed grape dregs etc. Combustion is the preferred technology for these solid wastes. The quantity of fuel used is reported on a net calorific value basis.

Tallow: The fatty tissue or suet of animals.

Tonne of Oil Equivalent (toe): This is a conventional standardised unit of energy and is defined on the basis of a tonne of oil having a net calorific value of 41686 kJ/kg.

Total Final Consumption (TFC): This is the energy used by the final consuming sectors of industry, transport, residential, agriculture and tertiary. It excludes the energy sector such as electricity generation and oil refining etc.

Total Primary Energy Requirement (TPER): This is the total requirement for all uses of energy, including energy used to transform one energy form to another (e.g. burning fossil fuel to generate electricity) and energy used by the final consumer.

Wind Energy: Kinetic energy of wind exploited for electricity generation in wind turbines.

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Appendix 1 Primary Energy Equivalence Methodology

The primary and final energy consumption for non-combustible renewable energy sources such as wind and hydro is very similar. For most combustible fuels this is not the case, due to the energy conversion losses associated with electricity generation. Depending on the efficiency of electricity generation, typically between 25% and 55% of the energy content of the fuel input into power plants is output in the form of electricity.

The primary energy of fossil fuels and combustible renewables is defined as the calorific content of the fuel, according to internationally agreed methodologies for presenting energy statistics[20]. For non-combustible renewable sources (wind and hydro) the primary energy is considered to be equivalent to the quantity of electricity generated. This follows the IEA principle that the primary energy should be the first energy form downstream in the production process for which multiple energy uses are practical. This allows for harmonised international comparisons, but it does not accurately represent how fossil fuels used for electricity generation are displaced by non-combustible renewable energy. This is because, in primary energy terms, the fuel input into a fossil fuel plant is currently considered to be equivalent to the electricity output from a non-combustible renewable energy plant, such as a wind farm or hydropower plant.

An alternative approach is to consider the primary energy of the non-combustible renewable source to be equivalent to the primary energy of the fuel that would have been required to produce the same amount of electricity. This is the principle behind the primary energy equivalent (PEE) method. By quantifying the combustible fuel displacement achieved by renewable energy, the environmental benefits and indeed the security of supply benefits may be quantified and used to inform policy decisions.

This raises a key question, however—what electricity generation is being displaced by renewable energy-generated electricity? This is a critical factor as different fossil fuel types and power plants have significantly different energy efficiencies and carbon intensities. For example displacing generation from an inefficient, CO_2 intensive coal powered plant will lead to significantly greater energy and carbon emissions reductions than displacing generation from a more efficient gas powered plant. Previously[21], the calculation of PEE was based on the assumption that each kWh of electricity generated from non-combustible renewable generation displaced a kWh of electricity from across the entire fossil fuel plant mix. The methodology used now draws on approaches that have been developed for use in baselining studies in credit-based emissions trading systems[22,23]. Renewable energy plants are primarily displacing electricity from the last fossil fuel plant dispatched to meet electricity demand. In the Republic of Ireland this comprises primarily of gas-fired plant. Calculating the PEE based on such plant provides a more accurate estimate than using the entire plant mix and the approach is known as the Operating Margin Approach.

A key limitation of this methodology is that it ignores the interaction between renewable electricity generation and both fossil generation and cross-border trade. A much more detailed and sophisticated analysis of the amount of fossil fuels and carbon emissions that are avoided by renewable energy was carried out by SEAI for a single year (2012) using a detailed dispatch model. This work is presented in the SEAI report *Quantifying Ireland's Fuel and CO_2 Emissions Savings from Renewable Electricity in 2012* which was published in May 2014[24,25]. The advantage of such a model is that it is capable of comprehensively accounting for the extensive range of dynamic factors that influence the interaction of renewable plant and fossil fuel generators and which affect the savings attributed to renewable generation, such as ramping and cycling effects, contingency reserve, network constraints, cross-border electricity trade etc. The disadvantage of dispatch models is that because of the level of detail involved they are very labour intensive to build, update and maintain. For this reason it is not practical to routinely use a dispatch model to estimate the annual avoided fossil fuel usage and carbon emissions from renewable energy. Instead, the results of the single year analysis using the dispatch model have been used to inform and refine the results of the simplified PEE approach, in particular by enabling the emissions resulting from ramping and cycling of fossil fuel plant in response to renewable electricity generation to be estimated and accounted for. There are clear limitations in this analysis but it does provide useful indicative results.

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22 Kartha S., Lazarus M. and Bosi M., 2004, *Baseline Recommendations for Greenhouse Gas Mitigation Projects in the Electric Power Sector,* Energy Policy 32, 545 - 566

23 For further information on Ireland see Ó Gallachóir B. P., O'Leary F., Bazilian M., Howley M. and McKeogh E. J., *Comparing Primary Energy Attributed to Renewable Energy with Primary Energy Equivalent to Determine Carbon Abatement in a National Context.* Journal of Environmental Science and Health Part A: Toxic /Hazardous Substances and Environmental Engineering, Vol. 41, No. 5

24 See http://www.seai.ie/Publications/Statistics_Publications/Energy_Modelling_Group_Publications/Quantifying-Ireland%E2%80%99s-Fuel-and-CO2-Emissions-Savings-from-Renewable-Electricity-in-2012.pdf

25 See also Di Cosmo V. and Malaguzzi Valeri L., October 2014, *ESRI Working Paper No. 493 – The Effect of Wind on Electricity CO_2 Emissions: The Case of Ireland*, ESRI.

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