Chapter 12
Environment and Energy

Environment and Energy

1. Introduction

Our health, environment and climate are significantly affected by how we source, manage and use energy. In Ireland, energy use has changed remarkably since the foundation of the state. Access to low-cost energy and technological development have improved our quality of life and been a key enabler of economic and social development. Further transformation of Ireland's energy systems is required if these social and economic gains are to be maintained and enhanced.

Electrification in the 1950s provided widespread access to the multitude of uses to which electricity can be applied. These uses have accelerated in recent decades through the development of consumer electronics, digital systems and the digital economy. When it was commissioned in 1929, hydropower from the Ardnacrusha power station, on the River Shannon, was the main source of electrical energy in Ireland. As a consequence of the growing demand for the convenience and cleanness of electricity, its contribution was increasingly overtaken in subsequent decades by electricity generation based on combustion of coal, oil, peat and gas. Wind power has recently become an important part of the energy mix, with coal and peat being phased out.

Transport and heating systems are largely based on the direct combustion of fossil fuels. Clean electric-powered heating and transport systems are becoming increasingly available; however, accelerated uptake of these clean systems is needed.

As a consequence, Ireland's energy systems are highly reliant on fossil energy and are largely dependent on fossil fuel systems, with lock-ins that need to be addressed. The dangers of fossil energy use for the stability of our climate, as well as its impacts on human health and the environment, are well understood. Reversing the current fossil energy lock-in and transitioning to renewable and sustainable energy sources is a challenge. It also provides a unique social and economic opportunity for sustainable development, with multiple benefits for human health, the environment and the stability of our climate. These issues are explored here through an assessment of the main activities by which energy is provided and consumed in Ireland, with a focus on electricity generation, transport and heating.

> Lock-in is defined as a situation in which the future development of a system, including infrastructure, technologies, investments, institutions and behavioural norms, is determined or constrained ('locked in') by historic developments (IPCC, 2018). Here we are specifically referring to fossil energy lock-in.

2. Energy Use, Human Health and Environmental Protection[1]

Energy use is central to all human activities; however, the energy choices we make and solutions that we adopt give rise to very different health and environmental outcomes.

Combustion-related energy use releases environmentally damaging by-products that have significant adverse impacts on human health, the climate and our environment. Addressing the range of adverse impacts caused by our energy use, while maintaining and enhancing our lifestyles, health and wellbeing, is a central element of a series of United Nations (UN) conventions and global policies, as well as key European Union (EU) and national policies (section 3). The approaches taken can be summarised as follows:

- reducing energy waste and loss through increasing energy efficiency
- reducing emissions through mitigation technologies (e.g. sulphur removal and carbon capture and storage)
- switching to clean and sustainable energy solutions.

The last of these would include energy from non-combustion sources, such as hydropower, wind or solar energy, and use of hydrogen. These do not give rise to combustion-related impacts, but there is a need to be cognisant of their social and environmental impacts. The issues are outlined here, with some being explored in more detail in Chapters 2 Climate, and 11 Transport.

1 https://www.eea.europa.eu/publications/transforming-the-eu-power-sector

The main climate and environmental impacts of the combustion of fossil fuels include:

- the direct production of reactive gases such as nitrogen oxides, sulphur dioxide and particulates, including black carbon (soot/diesel particulates)
- the production of secondary pollutant gases and particulates such as ozone, ammonium nitrate, ammonium sulphate and condensed compounds such as organic carbons
- the release of heavy metals such as mercury and the formation of persistent organic pollutants (POPs) such as polycyclic aromatic hydrocarbons, which build up in ecosystems and in food chains
- the release of greenhouse gases (GHGs) such as carbon dioxide and methane.

The relative impacts on air quality and climate change depend on the fossil fuel used and its quality. The combustion of solid fuels, such as coal and peat, has the largest impacts and gas combustion has the lowest impacts, with the combustion of liquid fuels typically having intermediate impacts. The most immediate impacts are local, over timescales of seconds to days. Acidification, ozone production and the build-up of heavy metals occur over longer periods of time and are regional and hemispheric in scale (Chapter 3).

Emissions of GHGs have global impacts over long periods of time, from decades to centuries or longer (e.g. fossil carbon dioxide emissions disrupt the natural carbon cycle in the atmosphere, oceans and land for centuries to millennia). This is the key driver of climate change and ocean acidification (Chapter 2). At a global level important negative impacts and risks are associated with the extraction, processing, transport and storage of fossil fuels (Olson and Lenzmann, 2016).

The combustion of biofuels can also result in significant emissions. These vary with fuel type and the combustion system used. Such emissions are being addressed through processes such as the Biofuels Obligation Scheme (DCCAE, 2019) (Table 12.1). However, sustainably produced biofuels, such as wood, biogas and ethanol, have reduced impacts on the climate system. The use of such fuels with mitigation technologies such as carbon capture and storage can provide significant negative emissions of carbon dioxide, which are required to prevent the dangerous impacts of climate change (IPCC, 2018).

Nuclear energy is not produced in Ireland. Ireland is one of a number of EU Member States that does not have nuclear power in its domestic electricity generation mix. Nuclear power generation in Ireland is currently prohibited by legislation. The potential dangers of waste produced by nuclear fission are well known, as is the need for safe management of these wastes with strong national and international oversight bodies.

3. European Union and National Energy Policy

Ireland is not positioned to meet its 2020 renewable energy target. Further steps are needed to meet its 2030 targets, and beyond.

Historically, energy policy has been based mainly on issues of supply, security and price. The industrial revolution led to the widespread use of fossil energy in various forms across all economic sectors. The implications of this for our environment, human health and climate are increasingly apparent. As outlined in Topic Box 12.1, UN conventions on a range of international policy issues have emerged to address these implications. However, it is action to address climate change that requires the most radical developments in energy policy. More specifically, there is a requirement to achieve net zero carbon dioxide emissions in order to protect the climate system (and achieve climate neutrality goals).

This imperative provides the basis for EU climate and energy policy as well as national policy, as articulated in the 2015 White Paper, Ireland's Transition to a Low Carbon Energy Future 2015-2030 (DCCAE, 2015). It is also central to the EU Green Deal (EC, 2019a) and proposed EU climate legislation (EC, 2020). The Green Deal includes the EU 2050 climate neutrality goal, which constitutes the basis for the EU long-term strategy under the Paris Agreement (UNFCCC, 2015). Similarly, EU Member States, including Ireland, will submit Long-Term Emissions Strategies (LTES)[2] under the 2015 Paris Agreement. These should reflect the messages from science on emissions pathways so that the Paris Agreement and EU climate goals can be achieved (Chapter 2).

By setting an emissions and energy pathway to 2050, the LTES provide a framing for shorter term actions to 2030, under the Paris Agreement Nationally Determined Contribution process (UNFCCC, 2015). The first EU Nationally Determined Contribution is based on its climate and energy package for the period 2020-2030. The level of ambition in this package may be increased under the EU Green Deal (Chapter 2).

At a national level, Ireland's energy policy remains as articulated in the energy White Paper, *Ireland's Transition to a Low Carbon Energy Future 2015-2030* (DCCAE, 2015), which would ultimately see a move away from fossil fuel use. The National Policy Position on climate change (Government of Ireland, 2014) includes energy in its ambition to reduce carbon dioxide emissions by at least 80 per cent by 2050. These policy goals have been expanded under the National Mitigation Plan (Government

2 The Paris Agreement and associated UN Framework Convention on Climate Change decisions require the development and submission of long-term low GHG emission development strategies.

of Ireland, 2017) and the Climate Action Plan (Government of Ireland, 2019), which contain a series of actions to reduce GHG emissions and include an assessment of how effective carbon pricing will contribute to the required energy transition.

Ireland has specific energy targets under the 2020 climate and energy package (EC, 2009). This sets out targets for the share of energy from renewable sources being consumed and used in transport by 2020. The share of renewable energy use in electricity and heating is determined nationally. The Renewable Energy Share (RES) target includes subsidiary targets for electricity (RES-E), transport (RES-T) and heat (RES-H). The overall RES target for 2020 is 16 per cent. The subsidiary targets are 40 per cent, 10 per cent and 12 per cent for RES-E, RES-T and RES-H, respectively. Currently, Ireland is not on track to achieve these targets, with RES-E at 33 per cent, RES-T at 7.4 per cent and RES-H at 6.5 per cent in 2018, with the contribution from renewable energy to final energy consumption at 11.0 per cent (SEAI, 2019a).

After 2020, Ireland will establish revised targets that are aligned with its national contribution to achievement of the EU-wide targets of at least a 32 per cent share for renewable energy and at least a 32.5 per cent improvement in energy efficiency. Under the Climate Action Plan (Government of Ireland, 2019), a target of 70 per cent for renewable electricity has been established for 2030. The level of national ambition is outlined in the 2020 National Energy and Climate Plan (Topic Box 12.1).

Topic Box 12.1 National Energy and Climate Plan 2021-2030

Ireland's National Energy and Climate Plan 2021-2030 (NECP)[3] published in 2020, recognises the need for a rapid transition to a net zero-carbon energy system. It outlines the policy goals to facilitate an energy transition to a low carbon energy system, providing secure supplies of competitive energy to citizens.

The objectives of the NECP are framed by the EU net-zero target for 2050 and outlined according to the key dimensions of the EU Energy Union. They are articulated under the following headings: decarbonisation, energy efficiency, energy security, the energy market and research, innovation and competitiveness. The objectives include:

Decarbonisation: GHG Emissions and Removals

- Reduce emissions from sectors outside the EU's Emissions Trading System by 30 per cent (relative to 2005 levels) by 2030.

Decarbonisation: Renewable Energy

- Achieve a 34 per cent share of renewable energy in energy consumption by 2030.
- Increase electricity generated from renewable sources to 70 per cent with at least 3.5 GW coming from offshore renewable energy, up to 1.5 GW coming from grid scale solar energy and up to 8.2 GW coming from onshore wind capacity.

Energy Efficiency

- Contribute towards the EU target of achieving at least a 32.5 per cent improvement in energy efficiency by 2030 and the aims established under the Energy Efficiency Directive.

Energy security

- Maintain the security of Ireland's energy system in the most cost-effective manner.

Internal energy market

- Deepen the integration of Ireland's wholesale electricity market, and its regulation, with the EU internal energy market.
- Develop further interconnection to facilitate Ireland's 2030 target of 70 per cent renewable electricity.
- Further align Ireland's retail electricity market with the EU internal energy market.
- Support customers' participation in the energy system, enabling them to sell excess electricity they have produced back to the grid.

Research, innovation and competitiveness

- Ensure that the best scientific evidence and advice is available to underpin government policy and support the policies and measures in Ireland's NECP.
- Develop and deploy new low-emissions technologies in the coming years.

3 https://www.gov.ie/en/publication/0015c-irelands-national-energy-climate-plan-2021-2030/

United Nations Energy – Related Policy Development

The dangers of smoke and fumes from energy-related combustion have been known for a long time, with various ventilation systems being used to reduce immediate impacts. These issues became more critical during the 20th century, when the impacts of smog on human health and mortality resulted in air quality policies being adopted at city or national levels (Chapter 3).

In the 1970s the impacts of sulphur and other emissions at a continental scale resulted in the first international convention to address these impacts (i.e. the 1979 United Nations Economic Commission for Europe Convention on Long-range Transboundary Air Pollution; UNECE, 1979). It initially focused on acidification linked to sulphur produced by coal combustion and its impacts but has evolved to address wider issues, including particulate matter (PM), ozone, POPs and heavy metals.

The global impacts of fossil emissions of GHGs were addressed in the 1992 UN Framework Convention on Climate Change (UNFCCC, 1992). Actions were advanced under the 1997 Kyoto Protocol, in which developed nations agreed to reduce their emissions of key GHGs. The 2015 Paris Agreement has global reach and aims to reduce GHG emissions to net zero during this century.

The 2013 Minamata Convention (UNEP, 2013) addresses the global impacts of mercury release, including that from fossil fuel combustion. Related EU policies are outlined in Chapters 2 and 3. These conventions and protocols inform and frame EU and national energy policy.

In addition, the UN Sustainable Development Goals, adopted in 2015, include targets to increase substantially the share of renewable energy in the global energy mix and to promote investment in energy infrastructure and clean energy technology.

4. Energy Consumption in Ireland

Combustion of mainly imported fossil fuels made up 89 per cent of Ireland's total energy use in 2018. Locally produced renewable energy made up about 10 per cent of energy used.

Since the formation of the state, energy consumption[4] in Ireland has increased substantially as our population has grown, our technologies have advanced, and our economic activity has increased. Energy consumption data from 1990 to 2018 are shown in Figure 12.1. These data show that peak energy consumption occurred in 2008, at 190,116 megawatt-hours (MWh). Fossil energy, including coal, oil and peat combustion, made up 96 per cent of the energy consumed. Renewable energy contributed just 4 per cent of the energy consumed (SEAI, 2019a).

Energy demand dropped significantly during the financial crisis but has been increasing since 2014 as economic activity has increased. In 2018, energy consumption in Ireland was 170,414 MWh. This remains lower than in 2008 while economic activity, as measured by gross domestic product, was 8.2 per cent and higher than before the economic crisis. Energy efficiency policy and actions are likely to have contributed to these changes on the energy demand side.

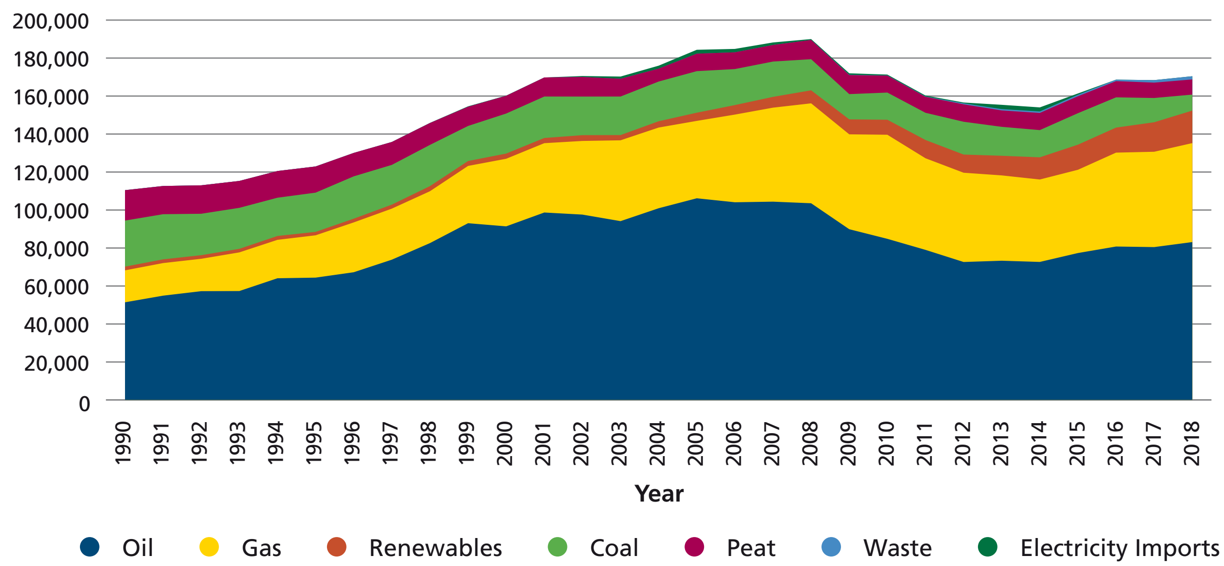
In 2018, combustion of fossil fuels made up 89 per cent of Ireland's total energy use. Renewable energy, including biomass, made up 10 per cent, with the residual 1 per cent being non-renewable waste. This percentage of renewable energy has increased significantly relative to 2008 but remains low compared with the European average of just under 20 per cent.[5] Taking fossil energy out of Ireland's energy system by 2050 would require an annual increase in renewable energy use of 2-3 per cent of total energy use.

Current Energy Use in Key Sectors

Fossil energy use is consistently Ireland's largest greenhouse gas emissions (carbon dioxide) source and the main source for a number of key air pollutants.

The impacts of energy use vary across sectors and energy type. Location and timing can vary, resulting in different exposure profiles. A summary of the main energy uses in 2018 is shown in Table 12.1, along with the emissions of carbon dioxide and air pollutants. In 2018, most energy was used in transport, with 94 per cent of this being provided by the direct consumption of fossil fuels. Heating was the second largest energy use, with oil and gas being the main energy types used. Electrical power generation consumed about 31 per cent of total primary energy. Owing to losses, about 20 per cent is available for use by customers (SEAI, 2019a).

Figure 12.1 Energy consumption (MWh) according to the main fuel types in Ireland from 1990 to 2018 (Source: SEAI)



4 *Here, primary energy consumption means total energy consumed including energy lost in generation, processing and transmission, which is not available to consumers. This lost energy makes up about 18 per cent of the total consumed energy.*

5 https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Share_of_energy_from_renewable_sources_2018_infograph.jpg

Table 12.1 Energy use in 2018 and emissions of carbon dioxide, particulate matter and nitrogen oxides (Source: EPA)

FUEL TYPE	KEY POLLUTANTS LINKED TO FOSSIL ENERGY USE							
	Energy		Carbon dioxide		Fine particulate matter ($PM_{2.5}$)		Nitrogen oxides	
	PJ[a]	% share	kt	% share	kt	% share	kt	% share
Liquid fuels	**255.2**	**47.5**	**18,602**	**51.7**	**2.43**	**23.3**	**56.7**	**77.1**
Refinery gas	3.8	0.7	300	0.8	0.00	0.0	0.2	0.3
Gasoline	34.4	6.4	2406	6.7	0.20	1.9	1.25	1.6
Kerosene	39.6	7.4	2830	7.9	0.12	1.1	2.2	3.0
Jet kerosene	0.2	0.0	15	0.0	0.00	0.0	0.18	0.1
Fuel oil	2.46	0.4	180	0.5	0.05	0.5	0.2	0.3
LPG	7.6	1.4	485	1.3	0.01	0.1	0.5	0.7
Gasoil/diesel/DERV	161.2	30.1	11,815	32.9	1.95	18.8	49.6	67.4
Petroleum coke	6.1	1.1	571	1.6	0.10	0.9	2.9	3.7
Solid fuels	**59.9**	**11.2**	**6080**	**16.9**	**6.54**	**63.1**	**6.46**	**8.7**
Coal	31.4	5.9	2952	8.2	3.17	30.6	4.01	5.4
Peat	28.5	5.3	3128	8.7	3.37	32.5	2.5	3.3
Natural gas	**188.6**	**35.3**	**10,459**	**29.1**	**0.14**	**1.4**	**8.4**	**11.4**

[a] *1 petajoule (PJ) is equivalent to 277,778 MWh.*

Note: DERV is White Diesel or Road Diesel; kt is kilotonne; LPG is liquid petroleum gas.

The Transport Sector

Energy used in transport has increased continuously since 2012, in line with the economic recovery, and made up 35 per cent of the primary energy consumed in 2018, producing 31 per cent of carbon dioxide emissions and 50 per cent of nitrogen oxide emissions.

In 2018, transport accounted for 35 per cent of the primary energy consumed, with approximately 7 per cent of this being used in aviation (SEAI, 2019a). Road transport used approximately 27 per cent of total energy while rail used less than 1 per cent. Road transport was the largest contributor to Ireland's energy-related pollutant emissions such as particulate matter, nitrogen oxides and carbon dioxide in 2018. Passenger car use represented almost half of the energy use within transport.

Transport and mobility are complex issues that are central to our economic and social systems but also create burdens for these systems. Current transport systems largely reflect historical development and settlement patterns. These have given rise to systematic and structural mobility issues relating to, for example, transport modes, road congestion and working arrangements. Integrated approaches to spatial and mobility planning can contribute to reducing transport-related economic and social losses as well as reduced energy use in transport.

The extent of the dependence of transport systems in Ireland on liquid fossil fuels is unsustainable. A range of zero emission or low-emission transport solutions exists. These solutions include electrification and emerging hydrogen-based transport, which can be deployed across a range of transport modes without addressing systemic and structural issues. However, strategic approaches to planning, mobility and energy that embrace the avoid-shift-improve framework discussed in Chapter 11 can have multiple gains, including for overall energy use in transport and its impacts. Currently, there are several issues related to the extent of energy used in transport:

- Energy use in transport contributes to poor air quality in cities and urban areas during periods of high population exposure such as rush hour and can be problematic in areas of traffic build-up.
- The continued use of fossil energy in transport systems is a significant contributor to climate change, with road transport being the largest energy source of GHGs in Ireland.
- There are economic and social costs resulting from delays because of congestion and energy wastage.

A transition to clean energy would by itself significantly reduce impacts on health, the environment and climate. The requirements for decarbonisation and the protection of human health provide key catalysts for this transition. However, the comprehensive sustainability approach in the 'avoid-shift-improve' framework (discussed in Chapter 11) would accelerate and embed this in an integrated way.

The Residential Sector

The residential sector/buildings accounted for approximately 19 per cent of energy consumption in 2018 and produced 22 per cent of carbon dioxide emissions and 24 per cent of $PM_{2.5}$ emissions.

Residential energy use in Ireland peaked in 2010. Fuel type, building standards and the efficiency of appliances fundamentally determine the demand for energy and environmental burden. In the short term, residential energy use can reflect weather events, with high use, and loss, during cold spells. As shown in Figure 12.2, energy sources for heating changed significantly during the 1990s, with a shift from coal and peat to oil and natural gas, particularly in large urban areas. Since 2000, the profile of residential energy use has remained relatively stable. This is displayed in Figure 12.3. Over this period oil has remained the main fuel used in residential heating. In 2018 the residential sector/buildings accounted for approximately 19 per cent of energy consumption in Ireland (SEAI, 2019a).

Figure 12.2 Energy (MWh) used for residential heating in Ireland from 1990 to 2018 (Source: SEAI)

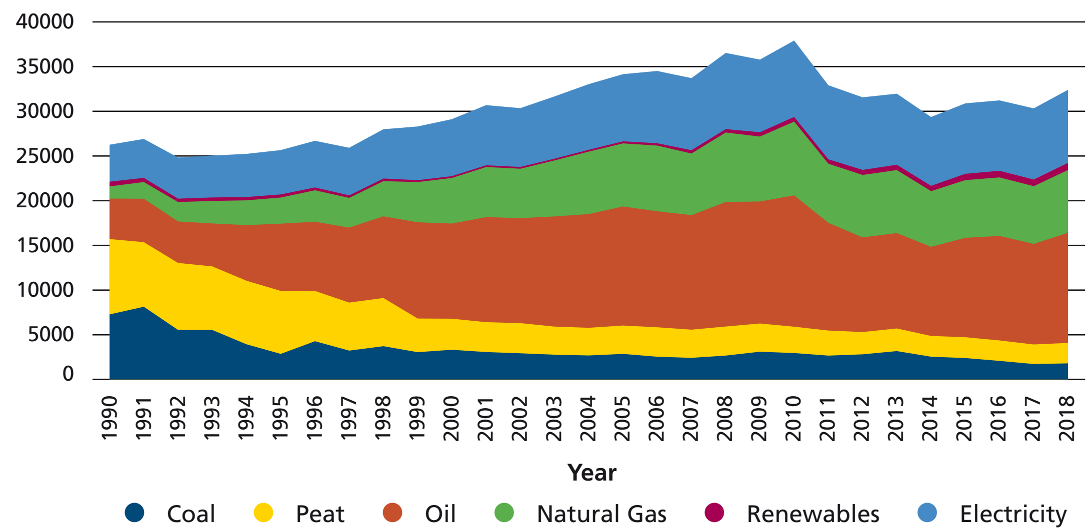
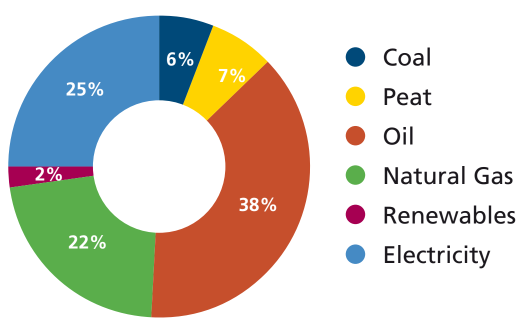


Figure 12.3 Residential energy use profile in 2018; this mix has remained relatively stable since 2000 (Source: SEAI)



The shift to natural gas from solid fuels has had considerable benefits for air quality in cities and urban areas that have access to gas networks. However, the rate of change has not continued, with the energy use profile being relatively stable over recent decades. Emissions from solid fuel use are the largest source of fine particulate matter ($PM_{2.5}$) which can have significant adverse impacts on air quality (Chapter 3). Personal everyday choices can impact air quality (Figure 12.4).

Figure 12.4 Actions to improve ambient air quality (Source: EPA)

Many residential properties in Ireland are poorly insulated. The Climate Action Plan (Government of Ireland, 2019) stated that over 80 per cent of homes and other buildings in Ireland assessed for their Building Energy Rating (BER) have a rating of C or worse. Consequently, much of the energy used to heat homes is lost rapidly because of poor insulation (SEAI, 2018). This entails ongoing costs for households, reduces comfort and can lead to health issues, including increases in winter morbidity and mortality rates (DCCAE, 2017). Energy poverty is a critical issue for vulnerable groups and individuals.

The combination of poor insulation and fossil energy heating systems represents a significant systemic and household-level lock-in to energy-related emissions. There are considerable benefits to addressing these lock-ins through reducing energy waste and losses (e.g. through increased building energy efficiency). This improves comfort and has long-term cost savings and health and climate benefits.

Future housing and building standards should be designed to provide energy-efficient and cost-effective housing and building. The nearly zero energy building standards came into force for public buildings in January 2019 and will come into force for all other buildings in January 2021 (eISB, 2019). Small-scale energy solutions such as solar panels and emerging energy storage solutions can contribute to reduced dependence on combustion for energy and generate energy for community use, thereby increasing resilience. Deployment of these standards and solutions can ensure energy security comfort and low operational costs along with high air quality and low to zero carbon dioxide emissions.

Without effective efficiency measures, current business and residential energy use is inefficient and costly and contributes to air pollution, with impacts on human health and the environment. The continued use of fossil energy in heating systems is a significant contributor to climate change. Its replacement with cleaner options such as heat pumps can be enabled by increasing the energy efficiency of homes and buildings by the use of insulation and retrofitting. Modern buildings are more energy efficient than older ones and future buildings can contribute to distributed micro-energy generation and storage.

Dealing with the significant legacy of poorly insulated buildings is a significant challenge. This can be addressed by reducing energy waste and loss through deep retrofits. These involve extensive insulation and energy efficiency measures and can be costly.[6] However, schemes exist or are emerging to assist in such renovations. These investments, coupled with a greater use of renewables on the electricity grid and the phasing out of peat, coal and oil use, can significantly reduce or eliminate the air pollution and climate impacts from housing and the wider built environment. A wider range of schemes is available to enhance the energy efficiency of businesses.[7]

6 *https://www.seai.ie/grants/home-energy-grants/*

7 *https://www.seai.ie/business-and-public-sector/business-grants-and-supports/*

Electricity Generation, Electrification and Industry

Increased use of wind energy and the switch to gas from coal for electricity generation means that the carbon intensity of electricity in Ireland has decreased; however, there is still a way to go to reach zero fossil emissions and climate neutrality.

Electricity generation in Ireland has evolved around a centralised generation capacity supported by a complex transmission grid and distribution system with limited storage (e.g. via pumped hydropower). The centralised generation was based on the combustion of coal, oil and peat and, later, gas. This model is being increasingly challenged by the requirements to provide access to renewable energy such as wind power and increasing options for small-scale energy generation and storage.

In 2018 there was a significant decline in the combustion of coal in electricity generation. This was combined with an increasing uptake of wind energy. Gas made up around 13.7 per cent of the reduction in coal and peat generation, while wind made up 53.8 per cent. The remainder was made up of increased electricity imports (26.7%) and non-renewable waste generation (5.8%). To an extent, this reflects the increasing costs of carbon emissions under the European Emissions Trading System (ETS). The ETS is a key pillar of European climate policy and applies to the power generation sector as well as other large emitting sectors, as detailed in Chapter 2. It also reflects the cost-effectiveness and efficiency of wind power, which provided 28 per cent of the total electricity generated, with renewables at 33 per cent (SEAI, 2019b). Consequently, the carbon intensity of electricity in Ireland dropped from 896 grams of carbon dioxide equivalent per kilowatt-hour (g CO_2eq/kWh) in 1990 to 375 g CO_2eq/kWh in 2018, a decrease of almost 60 per cent (SEAI, 2019a). Electricity generation will need to reach zero fossil carbon emissions in the coming decades for Ireland to become climate neutral by 2050.

Electricity generation and its distribution require careful management to ensure supply and avoid excessive costs. It is regulated by the Commission for Regulation of Utilities.[8] Combustion-based electricity generation is itself highly energy intensive, with about 50 per cent of the energy being lost in the generation process. Wind and hydropower generation do not suffer these transformation losses. This means that while wind represented just over 16 per cent of Ireland's generated electrical energy in 2018, it amounted to 28 per cent of the total electrical energy used by consumers (Table 12.2).

While Ireland has excellent renewable energy resources, with strong and relatively consistent winds off the Atlantic Ocean, there are considerable technological and management challenges in bringing renewable and distributed energy generation onto the grid. Addressing these challenges and availing of the opportunities provided by distributed generation are central to the decarbonisation of electricity generation. These opportunities include enabling the uptake of directly generated energy from wind and solar sources, along with the deployment of sophisticated energy storage and management systems. This is essential for the large-scale uptake of wind energy. The emergence of cheap solar power generation is a significant win-win situation for climate, air quality, energy security and energy efficiency. The national grid, which is managed by EirGrid, will need to be a proactive enabler of this transition.

Table 12.2 Breakdown of energy by electricity generation and use in 2018 (Source: SEAI)

ELECTRICITY GENERATION	INPUT	GENERATED	LOSSES
Total energy	191,086GJ (53,079 MWh)	91,565GJ (25,435 MWh)	
Hydropower	1.3%	2.2%	
Biogas	6.7%	3.8%	
Wind	16.3%	28.0%	52%
Fossil gas	53.9%	51.8%	
Coal	10.7%	7.0%	
Peat	10.3%	6.8%	
Oil	0.8%	0.5%	

Note: GJ is gigajoule.

8 https://www.cru.ie/

Electrification

Electrification has considerable benefits in terms of ease of use, end-user efficiency and reduction in maintenance and operational costs. Increasing use of electrical energy in homes and businesses has been an ongoing trend since national electrification. This has accelerated over recent decades through the widespread use of electrical appliances and the emergence of digital systems and the digital economy.

Electrification is projected to increase with the electrification of transport and heat being promoted as efficient and effective options to reduce emissions of key pollutants and, in particular, to decarbonise these sectors. From a climate perspective, electrification based on renewable energy can provide a pathway for large-scale decarbonisation.

The demands of electrification and the emergence of a range of renewable energy sources at a range of scales provide considerable challenges for current power generation systems and models, including for the grid and its resilience (see Topic Box 12.2 below). Innovative solutions, including enhanced energy management and storage systems, are likely to be part of the next national grid system.

Topic Box 12.2 EirGrid Strategic Objectives 2020-2025

EirGrid is the Irish state-owned electricity transmission system operator. It is a public limited company registered under the Companies Acts and its shares are held by the minister responsible for energy in Ireland. EirGrid operates and develops the national transmission grid infrastructure and interconnections with neighbouring grids to meet the needs of all electricity users and it also operates the Single Electricity Market. EirGrid ensures that electricity is reliably available in a cost-effective manner.

The EirGrid Strategy 2020-2025 (EirGrid, 2019) states its purpose – to Transform the Power System for Future Generations. Its primary goal is to Lead the Island's Electricity Sector on Sustainability and Decarbonisation. The strategy is shaped by two factors – climate change and the impending transformation of the electricity sector. The transition to low-carbon and renewable energy will have widespread consequences. There will be major changes in how electricity is generated and in how it is bought and sold. There will also be major changes in how electricity is used, such as for transport and heat. The electricity system will carry more power than ever before and most of that power will come from renewable sources. Coal, peat- and oil-based generation will be phased out in the next decade.

While this happens, new technology will allow electricity users to generate and store power and return any surplus to the grid. Combined with real-time consumption information from electricity users, this creates opportunities for all. Realising these opportunities will require a significant transformation of the electricity system. More importantly, these changes will need to be managed in a coordinated and cost-effective way. EirGrid Group has a unique role to play in leading the radical transformation that is now required and states that it will be a beacon towards an ultimate future for electricity that is sustainable and free from carbon.

The EirGrid Strategy 2020-2025 closely aligns with the government's Climate Action Plan published in 2019 and with the recently published Programme for Government 2020. Seventy per cent of electricity will be generated from renewable sources by 2030 and this target will require EirGrid to break new ground in the amount of renewable electricity we manage on the electricity system. In real terms, up to 10,000 megawatts of additional renewable generation will be connected to the electricity system and it will be able to accommodate 95 per cent of electricity from renewable sources at any one time.

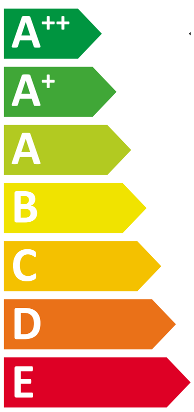
Energy Efficiency

Increasing energy efficiency has many benefits, including long-term savings, but barriers include financial obstacles and these need to be addressed to enable the uptake of energy-efficient solutions.

The lower energy use in 2018 relative to 2008 seen in Figure 12.1, which is also evident in residential energy use, can in part be attributed to a reduction in energy waste through energy efficiency measures. Figure 12.5 shows how simple energy rating labelling can inform consumer choices and reduce energy waste. Reducing and, where feasible, eliminating energy waste by increasing energy efficiency is one of the most cost-effective ways to reduce energy demand (see Figure 12.5). It is exemplified by the uptake of efficient lighting systems in the public and private sector. This has resulted in the removal of highly inefficient lights and their replacement with light-emitting diode (LED) lighting systems, which can use 80 per cent less energy.

Energy ratings on appliances and tools have also been a factor in reducing energy demand. The BERs for houses and buildings increase awareness of energy use and of the benefits and savings that accrue from energy efficiency and investments. This trend in increasing energy labelling is also increasing consumer awareness but there are barriers to consumer uptake. Energy-efficient choices tend to require significant upfront investment, with savings occurring over time. Approaches to address these issues are needed, including the provision of financial and fiscal instruments that enable or advance the efficiency transition (e.g. linking loans and mortgages for energy-efficient choices/investment or linking taxation/value-added tax to efficiency ratings).

Figure 12.5 The A-G energy label (Source: SEAI[9])



9 https://www.seai.ie/home-energy/energy-labelling-and-ecodesign/energy-labelling/

Losses in electricity generation, transmission and processing made up about 50 per cent of the total energy consumed in electricity generation, meaning that approximately 50 per cent of the original energy used to generate electricity was available for use by consumers. The use of renewable energy reduces or eliminates generation losses, which are significant for combustion-related generation. Reducing these losses also contributes to meeting energy targets and decarbonisation. Overall, reducing the loss and waste of energy has multiple benefits for the climate and human health and wellbeing.

Renewable Energy and Wind Energy

Wind, bioenergy and solar energy can provide additional opportunities for Irish businesses and consumers.

Ireland has excellent indigenous renewable energy resources, and renewable energy is playing an increasing role in the domestic energy supply (SEAI, 2019b). Ireland has more onshore (land-based) and offshore energy potential than most other European countries. In 2019 wind power is estimated to have provided 31.5 per cent of electricity in Ireland. Currently, there is 12 GW worth of energy from offshore wind in active development. This will significantly add to the current renewable generation capacity of over 3.7 GW, almost all of which is onshore. This has resulted in reduced costs for consumers and reduced imports of fossil energy. For more on the offshore wind sector see Topic Box 12.3.

Topic Box 12.3 Offshore Wind Energy Sector in Ireland (Source: SEAI)

Globally, the offshore wind energy sector is developing rapidly, with a current total capacity of 27 gigawatts (GW). Almost 80 per cent of this capacity is in Europe. The annual growth rate is almost 30 per cent annually. EU capacity is projected to increase by at least a factor of four by 2030, with offshore wind becoming the EU's largest source of electrical energy in the 2040s.

Ireland has one of the best offshore renewable energy resources in the world and has the capacity to accommodate high levels of offshore generation. This provides a significant opportunity to decarbonise our electricity system and to advance the decarbonisation of the energy used in transport and heating, including through the production of hydrogen for energy storage and for use in heating and transport.

The development of Ireland's offshore wind resources is critical if Ireland is to meet the 2030 renewable energy targets in the Climate Action Plan (Government of Ireland, 2019). The Programme for Government 2020[10] commits Ireland to a long-term plan to take advantage of Ireland's significant offshore energy potential, which also provides Ireland with a significant energy export opportunity. However, Ireland currently has only one offshore wind farm, Arklow Bank Wind Park, which has a capacity of 25 MW. Ireland's national capacity will need to increase to at least 3.5 GW to contribute 70 per cent of renewable electricity by 2030, equivalent to four Moneypoint power stations. This ambition was increased further to 5 GW by 2030 in the recently ratified Programme for Government.

A number of planned offshore energy projects are expected to be progressed to the next stage of development. These would contribute to meeting the 2030 target for offshore wind once the Marine Planning and Development Management Bill is passed. The Offshore Renewable Energy Development Plan (OREDP) (DCCAE, 2014) is the policy framework for offshore renewables in Ireland. A new OREDP is currently being developed. Along with the development of the National Marine Planning Framework (DHLGH, in preparation), it should accommodate the increased ambition.

Exploiting offshore wind will, however, require significant changes to our energy system. A strategy for exploiting this energy resource is needed, involving research, innovation and investments. The strategy's focus should be on production, transport, storage and use relating to this renewable resource. It is important that any adverse societal and environmental impacts from offshore energy development are addressed so that the benefits of this resource are available to all and opportunities are maximised. The Sustainable Energy Authority of Ireland is already funding work in this area under the National Energy Research, Development and Demonstration Programme.

(Credit: SEAI)

10 https://static.rasset.ie/documents/news/2020/06/draft-programme-for-govt.pdf

There is also an increased interest in microgeneration, with the popularity of solar panels increasing at domestic, business and farm levels. Linking these to the grid and the development of prosumer supports, including smart meters and energy citizen schemes, and advances in storage at a range of scales can add considerably to the levels of renewable energy used. Interest and adoption of these technologies increases awareness of energy management and the potentials of smart energy systems.

The continued uptake of these diverse energy resources and the realisation of the 70 per cent target for renewable energy by 2030 is dependent on the evolution of the national grid to accommodate and manage the uptake of large-scale renewable energy from offshore wind farms and small-scale microgeneration at domestic scales.

5. Challenges and Comparisons

The energy challenges that Ireland faces are significant but not unique. Similar transitions are required at European and global levels. There are opportunities to share learning and experiences with our European and international partners in the transition process. Some comparisons and shared issues are explored here.

Addressing Carbon Lock-In

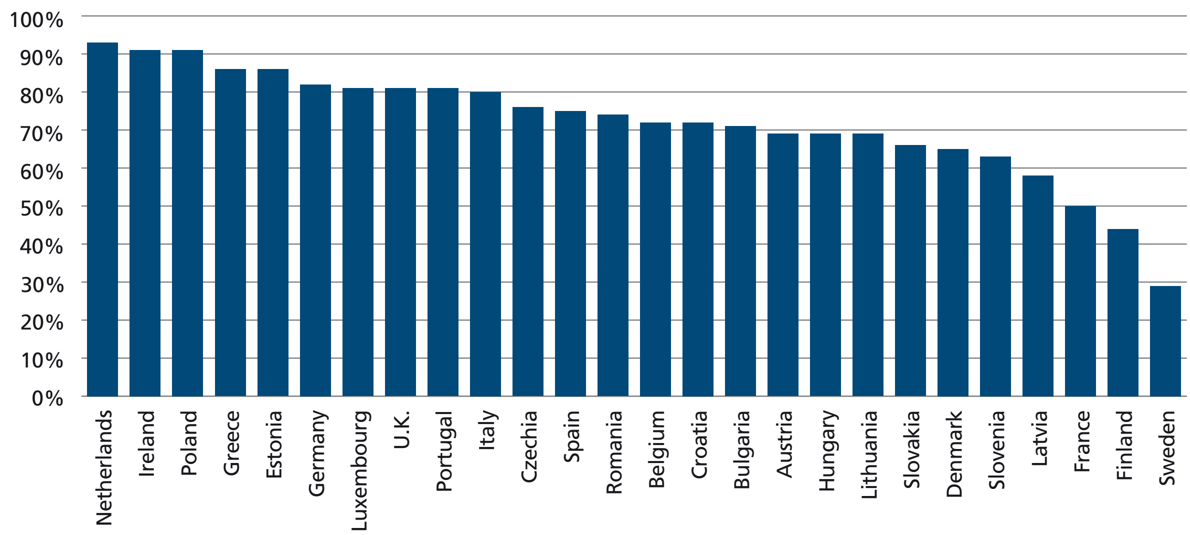
Current fossil carbon lock-ins in electricity generation, building and transport need to be assessed, quantified and managed as part of the transition away from these energy sources.

Carbon lock-in is a term that refers to the degree to which economies are effectively committed to long-term fossil fuel consumption because of the prevalence of significant long-term investments in fossil-based infrastructures and financial, institutional and other systems that support and maintain energy systems.

These systems have been fundamental to development pathways for many advanced economies, both in Europe and globally. However, the recognition of the threats and risks posed by the continued use of fossil energy for our climate, environment and health means that these lock-ins should be addressed as part of the transformation process.

The fossil carbon lock-in in electricity generation, building and transport needs to be assessed, quantified and managed as part of this transition. Figure 12.6 shows the scale of fossil energy use across the EU (2016 data); of the EU Member States, Ireland, the Netherlands and Poland are the most dependent on fossil energy.

Figure 12.6 Fossil fuels in the energy mix by EU Member State in 2016 (Source: Eurostat)



While there has been progress in the decarbonisation of electricity, Ireland remains almost 90 per cent dependent on fossil energy. This dependency is both expensive, with imported fossil energy costing on average €4.8 billion from 2010 to 2018 (CSO, 2020), and environmentally unsustainable (CSO, 2019).

Financing the Transition and Fossil Fuel Subsidies

Effective frameworks for investment in Ireland's energy transition are required and redirection of fossil fuel subsidies of over half a billion euros annually can contribute to this process.

Parties to the Paris Agreement have agreed to make finance flows consistent with a pathway towards low GHG emissions and climate-resilient development (Chapter 2). This goal is increasingly reflected in EU policy such as the Green Deal (EC, 2019a) and in the mandates of financing institutions and banks such as the European Investment Bank (EIB). Large-scale investment in energy infrastructure will be crucial to decarbonising the energy sector. EirGrid secured €530 million in funding directly from the European Commission to support the Celtic Interconnector project. The EIB has an aim to support €1 trillion of investments in climate action and environmental sustainability from 2021 to 2030 and to gradually increase the share of its financing dedicated to climate action and environmental sustainability to 50 per cent of its operations in 2025. The EIB has already funded energy infrastructure in Ireland and could become a very important supporter of low-carbon transformation in Ireland in the future. The Paris Agreement goal would also envisage the phase out of subsidies for fossil fuel production and use. The EU is committed to phasing out environmentally harmful subsidies (EC, 2019b).

These subsidies are diverse and include those provided for the exploration, production, distribution and purchase of fossil fuels, including coal, peat, oil and gas. The International Energy Agency data for 2018 suggest that these subsidies amount to over €339 billion annually at a global level and that these have increased in recent years, with oil being the most heavily subsidised. These are more than double the estimated subsidies for renewable energy sources (Matsumura and Adam, 2019).

The Central Statistics Office has applied international standards and methods to provide an analysis of fossil fuel subsidies in Ireland (CSO, 2018). This research paper also covers direct potentially environmentally damaging subsidies, and these are presented in Table 12.3.

Table 12.3 Direct potentially environmentally damaging subsidies for 2012-2016, including fossil fuel subsidies (Source: CSO, 2018)

	FOSSIL FUEL SUPPORTS, MILLION EUROS				
	2012	**2013**	**2014**	**2015**	**2016**
PSO Levy: electricity generation from peat	94.2	94.8	119.0	121.9	115.4
PSO Levy: security of electricity supply	42.2	61.0	104.7	47.3	0.0
Petroleum exploration and production promotion	1.3	0.5	1.6	2.2	2.4
Electricity allowance	176.7	161.0	154.6	149.6	150.7
Gas allowance	20.6	16.3	21.8	18.8	19.2
Fuel allowance	211.4	228.1	217.7	214.2	230.9
Other supplements (heating allowance)	11.2	–	8.1	7.4	6.7
Fuel grant for disabled drivers/passengers	–	–	–	–	8.6
Total fossil fuel supports	**557.6**	**561.7**	**627.5**	**561.4**	**533.9**

Note: PSO is Public Service Obligation.

A number of schemes are designed to address social and economic issues, and their removal would be problematic for equity and social justice reasons. However, the scale of these subsidies suggests that options to orientate the schemes to address underlying issues such as energy poverty as a result of poor construction and to promote non-fossil solutions are considerable. This could be strategically managed to ensure that long-term benefits and savings are accrued. There is a focus on retrofitting social housing, which could advance the development and wider deployment of these solutions.

Ensuring that subsidies for energy are both socially and environmentally progressive should be part of this process. This can be envisaged as part of the 'just transition'. This is discussed in Chapter 2: Climate Change. This would include transition to energy-efficient homes that use renewable energy. Investment to support the development and deployment of renewables in 2018 amounted to €383 million, mainly as a result of the Public Service Obligation supports for renewable energy generation, which were in the order of €375 million.

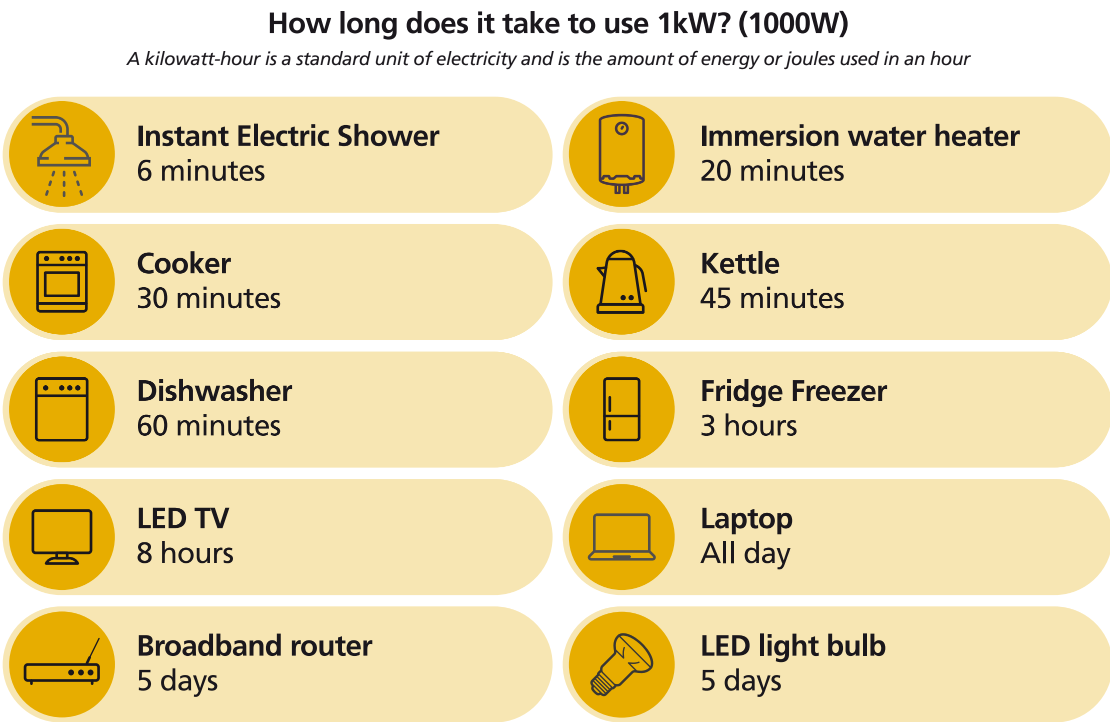
Energy Information

Clearer information can assist consumers on their energy choices and their implications.

Energy use is central to our lives but largely goes unnoticed and unquantified. Energy information is often obscure and difficult to include in decision-making. Making information about energy use, as well as information about energy options and solutions, more accessible will assist consumers to make choices around energy. This can be enhanced by the inclusion of associated environmental impacts, information on investment portfolios and media price reporting on energy production (Figure 12.7). This can enable and promote positive actions around energy management, investment choices and supporting prosumers who wish to support clean energy options. Steps in this process would include:

- using standard units for energy to enable the energy use to be more easily estimated at a range of timescales
- linking energy ratings to energy use and switching between energy choices
- providing information on the carbon content and other emissions associated with the energy commodity being produced, traded or used
- enabling transparency around fiscal incentives, or deterrents, and their impacts.

Figure 12.7 How long does it take to use 1kW (1000W)?
(Source: adapted from Electric Ireland, www.electricireland.ie)



Currently, a variety of units are used for energy production, reporting, use and trading. These include barrels, litres, tonnes of oil equivalent and other industry-specific units. For clarity, this report uses the international standard energy units of joules (J) and watt-hours (Wh). A watt is a unit of energy used in 1 second, with the unit of energy being a joule. The joule replaced the calorie in 1969. The calorie is still used in popular discussion of foods and dieting. One joule is equivalent to about 0.24 calories.

The use of standard energy units, along with price data and environmental impacts, would assist in comparisons and decision-making. This would allow individuals, households, communities and businesses to better understand and manage their energy use. The provision of such information could also be included in media and communications materials along with environmental impacts.

Energy and Negative Emissions

Ireland will need to plan for large-scale removal of carbon dioxide from the atmosphere (negative emissions) and a national framework for advancing robust negative emissions solutions is required.

Scientifically, it is recognised that there will be a need for large-scale removal of carbon dioxide from the atmosphere, which is termed negative emissions, to offset any overshoot of the carbon budgets required to meet the temperature goal of the Paris Agreement (IPCC, 2018) (Chapter 2). The scale required of such negative emissions will depend on the overshoot of carbon dioxide emissions relative to the Paris Agreement temperature goal and the scale of residual emissions of non-carbon dioxide GHGs from food production systems that cannot be reduced to zero.

Currently, the management of terrestrial sinks is the main approach for the provision of negative emissions or removal of carbon dioxide. A new national land use strategy could support further use of terrestrial sinks. However, the capacity and resilience of these sinks is limited, and management systems are needed to ensure that they are robust and quantifiable. While full estimates of the scale of negative carbon dioxide emissions that Ireland requires need to be developed, it is likely that these will be significant. They would include the long-term storage of carbon dioxide in geological or similarly secure systems for periods that are akin to those needed for the storage of nuclear wastes.

Globally, future energy systems will be central to the delivery of required large-scale negative carbon dioxide emissions (e.g. through the use of bioenergy with carbon capture and storage (BECCS) or direct air capture; IPCC, 2018). However, there are limits to how much land can be used sustainably for BECCS, and there are also environmental and food security risks (IPCC, 2019). These issues will need to be addressed but future energy systems are likely to have a key role in providing negative emissions. A national framework for the analysis and delivery of negative emissions solutions is required to complement the national decarbonisation process. In combination, these should have the objectives of reaching net zero carbon emissions in the coming decades and providing a framework for further negative emissions, at least until the end of this century.

EPA Research Programme 2014-2020 Environment and Energy

Since 2016, the EPA has funded up to 32 new research projects relevant to the Environment and Energy area; a commitment of €3.4 million. These projects were funded mostly under the Climate and Sustainability Pillars of the EPA Research Programme 2014-2020.

Examples of EPA-funded research projects include research on:

- green adsorbents for clean energy
- the production of advanced gaseous biomethane transport fuel in an integrated circular bioenergy system
- residential solid fuel use in Ireland and the transition away from solid fuels
- the potential for negative emissions technology in Ireland
- developing the potential of community energy action groups in the transition to a low-carbon society
- the Long-range Energy Alternatives Planning (LEAP) model and GHG emissions in Ireland analytical tool 1990-2030.

More information is available from http://www.epa.ie/researchandeducation/research/

6. Conclusions

Energy and Climate Change

Energy is essential to economic, social and cultural development. Ireland's energy systems are currently highly reliant on fossil energy, with many systemic and structural lock-ins. However, progress has been made on addressing these, particularly in the area of electricity generation, which has seen a significant uptake of renewable energy. This has to be accelerated over the coming years and a number of strategic plans have been articulated to do this.

Halting climate change at a level that is manageable is the key driver of the energy transition. This transition will have many benefits for sustainable economic and social development, human health and wellbeing, as well as for the environment and ecosystems. It will be progressed in line with European and global partners and be a driver of economic activity. It will be supported by the EU Green Deal as well as by investments from major European and international banks.

Becoming climate neutral by 2050 is a huge challenge. It entails rapid carbonization and delivery of large-scale carbon dioxide removal solutions (negative emissions) by 2050 which will need to be continued to the end of this century. Energy systems will need to deliver these as well as sustaining economic and social development. Energy and its use will need to be smart, efficient and designed to support carbon removals. Planning for this is urgent, as is investment in solutions that are currently available to enhance efficiency and utilise Ireland's renewable energy potential. This is an essential step in ensuring that Ireland's next one hundred years are secure and prosperous.

Ceri Breeze / Shutterstock.com

Energy Use is our Largest Source of Greenhouse Gas and Other Air Pollution

Fossil fuels provide almost 90 per cent of the energy used in Ireland. This reflects a high degree of lock-in to fossil energy systems, which have significant negative impacts on climate, health, ecosystems, biodiversity and water quality in Ireland and globally. Systemic and societal changes are required to enable the transition to net zero carbon emission energy systems. Citizens, communities and businesses need to be part of the transition, which will require strategic planning and investments. Incentives for more community participation in renewable energy generation projects are expected to be provided under the 2020 Renewable Electricity Support Scheme.

Eliminate Carbon Dioxide Emissions from Energy from Fossil Fuels by 2050

A transition of the energy system is needed to achieve climate neutrality by 2050. The elimination of fossil carbon dioxide emissions will be part of this transition.

The implementation of a transition strategy that encompasses energy providers and users is needed. Systemic, institutional, technological and financial barriers need to be addressed. The engagement of citizens and stakeholders is essential. Schemes such as the Renewable Electricity Support Scheme can incentivise the introduction of additional significant renewable electricity generation from a wide range of technologies, contributing to national and EU-wide renewable and decarbonisation targets out to 2030 and beyond.

Ireland's Renewable Energy Potential Should be Realised

Globally and in Ireland there is considerable renewable energy potential. Ireland has excellent renewable resources and it is planned that the economic and social potential of offshore wind around Ireland's coast will be developed. Systems to harvest, store and manage renewable energy resources are required. These will be a mix of existing and new technologies, which will be deployed at a range of scales to deliver energy needs in a resilient and secure manner. Elements of this include a smarter grid, more efficient distribution and smarter use. The Climate Action Plan (Government of Ireland, 2019) target of 70 per cent renewable electricity by 2030 is a step in this process.

Energy Transformation has Multiple Benefits for Health, Wellbeing and the Environment

The required transformation will require significant investments from public and private sector stakeholders. There will be significant medium and longer- term economic benefits and savings, including reduced dependency on imported fossil energy, energy security and energy resilience. Reduced emissions will directly and indirectly benefit human health and ecosystems.

Planning for Large-Scale Carbon Dioxide Removal (Negative Emissions)

Cumulative carbon dioxide emissions will determine the global temperature increase. Large-scale removals of atmospheric carbon dioxide are likely to be required. These will limit warming to well below 2°C or limit the increase to 1.5°C, and offset GHG emissions that cannot be reduced to zero (i.e. those from food production). Removals by sinks such as forests are not likely to be sufficient to offset these emissions. The future energy systems will be central to the delivery of required large-scale negative carbon dioxide emissions (e.g. through BECCS or direct air capture).

Chapter Highlights for Environment and Energy

Almost 90 per cent of Ireland's total energy use is provided by combustion of, mostly imported, fossil fuels. This is not sustainable. The resultant emissions are damaging for our health and our environment and continue to drive climate change.
To transform this situation, we need to start fast-tracking the measures in the Climate Action Plan and other necessary solutions. Strategic planning is required to transform this situation by 2050, including accelerated actions to 2030.

Transitioning to a clean energy future is essential for the protection of human health, climate and the environment, while having many benefits for sustainable development. The investment and implementation of currently available solutions to enhance efficiency and utilise Ireland's renewable energy potential needs to be urgently rolled out.

Current fossil carbon lock-ins in electricity generation, but particularly in buildings and transport, need to be assessed, quantified and managed as part of the rapid transition away from these energy sources. Such a transition will require effective frameworks for investment. The redirection of fossil fuel subsidies can contribute to this process.

References

CSO (Central Statistics Office), 2018. *Fossil Fuel and Similar Subsidies 2012-2016*. Available online: https://www.cso.ie/en/media/csoie/releasespublications/documents/rp/fossilfuelandsimilarsubsidies/Fossil_Fuel_and_Similar_Subsidies.pdf (accessed August 2020).

CSO (Central Statistics Office), 2019. Fuel excise clearances. Available online: https://www.cso.ie/en/statistics/climateandenergy/fuelexciseclearances/ (accessed August 2020).

CSO (Central Statistics Office), 2019. External Trade. Available online: https://www.cso.ie/en/statistics/externaltrade/archive/publicationarchive2020/ (accessed July 2020).

DCCAE (Department of Communications, Climate Action and Environment), 2014. Offshore Renewable Energy Development Plan. Available online: https://www.gov.ie/en/publication/e13f49-offshore-renewable-energy-development-plan/ (Accessed 19 November 2020).

DCCAE (Department of Communications, Climate Action and Environment), 2015. *Ireland's Transition to a Low Carbon Energy Future 2015-2030*. Available online: https://www.gov.ie/ga/foilsiuchan/550df-the-white-paper-irelands-transition-to-a-low-carbon-energy-future-2015-2030/ (accessed 20 November 2020).

DCCAE (Department of Communications, Climate Action and Environment), 2017. *Focussed Policy Assessment: SEAI Better Energy Homes 2009-2015*. DCCAE, Dublin. Available online: https://igees.gov.ie/wp-content/uploads/2018/05/SEAI-FPA-Better-Energy-Homes-2009-2015.pdf (accessed August 2020).

DCCAE (Department of Communications, Climate Action and Environment), 2019. Public consultation on the Biofuels Obligation Scheme. Available online: https://www.gov.ie/en/consultation/2c850-public-consultation-on-the-biofuels-obligation-scheme/ (accessed 20 November 2020).

DHLGH (Department of Housing, Local Government and Heritage), in prep. National Marine Planning Framework (Draft). DHLGH, Dublin. Available online: https://www.housing.gov.ie/planning/maritime-spatial-planning/maritime-spatial-planning-directive/maritime-spatial-planning (accessed August 2020).

EC (European Commission), 2009. *2020 Climate and Energy Package*. EC, Brussels. Available online: https://ec.europa.eu/clima/policies/strategies/2020_en (accessed August 2020).

EC (European Commission), 2019a. Communication from the Commission of the European Parliament, the European Council, the European Economic and Social Committee and the Committee of the Regions 'The European Green Deal'. COM (2019) 640 final, 11.12.2019, Brussels.

EC (European Commission), 2019b. European Council conclusions on climate finance. 13871/19, 8.11.2019, Brussels. Available online: https://www.consilium.europa.eu/media/41303/st13871-en19.pdf (accessed August 2020).

EC (European Commission), 2020. Proposal for a regulation of the European Parliament and of the Council establishing the framework for achieving climate neutrality and amending Regulation (EU) 2018/1999 (European Climate Law). COM(2020) 80 final, 4.3.2020. Brussels. Available online: https://ec.europa.eu/clima/policies/eu-climate-action/law_en (accessed August 2020).

EirGrid, 2019. Strategy 2020-25. Available online: http://www.eirgridgroup.com/about/strategy-2025/ (accessed August 2020).

eISB (electronic Irish Statute Book), 2019. *S.I. No. 183/2019* – European Union (Energy Performance of Buildings) Regulations 2019. Available online: http://www.irishstatutebook.ie/eli/2019/si/183/made/en/print (accessed August 2020).

EU (European Union), 2018. Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources. OJ L 328, 21.12.2018, p. 82-209.

Government of Ireland, 2014. *National Policy Position on Climate Action and Low Carbon Development.* Government of Ireland, Dublin. Available online: https://www.gov.ie/en/publication/6f393-national-climate-policy-position/ (accessed August 2020).

Government of Ireland, 2017. *National Mitigation Plan*. Government of Ireland, Dublin. Available online: https://www.gov.ie/en/publication/48d4e-national-mitigation-plan/ (accessed 19 November 2020).

Government of Ireland, 2019. *Climate Action Plan to Tackle Climate Breakdown*. Government of Ireland, Dublin. Available online: https://www.gov.ie/en/publication/ccb2e0-the-climate-action-plan-2019/ (accessed 19 November 2020).

IPCC (Intergovernmental Panel on Climate Change), 2018. *Global Warming of 1.5C, an IPCC Special Report on the Impacts of Global Warming of 1.5C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development and Efforts to Eradicate Poverty*. Available online: https://www.ipcc.ch/sr15/ (accessed August 2020).

IPCC (Intergovernmental Panel on Climate Change), 2019. *Special Report on Climate Change and Land*. Available online: https://www.ipcc.ch/srccl/ (accessed August 2020).

Matsumura, W. and Adam, Z., 2019. Fossil fuel consumption subsidies bounced back strongly in 2018. Available online: https://www.iea.org/commentaries/fossil-fuel-consumption-subsidies-bounced-back-strongly-in-2018 (accessed August 2020).

Olson, C. and Lenzmann, F., 2016. The social and economic consequences of the fossil fuel supply chain. *Materials Research Society* 3: E6. https://doi.org/10.1557/mre.2016.7.

SEAI (Sustainable Energy Authority of Ireland), 2018. *Energy in the Residential Sector: 2018 Report*. Available online: https://www.seai.ie/publications/Energy-in-the-Residential-Sector-2018-Final.pdf (accessed August 2020).

SEAI (Sustainable Energy Authority of Ireland), 2019a. *Energy in Ireland: 2019b Report*. Available online: https://www.seai.ie/publications/Energy-in-Ireland-2019-.pdf (accessed August 2020).

SEAI (Sustainable Energy Authority of Ireland), 2019b. *Renewable Energy in Ireland: 2019 Report*. SEAI, Dublin. Available online: https://www.seai.ie/publications/Renewable-Energy-in-Ireland-2019.pdf (accessed August 2020).

UNECE (United Nations Economic Commission for Europe), 1979. *Convention on Long-range Transboundary Air Pollution*. Available online: http://www.unece.org/fileadmin/DAM/env/lrtap/full%20text/1979.CLRTAP.e.pdf (accessed August 2020).

UNEP (United Nations Environment Programme), 2013. Minamata Convention on Mercury. UNEP, Geneva. Available online: http://www.mercuryconvention.org/Portals/11/documents/Booklets/Minamata%20Convention%20on%20Mercury_booklet_English.pdf (accessed August 2020).

UNFCCC (United Nations Framework Convention on Climate Change), 1992. *United Nations Framework Convention on Climate Change*. Available online: https://unfccc.int/resource/docs/convkp/conveng.pdf (accessed August 2020).

UNFCCC (United Nations Framework Convention on Climate Change), 2015. *The Paris Agreement*. Available online: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement (accessed August 2020).