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Research Paper

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Renewable energy: background scoping paper

NIAR 74-20

This paper, commissioned by the Committee for the Economy (the Committee), provides a range of background information on renewable electricity and renewable heat. The paper is intended to support the Committee in its scrutiny of the forthcoming Department for the Economy (DfE) Energy Strategy.

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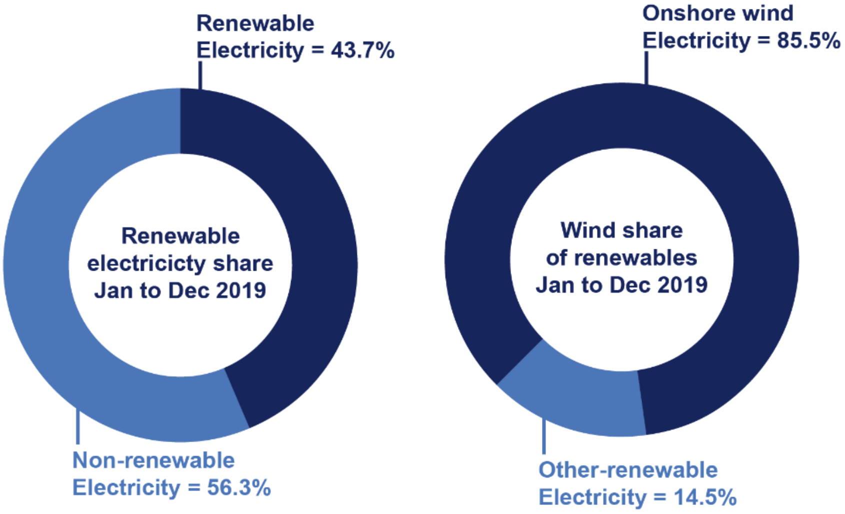
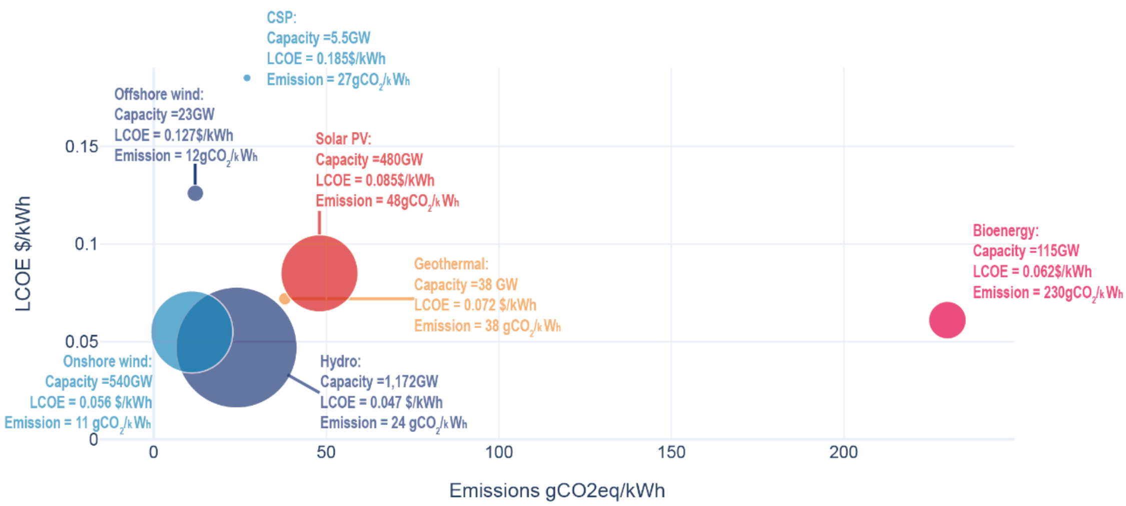
Renewable Electricty - key points

Renewable elecricty generation in NI Jan to Dec 2019



Target 40% renewables by 2020 Reached

Capacity, cost and emissions of renewable elecricty generation



Renewable technologies in NI key data

	2018 Capacity	2018 Turnover	2018 Jobs
Onshore Wind	1,393MW	£301m	500
Solar PV	321.8MW	£49m	200
Bioenergy	98.9MW	£47.5m	200
Hydropower	11MW	£2m	-
Offshore Wind	-	£12.5m	100

RaISe compiled infographic. Sources: DfE (2020), IRENA (2019), IPPC (2014), and ONS (2019)

Renewable Heat - key points

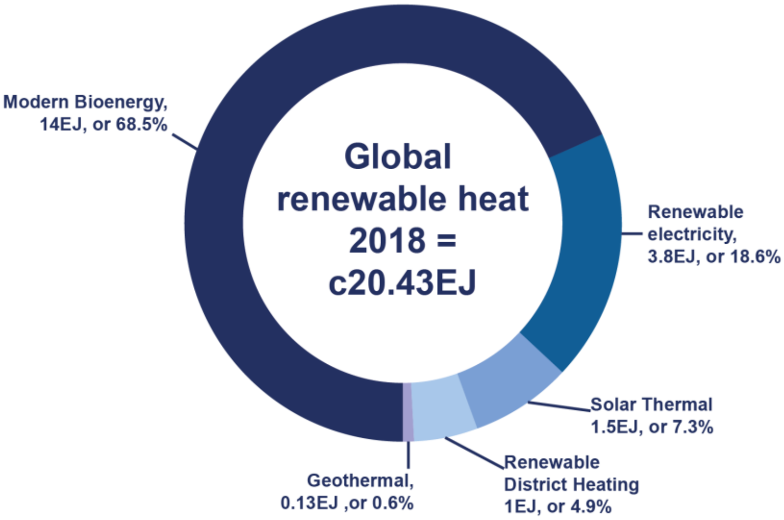
Renewable heat generation in NI

NI's Heat load
Unkown

NI's Renewable heat
Penetration unkown

Target
10%
renewables
by 2020
Not Met

Global renewable heat consumption 2018



Renewable heat in NI key data

	2018 Turnover	2018 Jobs
Renewable Heat	£5m	-
Renewable Combined Heat & power	£69m	200

RaISe compiled infographic. Sources: DfE (2019), IEA (2019), and ONS (2019)

Executive Summary

Between 2010 and 2020, renewable energy development in Northern Ireland (NI) has been largely steered by two targets:

- Achieving 40% electricity consumption from renewable generation by 2020; and,
- Achieving 10% heat consumption from renewable generation by 2020.

Both targets were part of the Strategic Energy Framework 2010 to 2020 – a strategy initially issued by the former Department for Enterprise, Trade and Investment, and following the 2016 reorganisation of departments, the Department for the Economy (DfE).

The DfE is about to launch a new Energy Strategy, which will set the framework for renewable development in Northern (NI) for a considerable length of time; potentially up to 2050. That Strategy is now under development, guided by the United Kingdom (UK) target of achieving zero net carbon emissions by 2050. NI's energy sector will play a vital role in helping to achieve that target. It therefore seems that NI will need to improve its current renewable development levels.

The information available on the forthcoming NI Energy Strategy suggests that it will include a renewable target for 2030 of achieving either 60%, 70% or 80% of electricity consumption from renewable generation. There presently is no indication of whether a renewable heat target will be included.

NI has had some successes and failures in the development of renewables. The 40% target for renewable electricity was achieved ahead of schedule, and has been surpassed. However, the renewable heat target was missed.

It is possible to indicate, with a strong degree of certainty, what the 2018 renewable electricity levels are on the system, i.e.: 1,393MW onshore wind; 322MW solar PV; 99MW of bioenergy; and, 11MW of hydropower. It, however, is not possible to do this for renewable heat levels at that time. Nor is it possible to provide an estimate of the total amount of heating load in NI, as it is not measured. We do know, from DfE estimates, that NI is reliant on oil and gas for much of its heating needs.

Despite the success of NI's renewable electricity generation development, some questions remain. Its success to date is predicated on the development of onshore wind; in 2019 onshore wind provided 85% of all renewable electricity in NI. Although other renewables have shown growth, some have not been developed, notably offshore wind. This raises the question of what is the right renewable energy mix going forward, and how we might further diversify renewable generation?

NI is currently without a support mechanism for renewable energy. Both the NI Renewable Obligation and the NI Renewable Heat Incentive are now closed to new applicants. To date no replacement has been put in place. A new DfE Energy Strategy for NI must determine what the correct level of support for renewables is. It may determine that the estimated cost of some renewable technologies is at level that the technology it does not require support. Section 3 of this paper, for example, shows that the estimated 2018 levelised cost of electricity[1] generated in 2018 by mature renewable technologies was broadly comparable to the unit cost of gas and fired generation, on a unit cost comparison basis.

Further questions arise about the future impact of further renewable electricity development on the NI grid system; how this can be managed, and how much it will cost to make the necessary upgrades? The System for Operator for NI has stated that NI meeting the UK's zero carbon ambitions will require the grid to have capacity to also accommodate up to 95% renewables. It is currently able to accommodate 65%.

Sections 3 and 4 of this paper demonstrate that renewable generation results in general in lower emissions than traditional fossil fuel generation. Though the emissions impacts do vary according to technology, according to the prevailing the Intergovernmental Panel on Climate Change estimates. In addition, it is clear from a range of government and academic sources that different renewable electricity technologies bring with them different potential environmental effects. This consequently raises the question as to how NI might seek to further develop renewable, while mitigating these effects? This will likely require cross-departmental work, including, but not limited to, linkages between the DfE and the Department of Agriculture, Environment and Rural Affairs. How will the Executive's Programme for Government and its Outcomes Delivery Plan facilitate in this regard?

Sections 3 and 4 also demonstrate that renewable generation has economic benefits. According to Office for National Statistics estimates, the onshore wind sector had estimated turnover of £301 million in 2018. The renewable heat sector had an estimated turnover in the region of £5 million in the same year. Development of renewables has the potential to bring economic as gains as well as emissions reductions. This suggests that the forthcoming DfE Energy Strategy will also have a significant economic impact. This raises the question as to how it might link up with the Department's forthcoming Economic Strategy, in order to maximise the positive economic impact? Again, this raises the question on how the Executive's Programme for Government and its Outcomes Delivery Plan will facilitate in this regard?

[1] Please note: the levelised cost of electricity is the price of electricity required for a project where revenues would equal costs, including making a return on the capital invested equal to the discount rate

Contents

Introduction

The following paper, commissioned by the Committee for the Economy (the Committee), provides a range of background information on renewable electricity and renewable heat. The paper is intended to support the Committee in its scrutiny of the forthcoming Department for the Economy (DfE) Energy Strategy.

The paper is structured as follows:

- Section 1 provides a brief overview of energy policy in Northern Ireland (NI) in relation to renewables to date, relying on information published in the DfE's call for evidence in December 2019 regarding its forthcoming Energy Strategy. This aims to provide some insight into the Department's future policy direction.
- Section 2 provides an overview of renewable electricity and renewable heat in NI, drawing on the latest available data, to provide a baseline against which future progress could be measured.
- Section 3 looks at individual renewable electricity technologies, with a specific focus on their global and local capacity, their costs, and their effect.
- Section 4 examines individual renewable heat technologies, with a specific focus on their global and local capacity, their costs, and their effect.
- Section 5 provides some concluding remarks.

Throughout the paper, the analysis provided is then used to raise key questions, which may aid the Committee's scrutiny of the DfE's strategy development in this area.

The paper is intended to provide an introduction to renewable technologies. It is not intended as a comprehensive assessment of each: such an assessment would be beyond the scope of this paper. The Committee may wish to commission further research into aspects of this paper, or question arising from it.

1 Energy Strategy in NI - background

This section aims to provide context to the rest of this paper, providing a brief outline of renewable energy as it featured in NI previous departmental energy strategy. It also looks at the DfE's December 2019 call for evidence in relation to the NES, outlining what the document states in relation to renewable electricity and renewable heat.

Since 2010, energy policy in NI has been driven by the *'Strategic Energy Framework'*[2] (SEF). The SEF set NI's strategic energy direction for the period 2010 to 2020. It was predicated on four, interlinked, goals:

- Building competitive markets;
- Ensuring security of supply;
- Enhancing sustainability; and
- Developing NI's energy infrastructure.

From a renewables perspective, the SEF set out two renewable energy targets for 2020:

- To deliver to 40% electricity consumption from renewable resources; and,
- To deliver 10% of heat consumption for renewable resources.

The SEF noted that delivery of the renewable electricity target would pose a challenge to the NI electricity system and to the planning process. It estimated £1 billion to enhance the grid infrastructure to enable delivery of the 40%. The SEF also recognised the need to support renewable electricity generation, stating such investment would:

> *Ensure that support mechanisms for renewable electricity are tailored and appropriate to Northern Ireland's needs, within the context of the wider wholesale electricity market.*

Steps to reach the renewable heat target included the publication of renewable heat map, which would set out key actions for developing the sector.

A number of support strategies were also introduced to help reach these targets. These were:

- The Renewable Heat Study (RHS): this study examined heat demand and consumption in NI, and outlined the role various heat technologies that were anticipated to play a role in meeting the 10% renewable heat target, as set out in the SEF.[3]

[2] Department for Enterprise, Trade and Investment, Strategic Energy Framework (2010) https://www.economy-ni.gov.uk/publications/energy-strategic-framework-northern-ireland

[3] Department for Enterprise, Trade and Investment, Renewable Heat Study (2010) https://www.economy-ni.gov.uk/sites/default/files/publications/deti/Executive%20summary%20-%20renewable%20heat%20study.pdf

- The *'Sustainable Energy Action Plan 2012-2015 and beyond'* (SEAP): as an out working of the SEF, the SEAP set out the actions taken forward across the NI Executive to promote sustainable energy development.[4]
- The *'Offshore Renewable Energy Strategic Action Plan 2012-2020'* (ORESAP), outlined NI's vision for offshore renewable development. It sought to maximise the development of offshore resources and positive economic development, while minimising the impact on the environment and other marine users. Section 3 of this paper draws on some of the findings of this Action Plan and its accompanying Strategic Environmental Assessment, to examine the impacts of potential offshore renewable energy in NI.[5]
- The *'Onshore Renewable Electricity Action Plan 2013 to 2020'* (OREAP), this sought to *'examine the role and cumulative impact of potential market led renewable electricity generation mixes'* in meeting the 40% target. It examined: the potential renewable electricity generation mix; the estimated cost to consumers of renewable development; and, the environmental impact of renewable electricity development. The findings of this study, particularly in relation to the environmental impact, will be drawn upon on Section 3 of this paper.[6]

All of the above strategic documents have now reached the end of their life-cycles. The *'New Decade, Dew Approach'* document, which outlined the priorities of the restored NI Executive, included a commitment to developing a new Energy Strategy (NES), which would include:

> *…ambitious targets and actions for a fair and just transition to a zero carbon society.*[7]

The NES is in the process of development. The Department for the Economy (DfE) issued a call for evidence in December 2019, and held a number of workshops with stakeholders during February 2020, as part of the NES development process.

The call for evidence notes that the development of the NES has the *'potential to impact positively'* on eight of the twelve Programme for Government Outcomes that were included in the December 2019 *'Outcomes Delivery Plan'*.[8] The eight outcomes where the NES was identified as having a potential impact were as follows:

[4] Department for Enterprise, Trade and Investment, Sustainable Energy Action Plan 2012 – 2015 and beyond (May 2012) https://www.economy-ni.gov.uk/sites/default/files/publications/deti/Sustainable%20energy%20action%20plan%202012-15.pdf

[5] Department for Enterprise, Trade and Investment, Offshore Renewable Electricity Action Plan 2012-2020 (March 2012) https://www.economy-ni.gov.uk/sites/default/files/publications/deti/Offshore%20Renewable%20Energy%20Strategic%20Action%20Plan%20%28ORESAP%29%202012-2020.pdf

[6] Department for Enterprise, Trade and Investment, Onshore Renewable Electricity Action Plan 2013-2020 (Nov 2013) https://www.economy-ni.gov.uk/sites/default/files/publications/deti/OREAP%202013-2020.pdf

[7] UK Government, New Decade, New Approach (January 2020) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/856998/2020-01-08_a_new_decade__a_new_approach.pdf

[8] The Executive Office, Outcomes Delivery Plan (December 2019) https://www.executiveoffice-ni.gov.uk/sites/default/files/publications/execoffice/odp-dec-%202019.pdf

- Outcome 1: "we prosper through a strong, competitive economy"; e.g. through developing economic opportunities and improving the skills of the workforce in the energy sector;
- Outcome 2: "we live and work sustainably protecting the environment"; e.g. through achieving net zero carbon by 2050 and delivering improvements in air quality;
- Outcome 4: "we enjoy long, healthy, active lives"; e.g. through a cleaner environment and reduced levels of pollution from heating, power and transport;
- Outcome 5: "we are an innovative, creative society where people can fulfil their potential"; e.g. by enabling opportunities for people and companies to develop, use new technologies to manage, use and generate energy;
- Outcome 6: "we have more people working in better jobs"; e.g. through the opportunities represented by installing advanced energy solutions including new heating technologies and servicing the smart energy sector;
- Outcome 8: "we care for others and we help those in need"; e.g. by tackling fuel poverty;
- Outcome 10: "we have created a place where people want to live and work, to visit and invest"; e.g. through cleaner transport, long-term policy certainty and enabling a positive contribution to the climate; and,
- Outcome 11, "we connect people and opportunities through our infrastructure"; e.g. by ensuring better access to a range of energy sources across Northern Ireland.[9]

It is clear from the call for evidence that that NES will set out policy for the period 2020 to 2050, and will include actions to deliver a net zero energy sector in NI by 2050. This will bring the NI energy sector in line with the UK Climate Change Act, which committed the UK to a 100% reduction in greenhouse gas (GHG) emissions by 2050, relative to from 1990 levels.[10]

It is also clear from the call for evidence that from the renewable electricity perspective, the DfE will seek to set a new target for renewable electricity generation in NI. The call for evidence document states that its starting point is to consider target three options for 2030:

- 70% (both Wales and the Republic of Ireland have introduced this target);
- 60%; and
- 80%. [11]

The DfE notes that this target will likely be met through a mix of large-scale developments and microgeneration. The call for evidence has also sought stakeholder opinions on the clustering of renewable technology to: reduce the impact on communities; speed up planning processes; and, allow for more strategic planning of

[9] *Ibid*

[10] DfE, Energy Strategy, call for evidence (December 2019) https://www.economy-ni.gov.uk/sites/default/files/consultations/economy/energy-strategy-call-for-evidence.pdf

[11] *Ibid*

grid connection and upgrades. The call for evidence has also raised the prospect of energy storage to maximise both existing renewable electricity generation and interconnection use to export surplus renewable generation.[12]

With regard to renewable heat, it seeks evidence on cost-effective ways to decarbonised NI's heat sector. It also seeks evidence on the potential for both district heating and wider deployment of heat pumps, in order to enable the displacement of fossil fuel in the heating sector via renewable electricity. Other options for consideration in the call for evidence are the decarbonisation of the gas network and geothermal heat.[13]

The remainder of this paper provides a range of background information, to enable the Committee for the Economy's scrutiny of the Department's development of the NES, with a specific focus on renewable energy. This is achieved by examining the current level of renewable energy in NI, before focusing on a range of specific renewable energy technologies, and examining their capacity, cost and environmental impact. Throughout the sections that follow, a number of questions arise from the data presented, which may assist the Committee's scrutiny of the Department's NES.

A number of such questions arise from this section, and have been outlined in the box below:

Energy Strategy - key issues and questions:

- How will the Department ensure the NES is aligned to the UK Climate Change Act? How will it ensure that NI's future energy policy will assist in delivering net zero carbon emissions by 2050?
- How will the Department ensure the NES will be aligned to the NI Climate Change Act? Note, the New Decade, New Approach states that the NI Executive to will bring forward a Climate Change Act. This will seek to give NI environmental targets a *'strong legal underpinning'.* How will the targets an action included in the NES contribute to an NI Climate Change Act?. .[14]

2 Current penetration of renewables in NI

This section examines current levels of renewable penetration in NI, looking at various themes, which serve to highlight limited information on NI's renewable heat penetration:

- Contribution of renewable electricity generation to NI electricity consumption (subsection 2.1.1);

[12] *Ibid*
[13] *Ibid*
[14] UK Government, New Decade, New Approach (January 2020) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/856998/2020-01-08_a_new_decade__a_new_approach.pdf

- Contribution of microgeneration in NI (subsection 2.1.2);
- Role of the NI Renewable Obligation in stimulating renewable electricity development (subsection 2.1.3);
- Extent to which the NI grid can accommodate greater levels of renewable electricity generation on the system (subsection 2.1.4); and,
- Key features of the NI renewable heating sector (subsection 2.2.1).

2.1 Renewable electricity in NI

This subsection first sets out: the latest data addressing renewable electricity in NI (subsection 2.1.1); and, data gaps relating to microgeneration (subsection 2.1.2). Thereafter, it provides brief overviews of: energy support schemes stimulating NI renewable growth (subsection 2.1.3); and, potential electricity grid strengthening to facilitate greater NI renewable electricity generation.

2.1.1 The contribution of renewable electricity generation in NI

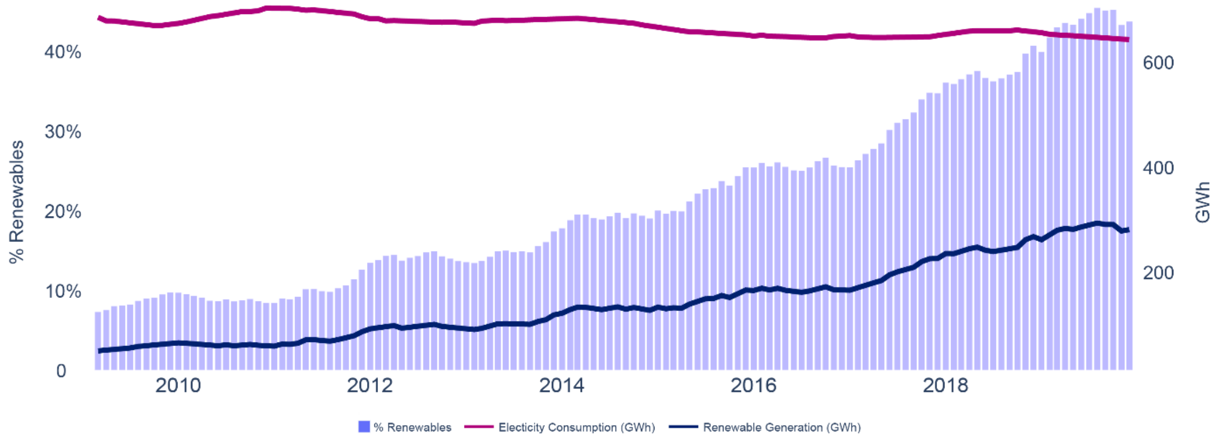
The DfE has published data on annual renewable electricity consumption in NI since September 2014, with annual data going back to May 2009. As such, it is possible to track the trajectory of renewable electricity generation in NI from March 2009 to December 2019. This importantly helps to show the proportion of electricity consumption that came from renewable generation over this period. Figure 1 below does this, showing the 12-month rolling average amount of renewable electricity generated in NI as a percentage to total electricity consumption. As can be seen from the Figure, there has been a significant increase in renewable penetration over the given period; rising from 7.3% in March 2009, to 43.7% in December 2019.[15]

As noted in section 1 above, the SEF set a target of generating 40% of NI electricity needs from renewable sources by 2020. The data from the DfE shows that target has been reached and exceeded. Looking more closely at the data shows this figure was first reached in a 12-month rolling period, in the 12-months leading up to December 2018, when 40.7% of electricity consumption came from renewable resources.

Figure 1 also plots the rolling 12-month rolling average level of electricity consumption during both this period and the rolling 12-month average level of renewable electricity generation during the same period. This shows that over the period electricity consumption decreased by 6.19%, whilst renewable energy generation increased by over 450%.

[15] Department for the Economy, Electricity Consumption and Renewable Generation NI – issue 14 (March 2020) https://www.economy-ni.gov.uk/sites/default/files/publications/economy/Electricity-Consumption-Renewable-Generation-NI-issue-14.pdf

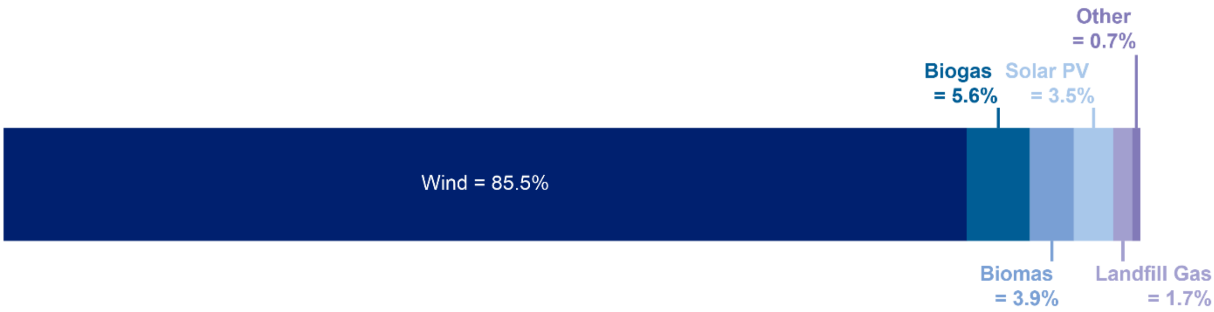
Figure 1: NI 12-month rolling average electricity consumption, renewable generation and proportion of renewable electricity generation, March 2009 to December 2019[16]



Source: DfE (2020)

Figure 2 takes a closer look at renewable generation in NI. The figure provides a breakdown of renewable generation energy by type, during the 12-month period January 2019 to December 2019. The figure shows wind to be the most predominant source of renewable generation. Onshore wind energy has consistently been the largest source of renewable generation in NI. It provided around 83.5% to 85.5% of renewable generation in each 12-month rolling period between December 2017 and December 2019.[17]

Figure 2: NI Renewable electricity generation mix during the 12-month period ending December 2019[18]

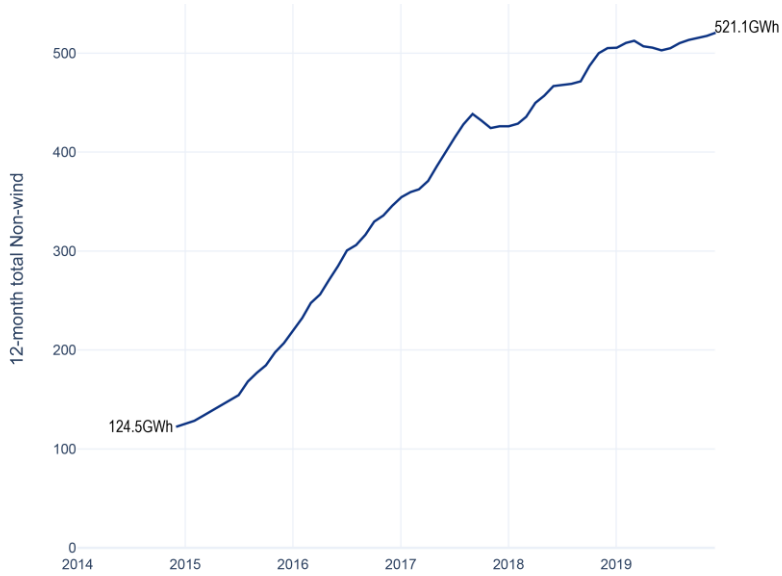


Source: DfE (2020)

Figure 3, however, shows that the volume of other forms of renewable generation have shown significant growth, from 122.4 Gigawatt hours (GWh) during the 12-month period ending December 2014, to 521.1GWh during the 12-month period ending December 2019.[19]

[16] *Ibid*
[17] *Ibid*
[18] *Ibid*
[19] *Ibid*

Figure 3: NI rolling 12-month volume of non-wind renewable electricity generation, December 2014 to December 2019[20]



Source: DfE (2020)

2.1.2 Electricity microgeneration in NI

The overall figure for renewable electricity generation in NI does not include microgenerators (defined as generators with a capacity of 50kW or less) and *'a small number of generating stations that are unable to export electricity to the grid'.* This is because:

> *Due to their particular circumstances, neither NIE Networks nor SONI have information on the electricity generated by some renewable generators.[21]*

The DfE notes, however, that:

> *…an estimate of the extent of renewable electricity generation in Northern Ireland and non-export generating stations has been provided by Ofgem from their Renewable Obligation Certificate (ROC) register. Assuming that the vast majority of these generators are accredited to the Northern Ireland Renewable Obligation and are (NIRO) and are therefore receiving ROCs for their renewable generation, this would represent a very good estimate of the volume of the renewable electricity and non-export generation in Northern Ireland.[22]*

Based on this method, the DfE estimated that during the 12-month period April 2018 to March 2019 an estimated 83.7GWh of renewable electricity was produced by microgenerators in NI, with a further 32.3GWh produced by non-export generators. The

[20] *Ibid*
[21] *Ibid*
[22] *Ibid*

DfE notes (and this is explored in more detail in subsection 2.1.3 below) that the NIRO closed for new entrants on 31 September 2017. As such, the Ofgem's ROC Register as a measure of micro and non-exporting generation, cannot fully capture all of these types of generating capacity. The department has stated that a *'small number'* of generators *'may not be accredited to the NIRO and would not be included in the Ofgem figures'.*[23] A key question arises here in relation to the future of NI's energy strategy, i.e. how best to capture developments in these types for generation going forward?

2.1.3 The Northern Ireland Renewable Obligation

Note that for the majority of the period examined in subsection 2.1.1, renewable energy development in NI was supported by the *'NI Renewable Obligation'* scheme (NIRO), which was launched in 2005.

Under the NIRO scheme, electricity suppliers were legally required to evidence specified renewable sources within the electricity provided to consumers. Evidence of compliance with this obligation was to be provided in the form of *'Renewable Energy Certificates'* (ROCs). ROCs were issued for free to accredited generators for every Megawatt hour (MWh) of electricity they generated. Generators then could sell these ROCs to electricity suppliers on the open market. This provided renewable energy generators with two income streams – one from electricity sold to the grid, and the other from the sale of ROCs to suppliers.

The NIRO scheme:

> *… closed to new large scale onshore wind on 31 March 2016, to new small scale onshore wind on 30 June 2016 and to all other technologies on 31 March 2017, with exceptions to those projects that met the criteria for grace periods.*
>
> *All grace periods*[24] *have expired and the NIRO is now closed to all new renewable electricity generation. It is important to note that all those projects already accredited will continue to receive ROCs for 20 years from their accreditation date or until 31 March 2027, whichever is earlier.*[25]

Two aspects of the NIRO were seen to be particularly favourable to NI. First, NI electricity consumers paid less for subsidising renewable development than their Great Britain (GB) counterparts, due to lower obligation levels. Second, the NIRO was a non-competitive scheme, supporting all eligible renewable projects.

The NIRO was phased out in line with equivalent schemes in GB. The GB schemes were replaced by the *'Contracts for Difference'* (CfD) scheme, with respect to large-

[23] *Ibid*

[24] The grace periods for NIRO applied from 1 April 2017 to the 31 March 2018, see Ofgem for details https://www.ofgem.gov.uk/system/files/docs/2016/08/niro_closure_factsheet.pdf

[25] DfE, Northern Ireland Renewable Obligation (accessed 15 April 2020) https://www.economy-ni.gov.uk/articles/northern-ireland-renewables-obligation

scale renewable electricity generation (generation with a capacity in excess of 5MW). The CfD scheme is an initiative of the UK Department for Business, Energy and Industrial Strategy. CfDs are based on the following principles:

- A generator is offered a 15-year contract with a known 'strike price' for the renewable electricity sold. The strike price is defined as 'a price for electricity, reflecting the cost of investing in a particular low carbon technology'.
- If the market price for electricity is below the strike price, the generator is paid the difference between the two. This is funded by a levy on consumers' bills.
- If the market price for electricity is above the strike price, the generator pays back the difference.[26]

The CfD has fundamentally changed how renewable electricity generation is incentivised in GB. Unlike the NIRO and its GB equivalents, which supported all eligible renewable electricity generation, the CfD scheme is based on a competitive auction and aims to keep costs low. The UK Government also has the power to cap the capacity that certain technologies can win. It can therefore then limit the amount of new capacity of a particular technology it chooses to support.

Additionally, the Government may choose not to support specific technologies through CfDs. CfD funding is set out in two 'Pots', which group together the technologies that can compete. Pot 1 is for established technologies, including onshore wind, solar photovoltaic (PV), energy from waste and hydro. Pot 2 is for 'less established technologies', including offshore wind, tidal, wave, and dedicated biomass. Following the 2015 election, the UK Government withdrew support for Pot 1 technologies. This decision was reversed in March 2020, with the UK Government announcing that it would reintroduce support for Pot 1 technologies as part of the 2021 CFD allocation.[27]

To date, the NI Executive has not chosen to join the CfD scheme. This coupled with the closure of the NIRO, means that large-scale renewable technology is not currently incentivised in NI.

A similar situation had existed with small-scale renewable technology. The NIRO was the main support scheme for small scale renewable electricity (defined as electricity generation projects of under 5MW). Since the closure of the NIRO, NI has not operated a support scheme for small-scale renewable electricity generation. In GB, however, support for small-scale renewables continued to receive support through a Feed-in tariff. This scheme was also closed to new applicants as of the 1 April 2019.[28]

[26] House of Commons Library, Briefing Paper, Support for low carbon power (8 April 2020) https://researchbriefings.files.parliament.uk/documents/CBP-8891/CBP-8891.pdf

[27] *Ibid*

[28] Ofgem, Feed-in tariffs: essential guide to closure of the scheme (March 2019) https://www.ofgem.gov.uk/system/files/docs/2019/03/guide_to_closure.pdf

The NIRO closed in 2017. Renewable generation has continued to grow in NI in the absence of a support scheme. This leads to questions of what financial support, if any, should be included in the NES?

Furthermore, the *'The Report of the Independent Public Inquiry into the Non-domestic Renewable Heat Incentive (RHI) Scheme'* (2020) (the RHI Report) made a number of recommendation with respect the introduction of new policies and initiatives by the NI Executive. Of particular relevance here is Recommendation 2, which stated:

> *Novel, potentially volatile and untested initiatives should in future be scrutinised thoroughly, well ahead of ministerial and business case approval. The Inquiry commends processes such as a 'starting point Gateway assessment' and, at a suitable point, a 'feasibility signoff' completed by the Department's Accounting Officer. With regard to particular policies driven by unpredictable demand, consideration should always be given, before the policy is implemented, to the inclusion of a clearly drafted statutory power to enable swift action to be taken to suspend and/or close the scheme in order to bring it under control.*

This leads to the questions of how the NES could ensure that any new renewable electricity incentive will be designed and implemented in a way that meets the RHI Report's recommendations.

2.1.4 Grid capacity

Section 2.1.1 showed that the 12-month rolling average level renewable electricity generation penetration on the NI system was 43.7% during the 12-month period to December 2019. This average figure does not reflect the true levels of renewable electricity generation on the NI system at any one time. For example, the monthly figure for the proportion of electricity consumption generated from renewable source fluctuates on a monthly basis. The record high for an individual month was in February 2019, when 58.6% of electricity consumption came from renewable generation.

If NI wishes to continue to increase the level of renewable generation on the electricity system, it is likely that this record high will be surpassed. The grid system, however, is limited in the level of renewable generation that it can incorporate. According to the System Operator for NI (SONI), the gird can currently operate with up to 65% renewables. SONI argues, however, in order to meet the UK Government's target of net zero carbon emissions by 2050, the grid must have capacity to incorporate 95% renewables by 2030.

To achieve this, SONI's *'Strategy for 2020 to 2025'* states that it will:

> *Operate, develop and enhance the Northern Ireland grid and market.*[29]

[29] SONI, Strategy 2020-25 http://www.soni.ltd.uk/about/strategy-2025/SONI-Strategy-2020-25.pdf

The Strategy states that this will include:

- Ensuring that the market is balanced, transparent and open. To permit greater competition and to allow for rapid growth in renewables;
- Preparing for growth in demand-side participation as more electricity users start to generate and store power;
- Utilising future interconnection to managed larger amounts of renewables and enhance energy security;
- Optimising existing grid assists and developing new infrastructure; and,
- Using innovative, yet proven, technologies to minimise the need for new infrastructure.[30]

The SONI Strategy notes that its actions will be guided by UK climate change policies and by NI energy policy. It states that those policies will collectively *'work constructively'* to support the process of developing a new NI energy strategy, *'… guided by its outcome'.* A key question then becomes what should the NES do to support grid enhancements to support renewable electricity generation?[31]

As noted in Section 1 of this paper, it was estimated that the grid enhancements to support 40% renewable penetration in the NI electricity market would cost approximately £1 billion. Coupling that information with what has been discussed in this sub-section, two questions:

- What has the actual cost been?
- What is the estimated cost of grid strengthening associated with the NES?

2.1.5 Summary

The analysis above shows that NI has delivered steady growth in renewable electricity generation, exceeding the targets set in the SEF. It also shows that this has largely been predicated on the development of wind energy in the region, but that other forms of energy also have shown growth.

There are a number of issues arising out of this analysis. These in turn give rise to a number of questions about the future of energy strategy in NI. These issues and questions are summarised box below.

Energy Strategy - key issues:

- What and how will the NES target renewable electricity generation levels as a proportion of overall energy need?

[30] *Ibid*
[31] *Ibid*

- Will the NES seek to diversify NI renewable electricity generation, given that onshore wind energy is the predominant source of renewable electricity generation in NI?
- If the NES will seek to diversify as stated, what technologies will be prioritised? How will this be achieved?
- How will the NES rectify the fact that it is not possible to provide a precise picture of NI existing microgeneration levels?
- Will the NES seek to introduce support for large or small-scale renewable generation in NI, given none currently exists?
- If the NES is to introduce the above support, what form is this anticipated to take? What controls will it include and how will they be reviewed as per the recommendation of the RHI Report? What is its anticipated impact on consumer bills?
- SONI has stated that the NI grid requires enhancement if the UK climate change targets are to be met in NI. If so, how will the NES support such enhancement? What is the estimated cost of that enhancement?

2.2 Renewable heat in NI

This subsection provides an overview of renewable heat in NI. As noted in section 1, the SEF (Strategic Energy Framework) set a 2020 target for 10% renewable heat consumption; but as highlighted in the 2019 DfE Energy Strategy call for evidence, that target remains unmet due to inadequate policy design:

> *…policy to achieve the 10% renewable heat target was poorly designed and the target was not achieved.*[32]

This subsection enables the Committee to examine existing NI renewable heat initiatives. It, however, is not as detailed or as comprehensive as subsection 2.1, which addressed NI's more developed and successful renewable electricity sector. Unfortunately, this is due to limited NI renewable heat data, which in turn restricts the level of sectoral analysis that can be carried out by RaISe.

2.2.1 Key features of the NI renewable heating sector

In NI, the heating sector is a significant energy consumer. It is responsible for approximately half of NI's total energy consumption, and accounts for approximately 52% of its household energy bills.[33]

A key issue with the NI heating sector is that the total heating load amount currently is not measured; instead 'best guess' estimates are the only present measurement

[32] Department for the Economy, Energy Strategy – Call for evidence (December 2019) https://www.economy-ni.gov.uk/energy-strategy-call-for-evidence

[33] *Ibid*

approach for consumption and generation in the sector. This means an accurate heating sector baseline is not possible at present.

Nonetheless, drawing on the most recent DfE data in this area, published in 2019, but covering the year 2016, the following is known:

- Oil was the predominant form of heating in households; with approximately 68% of homes heated this way;
- Natural gas was the heating source in 24% of homes; while 8% of homes used solid fuel, electric, dual fuel or other forms of heating;
- NI was home to 90 heat networks; the majority of which were communal heat networks in social housing, and a number of industrial and commercial premises utilised heat networks. Few such networks existed outside of these sectors.[34]

In addition to the above, in 2012 a *'Renewable Heat Incentive'* (RHI) support scheme was introduced for non-domestic renewable heat. This was followed in 2014, by a RHI for domestic heat. The implementation of these incentives resulted in the installation of approximately 4,500 biomass boilers that were split between 2,000 non-domestic and 2,500 domestic boilers. A small number of heat pumps were also installed under the RHI scheme.[35] This was not in line with the DfE's expectations. When commenting on the scheme in its December 2019 NES call for evidence, the DfE stated:

> *While this was designed to incentivise the use of a number of alternative, sustainable heat technologies including heat pumps and solar technology, it became associated almost exclusively with biomass boilers. Flaws in the tariffs for biomass users accredited to the Non-Domestic RHI scheme meant the scheme significantly exceeded its budget, putting wider public services at risk. Ultimately, the schemes were closed to new applicants in 2016 cost controls have been implemented through amended tariffs and the scheme remains the subject of litigation.*
>
> *This support scheme for renewable heat did not deliver the targeted outcomes.* ***Lessons have been learned and it is vitally important that any future support schemes to facilitate decarbonisation of our homes and or businesses are considered in this context.***[36] [emphasis added]

The highlighted part of the above quote suggests that a future support scheme within the heat sector is possible. No details, however, are available at present, to indicate how such a scheme may support the decarbonisation of the heating sector.

[34] *Ibid*
[35] *Ibid*
[36] *Ibid*

The DfE call for evidence document does not indicate that the DfE is considering a renewable heat generation target that would be similar to the SEF 10% target. The DfE therefore is instead seeking evidence on:

> *…the appropriate pathway and timeline for the decarbonisation of heat between now and 2030, and subsequently to 2050.*[37]

The:

> *…appropriate ways to measure the progress of decarbonising heat.*[38]

And:

> *…the most cost-effective and sustainable steps that the government might take to accelerate the reduction of the carbon intensity of heating fuels.*[39]

The above call for evidence suggests that a number of options are under consideration: these include: district heating; decarbonisation of the gas network; geothermal; and, other renewable heat forms. These technologies are explored below in Section 4 of this paper.

Energy Strategy - key issues:

- Will the NES include a renewable heat target?
- If the above target is set, at what level of renewable heat generation, as a proportion of final heat need, will it be?
- If the above target is not set, what other heating targets could be included?
- How will the NES seek to improve data collection regarding the NI heating load?
- Will the NES include a support scheme for the heating sector?
- If a heating sector scheme is included, what form will that scheme take?What controls will it include and how will they be reviewed as per the recommendation of the RHI Report? What is its anticipated impact on consumer bills?
- Beyond social housing and industry, what is the potential for district heating in NI?
- What is NI's geothermal capacity?

3 Renewable electricity technologies – capacity, cost and impact

This section utilises a number of sources to provide background information on a range of renewable electricity generation technologies, i.e.:

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[37] *Ibid*
[38] *Ibid*
[39] *Ibid*

- Subsection 3.1 uses data from the International Renewable Energy Agency and the Intergovernmental Panel on Climate Change, to compare global capacity, cost and emissions of range of technology types.
- Subsection 3.2 supplements subsection 3.1: looking at each technology in greater detail; defining each and examining the broader potential environmental impact; examining the capacity of each technology in NI; and, outlining the economic impact in NI, when available.
- Subsection 3.3 provides a brief summary and raises some key points and questions, which the Committee may wish to consider in its scrutiny of the DfE's NES.

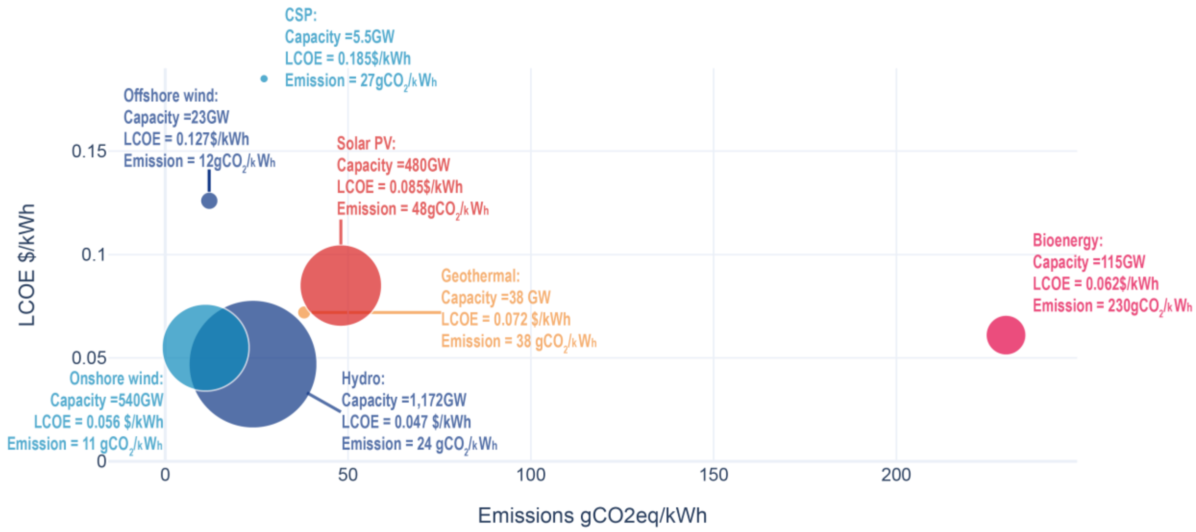
3.1 Renewable electricity technologies – global capacity, cost and impact

Outlining specific renewables electricity generation technologies at a global level, this subsection examines their global capacity, estimated cost and emissions impact.

Figure 4 below provides a summary the findings arising from this section. The Figure plots each technology type, according to the three variables outlined above – capacity, cost and emissions impact.

When interpreting the Figure, note that technologies situated to the top of the graph have a higher cost than those situated to the bottom. Technologies situated to the right of the graph have a greater emissions impact than those technologies situated to the left. The size of the circles represents the level of installed capacity, with bigger circles representing a greater amount of installed capacity.

Figure 4: Renewable electricity technologies by capacity, cost and emissions impact[40][41][42]



Sources: IRENA (2019), IPCC (2014)

Data for global installed capacity are sourced from the International Renewable Energy Agency (IRENA) report *'Renewable Energy Capacity Statistics 2019'*.[43] Figure 4 presents global installed capacity is in Gigawatts (GW) and for the year 2018. As can be seen from the Figure, at 2018, hydropower had the largest installed capacity at 1,1172GW. This was followed by onshore wind, which had installed capacity of 540GW. Of the technology types considered in Figure 4, concentrated solar power had the lowest installed capacity at 5.5GW.

Energy cost data also was sourced from the IRENA report *'Renewable Power Generation Costs in 2018'*.[44] The report provides a comparative look at electricity generation costs across a range of established technology types. Specifically, the report measures the cost of each technology using estimates of the global 'Levelised cost of electricity' (LCOE). The LCOE:

[40] IRENA, Renewable Capacity 2019 (2019) https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Mar/IRENA_RE_Capacity_Statistics_2019.pdf

[41] IRENA, Renewable Power Generation Costs in 2018 (2019) https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/May/IRENA_Renewable-Power-Generations-Costs-in-2018.pdf?la=en&hash=99683CDDBC40A729A5F51C20DA7B6C297F794C5D

[42] Schlömer S., T. Bruckner, L. Fulton, E. Hertwich, A. McKinnon, D. Perczyk, J. Roy, R. Schaeffer, R. Sims, P. Smith, and R. Wiser, 2014: Annex III: Technology-specific cost and performance parameters. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf

[43] IRENA, Renewable Capacity 2019 (2019) https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Mar/IRENA_RE_Capacity_Statistics_2019.pdf

[44] IRENA, Renewable Power Generation Costs in 2018 (2019) https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/May/IRENA_Renewable-Power-Generations-Costs-in-2018.pdf?la=en&hash=99683CDDBC40A729A5F51C20DA7B6C297F794C5D

> *…is the price of electricity required for a project where revenues would equal costs, including making a return on the capital invested equal to the discount rate.*[45]

A basic formulation of an LCOE is total life cycle costs/ total lifetime energy production, where life cycle costs include investment expenditure, operations and maintenance and any fuel expenditure associated with the technology. The calculation does not include any financial support that may be offered to renewable energy developers. Estimates of LCOE allow for comparison across different technologies. The LCOE is presented in US Dollars per Kilowatt hour of electricity produced ($/Kwh). As can be seen from the figure, the LCOE of the energy technologies examined range from 0.047$/kWh for hydropower to 185$/kWh for concentrated solar power. The LCOE for onshore wind was 0.056$/kWh, and 0.085$/kWh for solar PV.

To place all these in context, the IRENA report estimates that fossil fuel-fired generation costs range between 0.049$/kWh to 0.174$/kWh, based on country and fuel type. Based on these estimates, onshore wind was comparable to the lower end of the fossil fuel cost range, and solar PV comparable to the mid-point of the same range.

Data for the environmental impact is sourced from the Intergovernmental Panel on Climate Change's (IPCC) *'Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change'.*[46] It represents the most recent publication of data of this type from the IPCC, updated estimates are expected in 2022. The IPPC measure of environmental impact used in this paper estimates whole life emissions for each technology type. The IPPC explained their approach as follows:

> *The emission intensity of electricity production (measured in kg CO_2 equivalents (CO_2eq) / MWh) can be used as a measure to compare the specific greenhouse gas (GHG) emissions of suggested emission mitigation options and those of conventional power supply technologies.*[47]

The IPPC methodology uses estimates of direct emission, infrastructure and supply chain emissions, biogenic carbon dioxide emissions[48] (CO_2), the albedo effect[49], and methane emissions, to establish a maximum, median and minimum estimate of grams CO_2 per kWh (gCO_2/kWh) for each technology. Figure 3 uses the median value. As can be seen from the Figure, onshore wind is estimated to have the lowest emission

[45] *Ibid*

[46] Schlömer S., T. Bruckner, L. Fulton, E. Hertwich, A. McKinnon, D. Perczyk, J. Roy, R. Schaeffer, R. Sims, P. Smith, and R. Wiser, 2014: Annex III: Technology-specific cost and performance parameters. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf

[47] *Ibid*

[48] Emissions resulting from the combustion of decomposition of biologically-based materials other than fossil fuels.

[49] The amount of solar radiation reflectimg from a surface.

impact, with lifecycle emissions of 12gCO_2/kwh. Dedicated bioenergy is estimated to have the largest emission impact of 230gCO_2/kWh. To put these figures into context, the IPPC calculated the following median estimates for traditional fossil fuel generation and nuclear:

- Coal – 820gCO2/kWh;
- Gas – 490gCO2/kWh; and,
- Nuclear – 12gCO2/kWh.[50]

According to these findings, all renewable electricity sources have lower emissions than coal and gas. Nuclear was found to have lower lifecycle emission than all sources, except for onshore wind, which was slightly higher, and offshore wind, which was equal to it.[51]

Data for tidal and wave renewable electricity generation is not included in Figure 4, as there was insufficient information in one or more of the variables to enable an accurate comparison. The installed capacity, LCOE and emission impact of each noted technology, is explored later in this paper, at the below subsections found in 3.2 examining renewable electricity generation technologies, generally and in particular (see 3.2.8 for details of wave and tidal electricity generation)

3.2 Renewable electricity generation technologies

Drawing on a range of sources, notably the IEA, IRENA, the IPPC and the UK Office of National Statistics (ONS), the following paragraphs provide a more detailed look at a range of renewable electricity generation technologies. The subsections: define each technology type; provide greater detail on its global and NI capacity; and, highlight technology costs and estimated emissions. They also examine key broader environmental effects of each technology, and outline some of the economic benefits in a NI context, when available.

The following technologies are examined:

- Onshore wind (subsection 3.2.1a)
- Offshore wind (subsection 3.2.2a)
- Solar PV (subsection 3.2.3a)
- CSP (subsection 3.2.4a)
- Geothermal electricity (subsection 3.2.5a)
- Hydroelectricity (subsection 3.2.6a)
- Bioenergy (subsection 3.2.7a)
- Ocean energy: Wave and tidal (subsection 3.2.8a)

[50] *Ibid*
[51] *Ibid*

This subsection is intended only as an introduction to these technologies, not a comprehensive assessment of each, which is beyond the scope of this paper.

3.2.1a Onshore wind

IRENA explain the process by which wind is converted to electricity as follows:

> *Wind is used to produce electricity using the kinetic energy created by air in motion. This is transformed into electrical energy using wind turbines or a wind energy conversions systems. Wind first hits a turbine's blades, causing them to rotate and turn the turbine connected to them. That changes the kinetic energy rotational energy, by moving a shaft which is connected to a generator, and thereby producing electrical energy through electromagnetism.*
>
> *The amount of power that can be harvested from wind depends on the size of the turbine and the length of its blades. The output is proportional to the dimensions of the rotor and to the cube of the wind speed. Theoretically, when wind speeds doubles, wind power potential increases by a factor of eight.* [52]

As noted in Figure 4 above, in 2018, the global installed capacity of onshore wind was 540GW, making it the second largest form of installed renewable capacity after renewable hydro. It also had the second lowest LCOE (0.056$/kWh) and the lowest lifecycle emissions (12gCO2/kwh) of all the technologies examined in Figure 4.

In NI, as of 2018, a total of 1,393MW of onshore wind was installed. The technology has the highest installed capacity of any NI renewable resource, equivalent to 76% of total renewable installed capacity in 2018. Onshore wind capacity represents 10% of the total onshore wind capacity in the UK.[53]

3.2.1b What are the potential impacts of onshore wind?

As noted, the onshore winds' median emissions impact is deemed to be low relative to other renewable electricity generation technologies. In 2014, it was estimated to be considerably lower than fossil fuel generation, and broadly equivalent to nuclear energy. According to the IPCC, the emissions associated with onshore wind are infrastructure and supply chain emissions. The technology is estimated to have no direct emissions.[54]

[52] IRENA, Wind Energy (accessed 16 April 2020) https://www.irena.org/wind

[53] ONS, Regional Renewable Statistics (update 26 September 2019) https://www.gov.uk/government/statistics/regional-renewable-statistics

[54] [54] Schlömer S., T. Bruckner, L. Fulton, E. Hertwich, A. McKinnon, D. Perczyk, J. Roy, R. Schaeffer, R. Sims, P. Smith, and R. Wiser, 2014: Annex III: Technology-specific cost and performance parameters. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)].

Beyond emissions, onshore wind energy has a number of other environmental and societal impacts. From an environmental perspective, these include visual impacts, noise impacts and impacts on wildlife. These impacts are summarised in Table 1 below:

Table 1: Summary of potential non-emission environment impacts of onshore wind[55]

Type	Impact	Mitigation
Visual	Turbines placement on higher ground to access the best wind resource can result in views being affected.	The impact may be minimised through careful siting decision, such as avoiding sensitive locations, or making use of natural landscape features, such as trees and hills, to screen turbines.
Visual	Sun shine through a moving turbine can cast a flickering, moving shadow.	This impact is generally experienced by dwellings within 130 degrees either side of north relative to the wind turbine, and within 10 rotor diameters of the site. It can be minimised by careful siting of wind turbine. Turbine may also be set to stop if the flickering effect occurs.
Sound	Turbine operation can result in noise, which can be particular noticeable in rural areas where there is little background noise.	Modern turbines have been designed to minimise noise impacts.
Wildlife	Turbines may impact on birds through collision, disturbance or habitat damage.	Careful siting of turbines can minimise impacts. Turbine should avoid situating close to migration pathways and habitats.
Wildlife	Turbines may also impact bat populations in similar ways to birds.	Again, careful siting, away from trees and hedgerows, can minimise these impacts.

Source: LGA (2019)

The UK Local Government Association (LGA) notes that while the lower emission benefits of wind energy are of global and national significance, the environmental impacts *'tend to be felt locally'*.[56]

In addition to the direct impacts associated with the development of onshore wind, consideration also should be given to any associated development. The *'Onshore Renewable Electricity Action Plan'* (OREAP), published by the then Department for Enterprise, Trade and Investment in 2013, noted:

> *There is potential increased likelihood of significant effects occurring where development is dispersed to new locations/areas, in particular where there are currently no wind farm developments or very few developments and where there would also be a requirement to provide new grid infrastructure*

Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf

[55] Local Government Association, Benefits and potential impacts wind energy (accessed 16 April 2020) https://www.local.gov.uk/benefits-and-potential-impacts-wind-energy

[56] *Ibid*

or substantial reinforcements in order to enable development in new areas.[57]

Onshore wind has been shown to have some societal benefits, beyond a reduction in emissions. From an economic perspective, the ONS estimated there to be 500 onshore wind businesses operating in NI (rounded to the nearest 100) in 2018. The sector: had an estimated turnover of £301 million (m) (rounded to the nearest £500,000); employed an estimated 700 people (on a full-time equivalent basis, rounded to the nearest 100) in the same year; and, was responsible for £4m (rounded to the nearest £500,000) in exports in 2017.[58]

3.2.2a Offshore wind

Offshore wind produces electricity, using the same processes as onshore wind. One difference between the two technologies is that offshore can facilitate larger capacity turbines. According to IRENA, individual offshore wind turbines tend to have capacities in the region to 3-5MW, compared to 2MW for onshore turbines.[59]

Figure 4 above shows offshore wind to have the second highest LCOE (0.127$/kWh), which is comparable to the higher end of the fossil fuel range. Offshore winds lifecycle emissions (12 gCO_2/kWh) were only slightly higher than onshore wind energy, making it the second lowest of all technologies examined, and significantly lower than both coal and gas. It had the second lowest installed capacity of the renewable technologies examined.

As of 2018, NI had zero or negligible[60] amounts of offshore wind installed.[61] Although NI has not developed any offshore wind capacity, the UK as a whole is a world leader in the technology. Offshore wind generation provided 6.2% of total energy generation in 2017, and is expected to reach 10% in 2020. The UK is supporting the technology through the CfD scheme, with support of up to £557m in auctions, which will take place every two years (auctions began in 2019). The UK has ambitions to install 30GW by 2030.[62] As noted in subsection 2.1.3 of this paper, NI does not currently participate in the CfD scheme. NI developers are unable to take part in this auction process. There is the potential for NI companies to benefit from this development by taking advantage of supply chain opportunities.[63]

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[57] Department for Enterprise, Trade and Investment, Onshore Renewable Electricity Action Plan 2013-2020 (Nov 2013) https://www.economy-ni.gov.uk/sites/default/files/publications/deti/OREAP%202013-2020.pdf

[58] ONS, Low Carbon and Renewable Energy Economy Estimates (Jan 2020) https://www.ons.gov.uk/file?uri=%2feconomy%2fenvironmentalaccounts%2fdatasets%2flowcarbonandrenewableenergyeconomyfirstestimatesdataset%2fcurrent/lcreedataset2018.xlsx

[59] IRENA, Wind Energy (accessed 16 April 2020) https://www.irena.org/wind

[60] Source data does not make clear whether installed capacity is at zero. No figure for NI is provided, rather the data shows a dash which is indicative of 'Nil or less than half the final digit shown'.

[61] ONS, Regional Renewable Statistics (update 26 September 2019) https://www.gov.uk/government/statistics/regional-renewable-statistics

[62] Department for Business, Energy & Industrial Strategy, Offshore wind sector deal (updated 4 March 2020) https://www.gov.uk/government/publications/offshore-wind-sector-deal/offshore-wind-sector-deal#fn:1

[63] *Ibid*

Whilst NI has not developed any offshore wind capacity, it has taken forward a number of work streams in the area, as outlined in the *'Offshore Renewable Energy Strategic Action Plan 2012-2020'* (ORESAP). The most recent ORESAP annual progress report, which covers the period April 2018 to March 2019, highlights a number of significant issues with regard to offshore wind development in NI, which are of relevance to this paper.

- In October 2012 a consortium consisting of B9 Energy, RES and DONG Energy, were awarded development rights in respects to a 400MW offshore wind project off the County Down Coast. In December 2014, the consortium, announced that it had taken the commercial decision not to proceed. The consortium stated its decision to pull out of the project was *'as a result of delays to the design of the new market and renewable incentive arrangements for Northern Ireland'*[64].[65]
- During 2018 DfE and the Department of Agriculture, Environment and Rural Affairs liaised with The Crown Estate (TCE) on its policy development for offshore renewables. From an NI perspective, this focused on the potential to participate in a seabed leasing round in UK waters during 2019. Following a process of 'characterisation modelling', NI water was excluded from the leasing process. The DfE outlined the reason for this in their 2018-2019 ORESAP Progress Report:

> *The modelling found that there were significant challenges, even with mitigation, mean that the conditions are not yet right for fixed foundation offshore wind development around NI's coastline. The primary criteria used to assess the suitability is the 99 per cent of the NI characterisation area (as defined by The Crown Estate) is within 13km of the coast and is therefore constrained by risk and uncertainty associated with visual sensitivity from shore. Other challenges assessed in refining regions included Ministry of Defence activity; and high density shipping activity (traffic of more than 1,000 ships per year).*
>
> *This does not mean that offshore wind developments cannot be taken forward in NI waters in the future, particularly given the significant advances that are being made in terms of alternative technologies e.g. floating wind platforms.*
>
> *DfE officials will continue to work closely with their TCE colleagues to ensure that NI remains fully engaged and is a consideration for any future development opportunities.*[66]

[64] Wind Power Monthly, First Flight cancels Northern Ireland offshore project (2 December 2014) https://www.windpowermonthly.com/article/1324596/first-flight-cancels-northern-ireland-offshore-project

[65] DfE, Offshore Renewable Energy Strategic Action Plan (ORESAP) 2012-2020 Progress Report 1 April 2018 to 31 March 2019 (July 2019) https://www.economy-ni.gov.uk/sites/default/files/publications/economy/ORESAP-progress-report-to-March%202019.pdf

[66] *Ibid*

3.2.2b What are the potential impacts of offshore wind?

As noted above, offshore wind has one of the lowest estimated lifecycle emissions of the renewable electricity technologies examined. However, as noted in the DfE quote above, the technology does have a number of potential environmental and other effects beyond emissions output. These are summarised below in Table 2.

Table 2: Summary of potential non-emissions impacts of onshore wind[67]

Type	Impact	Mitigation
Noise	Development of offshore wind may result in noise during survey, installation/decommissioning and operation.	Mitigation measures include minimise the use of high noise mission activities, appropriately timing construction activities, and using sound insulation where appropriate.
Wildlife	Physical habitat disturbance, bird collision, and creating barriers to wildlife movement.	Impacts can be minimised through careful site section and careful device design (using acoustic deterrents for example).
Contamination	The potential for toxic contamination exists during the installation, operation and decommissioning phases	Mitigation measures include the use of non-toxic materials, risk assessment and mitigation planning, carrying out potentially hazardous operations under appropriate conditions.
Vessel activity	Installation/decommissioning of devices and cables are likely to lead to increase vessel activity in the site area.	Mitigation measures include: speed limits for construction vessels; a code of conduct to avoid disturbance to animals both during construction and transit.
Sediment mobilisation	Installation may result in sediment mobilisation	Mitigation measures include: minimising dredging; carrying out work in appropriate conditions; avoiding sensitive areas and areas of sediment contamination.
Coastal processes	Installation may result in changes to coastal processes.	This can be minimised through modelling led site placement.
Scour	Scour is the movement of sediment that can erode the seabed around a fixed structure. This can result from cable and device operation.	Mitigation measures include: site selection; use of scour protection; and use of cable protection.
Water	Device operation may result in decreased water flow.	This can be mitigated through careful site selection and assessment of effects on water flow
Wildlife	Electromagnetic fields from cable operation may impact some species.	Appropriate burial depth can minimise these impacts.

Source: DETI (2012)

According to the ONS publication *'Low Carbon and Renewable Energy Economy Estimates'*, the offshore wind sector in NI had a turnover of £12.5m (rounded to the nearest £500,000), and employed 100 people (on a full-time equivalent basis, rounded to the nearest 100) as of 2018. Precise data on the number of business and exports is unavailable for NI. The ONS data notes that the number of offshore wind businesses in

[67] Department for Enterprise, Trade and Investment, Offshore Renewable Electricity Action Plan 2012-2020 (March 2012) https://www.economy-ni.gov.uk/sites/default/files/publications/deti/Offshore%20Renewable%20Energy%20Strategic%20Action%20Plan%20%28ORESAP%29%202012-2020.pdf

NI was below 100 and the value of sectoral exports was below £500,000. Figures below these values are not recorded in the original dataset.[68]

3.2.3a Solar PV

IRENA define solar PV cells as *'electronic devices that convert sunlight directly into electricity'.*[69] As can be seen from Figure 4, as of 2018, Solar PV has the fourth largest global installed capacity of the technologies examined at 480GW. It had the third highest LCOE at 0.085$/kWh, and the second highest life-cycle emissions impact (48gCO_2/kWh) of all technologies, excluding bioenergy. From a cost perspective, solar PV's LCOE placed it in the middle of the fossil fuel cost per kWh range (0.049$/kWh to 0.174$/kWh). From an emissions perspective, solar PV compares favourably to both coal and gas generation, but was above nuclear generation.

As of 2018, NI had a total of 321.8MW of solar PV installed. This was equivalent to 17% of NI total installed renewable electricity capacity in the same year. NI installed solar PV capacity represents 2.5% of all solar PV capacity in the UK.[70]

3.2.3b What are the potential impacts of solar PV?

As noted above, Solar PV was found to have the second highest lifecycle of the renewable technologies examined. Although it should be noted that this remains significantly below fossil fuel generation. According to the IPCC, the emissions associated with solar PV are infrastructure and supply chain emissions[71]. Solar PV cells utilise silicon, which is derived from quartz. Quartz is mined and then heated to extract silicon. This is an energy intensive process, which produces greenhouse gases.[72] The technology does not have any direct emission associated with its operation. The figure of 48gCO_2/kWh used in this paper refers to the lifecycle emissions of utility sized solar PV installations. The IPCC has estimated rooftop installations to have a smaller median emissions impact of 41gCO_2/kWh.[73]

[68] ONS, Low Carbon and Renewable Energy Economy Estimates (Jan 2020) https://www.ons.gov.uk/file?uri=%2feconomy%2fenvironmentalaccounts%2fdatasets%2flowcarbonandrenewableenergyeconomyfirstestimatesdataset%2fcurrent/lcreedataset2018.xlsx

[69] IRENA, Solar Energy (accessed 16 April 2020) https://www.irena.org/solar

[70] ONS, Regional Renewable Statistics (update 26 September 2019) https://www.gov.uk/government/statistics/regional-renewable-statistics

[71] [71] Schlömer S., T. Bruckner, L. Fulton, E. Hertwich, A. McKinnon, D. Perczyk, J. Roy, R. Schaeffer, R. Sims, P. Smith, and R. Wiser, 2014: Annex III: Technology-specific cost and performance parameters. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf

[72] Green Journal, Solar energy clean or harmful (June 2019) https://www.greenjournal.co.uk/2019/06/solar-energy-clean-or-harmful/

[73] [73] Schlömer S., T. Bruckner, L. Fulton, E. Hertwich, A. McKinnon, D. Perczyk, J. Roy, R. Schaeffer, R. Sims, P. Smith, and R. Wiser, 2014: Annex III: Technology-specific cost and performance parameters. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S.

Solar PV has a range of potential impact beyond lifecycle emissions. These are summarised in Table 3 below.

Table 3: Summary of potential non-emissions impacts of solar PV wind[74]

Type	Impact	Mitigation
Land use	Large scale solar PV installations required a large area of land per MW.	Use of wastelands, such as contaminated, marshy and barren lands for Solar PV installations lowers the environmental impact.
Wildlife	The clearing and utilisation of agricultural land can affect flora and fauna, rainfall and drainage systems.	Use of wastelands, such as contaminated, marshy and barren lands for Solar PV installations lowers the environmental impact.
Contamination	The production of silicon can result in toxic by-products, including silicon tetrachloride. If released in into water it can release hydrochloric acid and can contaminate water sources.	Proper disposal of silicon tetrachloride is required.
Contamination	Disposal of solar PV panels can have a significant ecological impact. Panel contain cadmium lead and other toxic chemicals. Solar PV panels cannot be fully recycled.	A treatment process comprising mechanical and thermal process can result in a 96% recovery rate for silicon based Solar PV panels. The remaining 4% can be used in waste-to-energy systems.

Source: Green Journal (2019)

According the ONS's 'low carbon and renewable economy estimates', solar PV companies in NI had a combined turnover of £49m (rounded to the nearest £500,000), and employed 200 people (on a fulltime equivalent basis, rounded to the nearest 100) in 2018. Data on the number of companies and the value of exports from the sector are unavailable for 'confidentiality reasons'.[75]

3.3.4a CSP

CSP (concentrated solar power) is a different method of generating electricity from sunlight. According to IRENA, CSP:

> *…uses mirrors to concentrate solar rays. These rays heat fluid, which creates steam to drive a turbine and generate electricity. CSP is used to generate electricity in large-scale power plants.*[76]

It is the most expensive renewable energy technology examined in Figure 4 above, it has an estimated LCOE of 0.185$/kWh. This would make it more expensive than the most expensive fossil fuel generation on a per kWh basis. It also had the lowest installed capacity of all technologies examined at 5.5GW. The technology's emissions

Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf

[74] Green Journal, Solar energy clean or harmful (June 2019) https://www.greenjournal.co.uk/2019/06/solar-energy-clean-or-harmful/

[75] ONS, Low Carbon and Renewable Energy Economy Estimates (Jan 2020) https://www.ons.gov.uk/file?uri=%2feconomy%2fenvironmentalaccounts%2fdatasets%2flowcarbonandrenewableenergyeconomyfirstestimatesdataset%2fcurrent/lcreedataset2018.xlsx

[76] IRENA, Solar Energy (accessed 16 April 2020) https://www.irena.org/solar

impact compares favourably with solar PV, but is higher than both off and onshore wind, as well as hydro. It compares favourably on an emissions basis to both coal and gas fired generation, but emits more per kWh than nuclear.

The ONS publication *'Regional Renewable Statistics'* that has been used throughout this section does not include data on CSP's installed capacity in the UK or NI.[77]

3.2.4b What are the potential impacts of CSP?

As noted above, CSP's lifecycle emissions compare favourably to fossil fuel generation. The technology, however, does have a number of other potential environmental impacts. Like solar PV, CSP also requires a considerable amount of land per MW of capacity. As such, it shares the similar land and wildlife impacts as solar PV, as outlined in Table 3. In addition to these, CSP requires a significant amount of water during operation, which can be a particular concern in areas where water is scarce.[78]

No data on the economic performance of CSP in the NI or the UK is recorded in the ONS publication Low Carbon and Renewable Energy Economy Estimates.[79]

3.2.5a Geothermal electricity

Geothermal energy is energy stored below the earth's surface in the form of heat. Geothermal electricity generation can be achieved through a number of processes. The process used will depend on the heat content of a geothermal field. There are four technology options:

- Direct dry steam plants: steam directly sourced from the geothermal field is used to drive a turbine. Such plants range in size from 8-140MW;
- Flash plants: similar to dry steam plants in that steam is used to drive a turbine. Steam is obtained using a process known as flashing. Plants range in size from 0.2MW to 160MWs;
- Binary plants: the heat from the geothermal field is used to heat a 'process fluid' (such as water or ammonia), the steam from which his used to drive a turbine.
- Combined-cycle plants or hybrid plant: waste heat from a binary plant is used to produce electricity. In hybrid plants, heat from another process (such as CSP) is used to generate electricity.[80]

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77 ONS, Regional Renewable Statistics (update 26 September 2019) https://www.gov.uk/government/statistics/regional-renewable-statistics

78 Green Journal, Solar energy clean or harmful (June 2019) https://www.greenjournal.co.uk/2019/06/solar-energy-clean-or-harmful/

79 ONS, Low Carbon and Renewable Energy Economy Estimates (Jan 2020) https://www.ons.gov.uk/file?uri=%2feconomy%2fenvironmentalaccounts%2fdatasets%2flowcarbonandrenewableenergyeconomyfirstestimatesdataset%2fcurrent/lcreedataset2018.xlsx

80 IRENA, Geothermal Power (2017) https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Aug/IRENA_Geothermal_Power_2017.pdf

Figure 4 shows that geothermal electricity has a LCOE of 0.072$/kWh, which was the fourth highest of the technologies examined. This would place it an around the mid-point of the fossil fuel cost per kWh range. Geothermal had the third lowest installed capacity at 38GW. It also had the third highest lifecycle emissions at 38gCO_2/kWh. This was still considerably lower than both coal and gas, but higher than nuclear.

Throughout this section, the ONS publication *'Regional Renewable Statistics'* relied on does not include data on geothermal electricity.[81] The UK does have a geothermal resource, which could be used for the generation of electricity. The House of Commons' Library published a useful summary of studies into the geothermal potential of the UK in 2018. This shows that there are a number of estimates of exist. The estimates vary:

> *…due to the areas of the UK being considered, the depth of drilling considered, and the extent to which the resource is deemed technically and economically recoverable.*

The House of Commons' Library highlighted three estimates in particular:

- A 2012 paper by the consultancy group SKM, in association with the trade body the Renewable Energy Association argued that geothermal power could provide 20% of the UK's electricity demand;
- A 2013 UK Government commissioned *'Deep Geothermal Review Study'* estimated that a much lower 4% of electricity requirements could be met through geothermal power.
- A 2017 study in the academic journal *'Geothermal Energy'* estimated that the UK had a 'theoretically available' resource that was sufficient to surpass all UK energy demand, but the 'technically available' resource was much smaller, and would depend on the depths drilled and the areas targeted.[82]

3.2.5b What are the potential impacts of geothermal electricity?

As noted above, the emissions impact of geothermal electricity compares favourably to other renewable sources of electricity generation and to fossil fuel generation. The technology does have a range of other environmental impacts. These are largely associated with the drilling processes required to access a geothermal resource, but also occur during the ongoing operation of geothermal generation. Table 4 below provides a summary of these impacts. The information contained in the Table is sourced from the GEOENVI project, which seeks to understand and address the environmental concerns associated with geothermal energy. The GEOENVI is a cross-

[81] ONS, Regional Renewable Statistics (update 26 September 2019) https://www.gov.uk/government/statistics/regional-renewable-statistics

[82] House of Commons Library, Potential for geothermal energy resources in the UK (14 June 2018) https://commonslibrary.parliament.uk/research-briefings/cdp-2018-0146/

European project, and has received funding through the European Union's Horizon 2020 project.[83]

Table 4: Summary of potential non-emissions impacts of geothermal electricity[84]

Type	Impact	Mitigation
Energy, water consumption and associated emissions	Energy consumption from the use of engines and associated emission during surface operations, including drilling. Water is also consumed during the drilling phase and also during plan operation.	Energy consumption is limited to the development phase and can be minimised by utilising alternative power supply to power machinery. Water consumption can be reduced by the recirculation of drilling mud.
Waste	Geothermal plants produce liquid and solid waste during the construction phase.	Design to minimise waste and treatment of unavoidable waste during operations.
Surface disturbance	The development phase can result in surface disturbance, including land occupation, visual and noise impacts, vibrations noise, dust and smells.	Careful siting and project design may limit the extent of site disturbance. Visual effects may be painted to minimise impact, or hidden by fences. Noise impacts can be minimised by using sound absorption, and reducing noisy activities to specific times.
Disturbance of eco systems	Land disruption may disturb habitats.	A pre-project environmental study can be used to identify potential issues and plan mitigation measures. Post-project restoration of habitat by, for example, replanting programs, can also mitigate impact.
Leaks	The accidental escape of fluids from tanks storing waste are possible during installations and operation.	Monitoring and planning can mitigate potential for accidental leakage.
Liquid and solid effusions on surface	Geothermal power plants produce at surface both liquid and solid underground materials, resulting from drilling wells and the construction, operation and maintenance of the plant, which may accidentally effuse in the environment.	Prevention and mitigation of the environmental effects of solid and liquid waste are generally addressed by clear regulations and enforcement, and developers are required to collect and dispose of any material produced from drilling.
Degassing	The phenomenon of release of gases in the atmosphere, called degassing, may occur during the geothermal development if the geothermal fluids produced at the surface have a gas content.	Preventive measures for degassing consist in the adoption of technologies able to avoid the release of gases in the atmosphere. For example, accidental emissions during the drilling phase are prevented adopting blowout preventers and expansion vessels.
Radioactivity	In the infrequent case of abundant circulation and drilling in natural radioactive rocks, like granite for example, there is a potential for radioactive contamination at surface.	Monitoring and prevention measures are applied only in those few cases involving radioactive material. Mitigation includes, protection for personnel working at site and restricting visitors to public zones and ensuring they are equipped with protection equipment.
Blowout	Blow-outs are uncontrolled flows of formation fluid from drilled wells. They are very rare incidents, that may occur from natural causes, or in relation to drilling operation.	Good drilling practices, including project planning, well design, proper training and use of correct blow-out prevention equipment can be used to prevent blow-out.

[83] GEOENVI, About the project https://www.geoenvi.eu/about-us/

[84] GEOENVI, Report on Mitigation measures (2019) https://www.geoenvi.eu/wp-content/uploads/2019/12/D2.2-Report-on-mitigation-measures-2.pdf

Type	Impact	Mitigation
Ground surface deformation	Geothermal development and operation may cause deformation of the ground surface that subsides (lowers) or uplift, generally in response to pressure and/or temperature changes within the geothermal reservoir.	Monitoring, prediction and control are the three main means to mitigate the effects of ground surface deformation in geothermal fields.
Seismicity	Geothermal development tends to modify the characteristics of a reservoir by withdrawing and injecting hot and/or cold fluid into the underground. In particular, circulating water through the geothermal reservoir creates pressure changes that can cause small seismic events.	Mitigation methods include: studies; using technology to maintain a balance between produced and reinjected fluid and minimize pore pressure changes at depth; seismic monitoring networks; operational protocols; and transparent and effective communication to achieve informed public acceptance.
Pressure and flow changes	Extraction of fluids during the geothermal plant operation produce underground hydraulic pressure changes.	The injection of fluids in the reservoir to replace the volume of extracted fluids is the only long-term risk-mitigation measure which helps to avoid the pressure decline in the resource (reservoir depletion) on a large scale, and during long-term operation.
Interconnection of aquifers and disturbance of non-targeted aquifers	Without the adoption of proper mitigation measures, during development, in particular drilling, and operation of a geothermal industrial plant, there is a risk of accidental connection of aquifers via the wellbore or disturbance of non-targeted aquifers with fluid intrusion	Mitigation measures include: well design; monitoring of reservoir behaviour.
Thermal changes	Production from geothermal reservoirs and reinjection into the reservoir may cause thermal changes, when production exceeds the natural long-term rate of thermal recharge, resulting in reservoir thermal decline.	Thermal decline due to geothermal fluid extraction and fluid injection can be minimised by keeping production in balance with the natural inflow of water and by careful siting of injection wells.

Source: GEOENVI (2019)

No data on NI or UK geothermal energy economic performance are recorded in the ONS publication *'Low Carbon and Renewable Energy Economy Estimates'*.[85]

3.2.6a Hydro electricity

According to IRENA:

> *The basic principle of hydropower is using water to drive turbines. Hydropower plants consist of two basic configurations: with dams and reservoirs, or without. Hydropower dams with a large reservoir can store water over short or long periods to meet peak demand. The facilities can also be divided into smaller dams for different purposes, such as night or day use, seasonal storage, or pumped-storage reversible plants, for both pumping and electricity generation. Hydropower without dams and reservoirs means producing at a smaller scale, typically from a facility*

[85] ONS, Low Carbon and Renewable Energy Economy Estimates (Jan 2020) https://www.ons.gov.uk/file?uri=%2feconomy%2fenvironmentalaccounts%2fdatasets%2flowcarbonandrenewableenergyeconomyfirstestimatesdataset%2fcurrent/lcreedataset2018.xlsx

designed to operate in a river without interfering in its flow. For this reason, many consider small-scale hydro a more environmentally-friendly option.[86]

Figure 4 shows hydro to have lowest LCOE (0.047$/kWh), the highest global installed capacity (1,172GW) and the third lowest lifecycle emissions (24gCO_2/kWh). It compares favourably to fossil fuels on a cost basis, and has considerably lower lifecycle emissions than both coal and gas generation, though it above nuclear.

As of 2018, NI had 11MW of hydropower installed. This is equivalent to 0.6% of total renewable capacity in NI, and 0.6% of total hydropower in the UK.

3.2.6b What are the potential impacts of hydropower?

As noted, the lifecycle emissions of hydropower are similar to other renewable generation technologies, apart from bioenergy. They also compare favourably to fossil fuel generation. There are a number of possible environmental effects of hydropower. Table 5, summarises the main potential impacts as identified by the European Commission (EC).

Table 5: Summary of potential non-emissions impacts of hydro electricity[87]

Type	Impact	Mitigation
Wildlife	Hydropower development may affect up and down stream river continuity, reducing or interrupting fish migration.	Design techniques may be employed to prevent fish strike. Options include ramps, by-channels, and less damaging turbines for fish.
Wildlife	Development may change river flow in a number of ways, impacting plant and animal species.	Design techniques may be employed to maintain appropriate flow.
Chemical alteration	Development may alter the 'physico-chemical' condition both up- and downstream (e.g. temperature)	Design and operation techniques may mitigate.
Lake level	Development may result in 'artificially extreme changes in lake level, reduction in quality and extent of shallow water and shore habitat. This may lead to reduction in plant and animal species.	Design and operation techniques can mitigate. Management of shore and shallow habitats, creation of artificial floating islands and connectivity to tributaries may also mitigate.
Sediment	Hydropower can result in the disruption of sediment dynamics. This may reduce fish and invertebrate levels.	Mitigation includes techniques to minimise sediment distribution and the reintroduction of sediment to impacted areas.
River impoundments	Dewater shoreline and reduced river flow. Alternation to plant and animal species composition.	Design techniques such as bypass channel and a reduction in storage level, may mitigate.

Source: EC (2018)

According the ONS's *'Low Carbon and Renewable Economy Estimates'*, as of 2018, NI hydro companies had a combined turnover of £2m (rounded to the nearest £500,000)

[86] IRENA, Hydropower (accessed 16 April 2020) https://www.irena.org/hydropower

[87] European Commission, Guidance document on the requirement for hydropower in relation to EU Nature legislation, a summary (2018) https://ec.europa.eu/environment/nature/info/pubs/docs/brochures/HYD_Summary_EN_PDF_HR_Final_rev_19.pdf

in 2018. Data on the number of companies, levels of employment and the value of exports from the sector are not published.[88]

3.2.7a Bioenergy

Bioenergy refers to a range of energy generation techniques that use some form of biological material to produce power. Bioenergy:

> *…falls into two main categories: 'traditional' and 'modern'. Traditional use refers to the combustion of biomass in such forms as wood, animal waste and traditional charcoal. Modern bioenergy technologies include liquid biofuels produce from bagasse and other plants; bio-refineries; biogas produced through anaerobic digestion of residues; wood pellet heating systems; and other technologies.*[89]

Figure 4 shows bioenergy to have third lowest LCOE (0.062$/kWh), the fourth highest global install capacity (115GW), but the highest lifecycle emissions (230gCO_2/kWh). This places its cost is in the middle of the fossil fuel per kWh cost range. Although its emissions are high compared to other renewable technologies, it still below both coal and gas. According to the IPCC, bioenergy's emissions impact is a result of infrastructure and supply chain emissions. They note too that:

> *Direction emissions from biomass at the power plant are positive and significant, but should be seen in connection with the CO_2, absorbed by growing plants.*

As of 2018, there were 218.8MW of bioenergy installed in NI. This was equivalent to 11.8% of total NI renewable capacity, and 1.6% of total UK bioenergy capacity. NI bioenergy use consisted of a number of different types. The levels of each are summarised in Table 6 below. As can be seen from the Table, 'other bioenergy' was the largest single bioenergy generation type in NI, with an installed capacity of 98.9MW, as of 2018. This represented 45.2% of bioenergy and 5.36% of all renewable energy, installed in NI as of 2018.[90]

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[88] ONS, Low Carbon and Renewable Energy Economy Estimates (Jan 2020) https://www.ons.gov.uk/file?uri=%2feconomy%2fenvironmentalaccounts%2fdatasets%2flowcarbonandrenewableenergyeconomyfirstestimatesdataset%2fcurrent/lcreedataset2018.xlsx

[89] IRENA, Bioenergy (accessed 16 April 2020) https://www.irena.org/bioenergy

[90] ONS, Regional Renewable Statistics (update 26 September 2019) https://www.gov.uk/government/statistics/regional-renewable-statistics

Table 6: Breakdown of installed bioenergy in NI as of 2018[91]

Bioenergy type	Installed capacity 2018 (MW)	% of total NI Bioenergy	% of total NI Renewables
Other Bioenergy	98.9	45.2	5.36
Anaerobic Digestion	55.8	25.5	3.02
Biomass and waste	43.8	20.02	2.37
Landfill gas	20.1	9.19	1.09
Sewage gas	0.2	0.09	0.01

Source: ONS (2019)

3.2.7b What are the potential impacts of bioenergy?

As noted above, estimated median lifecycle emissions from bio energy are high relative compare to other renewable resources. They remain below estimated the median lifecycle emissions of fossil fuel generation.

There are a range of other potential environmental impacts associated with bioenergy development. These are summarised in Table 7 below; sourced from the Committee for Climate Change's (CCC)[92] 2018 publication *'Biomass in a low carbon economy'.[93]*

Table 7: Summary of potential non-emissions impacts of bioenergy[94]

Type	Impact	Mitigation
Biodiversity	The cultivation of bioenergy crops may impact biodiversity can negatively impact biodiversity through: the planning on large-scale forest monocultures or non-native tree species; soil complication due to use of heavy machinery; and planting crops in sensitive areas such as migratory bird routes.	Bioenergy crops sustainability can be enhanced by thinning forests to improve growth and sequestration to allow more sunlight in can support a wider range of specifies. Using short-rotation crops. Planting 'switchgrass' on migratory bird routes.
Soil health and fertility	Some annual crops are associated with soil erosion.	Crop choice and other farming techniques can minimise soil erosion.
Water availability and quality.	Some crops (such as short rotation coppice) can have negative effects on water availability, especially when grown on arable land. Water quality can be negatively impacted by soil erosion.	Crop choice can improve water use, some crops (sugar beet and wheat are more water efficient). Other farming techniques can be employed to improve the availability and quality of water.
Other ecosystem services	Converting mature fort to perennial crops (e.g. short rotation coppice) can have negative effects on flood regulation and soil erosion.	Crop choice and land choice can mitigate impacts.
Invasive species	Some crops have proven to be invasive – including popular and eucalyptus.	Crop choice, using non-invasive specifies can mitigate impact.
Socio-economic impacts in developing countries	Unsafe working environments. 'Land grabs' for biomass from traditional land users.	Local jobs with established workers' rights. Respect for peoples' land rights and access to resources.

[91] *Ibid*

[92] The Committee on Climate Change is an independent, statutory advisory body established under the UK Climate Change Act 2008.

[93] Committee for Climate Change, Biomass in a low carbon economy (2018) https://www.theccc.org.uk/wp-content/uploads/2018/11/Biomass-in-a-low-carbon-economy-CCC-2018.pdf

[94] *Ibid*

Type	Impact	Mitigation
Food security in developing countries	Growing energy crops can displace food production, or make food less accessible or affordable, particularly for at-risk groups.	Using waste and residues to produce biogas and digestate. Integrate food and bioenergy crop systems.

Source: CCC (2018)

According to the ONS's 'low carbon and renewable economy estimates', as of 2018, NI bioenergy companies had a combined turnover of £47.5m (rounded to the nearest £500,000) and employed 200 people (on a full time equivalent basis, rounded to the nearest 100) in 2018. The sector also had estimated exports to the value of £1.5m in the same year (rounded to the nearest £500,000). Data on the number of companies is not published.[95]

3.2.8a Ocean energy: Wave and tidal

Wave energy is a form of ocean energy that works as follows:

> *…convertors capture the energy contained in ocean waves and use it to generate electricity. Converters include oscillating water columns that trap air pockets to drive a turbine; oscillating body converters that use wave motion; and overtopping converters that make use of height differences.*[96]

Wave energy is still at the research and development stage, and is not yet commercially available.[97]

Like wave energy, tidal energy is also a form of ocean energy, whereby electricity is produced:

> *Either by tidal-range technologies using a barrage (a damn or other barrier) to harvest power between high and low tide; tidal-current or tidal-stream technologies; or hybrid applications.* [98]

Tidal energy is still at the research and development stage and is not yet commercially available.

As noted in subsection 3.1 above, comparable estimates on the LCOE, and installed capacity of wave and tidal energy, were unavailable from IRENA. The IPCC study on the lifecycle emissions of renewable technologies did include an estimate for ocean energy, but did not include disaggregated figure for technology types. The IPCC's median lifecycle emissions estimated for ocean energy was 17gCO_2/kWh.[99] This is

[95] ONS, Low Carbon and Renewable Energy Economy Estimates (Jan 2020) https://www.ons.gov.uk/file?uri=%2feconomy%2fenvironmentalaccounts%2fdatasets%2flowcarbonandrenewableenergyeconomyfirstestimatesdataset%2fcurrent/lcreedataset2018.xlsx
[96] IRENA, Ocean energy (accessed 16 April 2017) https://www.irena.org/ocean
[97] *Ibid*
[98] *Ibid*
[99] Schlömer S., T. Bruckner, L. Fulton, E. Hertwich, A. McKinnon, D. Perczyk, J. Roy, R. Schaeffer, R. Sims, P. Smith, and R. Wiser, 2014: Annex III: Technology-specific cost and performance parameters. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)].

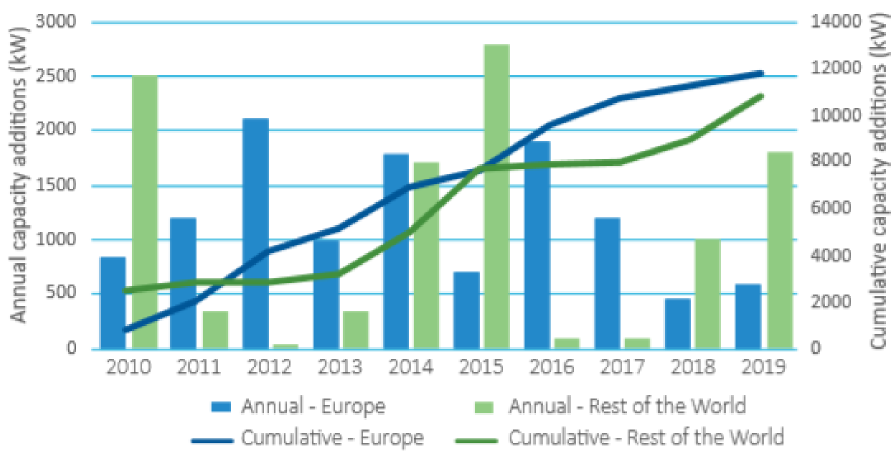
higher than the estimated emissions of onshore and offshore wind and nuclear generation. It, however, is lower than all other renewable and fossil fuel generation types examined.

The Ocean Energy Systems Technology Collaboration Programme (OES) is an intergovernmental agency, launched in 2001, to advance ocean energy research and development. In 2015, the OES conducted a study to estimate the LCOE of ocean energy technologies. This included estimates commercial scale ocean energy installations. As is the case with the IRENA's LCOE estimate, the OES estimates do not include any financial subsidy. Moreover, they estimate what the cost per kWh would be if development was taken forward in the absence of such support.

For wave energy, the LCOE was estimated to be between 0.12 and 0.47$/kWh. This suggests that the technology is amongst the most expensive renewable electricity generation technologies of those examined in this paper.[100]

The OES also monitors levels of installed ocean energy globally. The latest data available is for 2019. Figure 5 below outlines the annual and cumulative capacity of wave energy in Europe and the Rest of the World (RoW). As can be seen from the Figure, European cumulative capacity as of 2019 was approximately 12MW, whilst the RoW was approximately 11MW. This demonstrates that wave energy is currently not at a comparable scale to other technologies. It also be noted that this capacity is for research and development, rather than commercial purposes.[101]

Figure 5: Annual and Cumulative wave capacity in European and the RoW 2010 to 201[102]9



Source: OES (2020)

Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf

[100] OES, International Levelised Cost of Energy for ocean energy technologies (May 2015) https://www.ocean-energy-systems.org/documents/57387-cost-of-energy-for-ocean-energy-technologies-may-2015-final.pdf/

[101] OES, Ocean energy: key trend and statistics 2019 (March 2020) https://www.oceanenergy-europe.eu/wp-content/uploads/2020/03/OEE_Trends-Stats_2019_Web.pdf

[102] *Ibid*

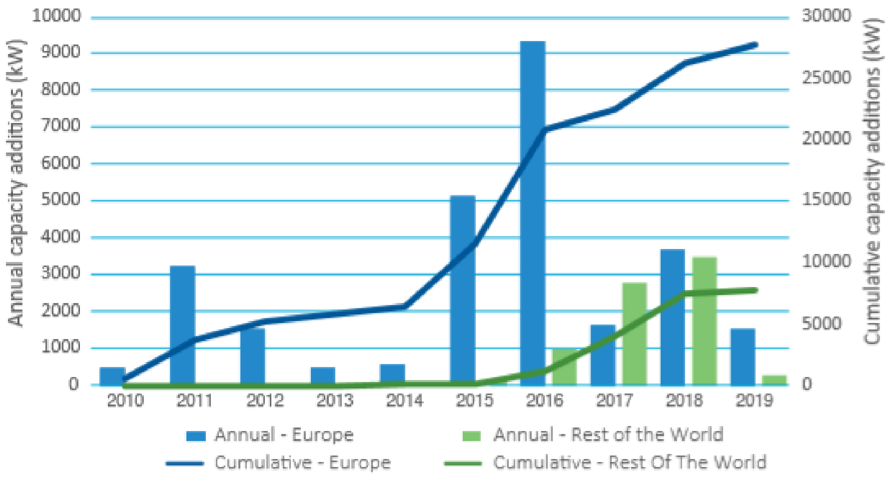
The OES's estimated LCOE range for commercial tidal energy was 0.13 to 0.28$/kWh. Like wave generation, this places it amongst the most expensive of the renewable and fossil fuel electricity generation technologies examined in this paper.[103]

Figure 6 below shows the cumulative and annual installed tidal capacity in Europe and the RoW. According to the OES:

> *27.7MW of tidal stream technology has been deployed in Europe since 2010. Of this, 10.4MW is currently operating, and 17.3Mw has been decommissioned as projects successfully complete their testing.*[104]

As can be seen from Figure 6, much smaller levels of tidal energy have been installed in the RoW. As is the case with wave energy, tidal remains in the pre-commercial stage of development.

Figure 6: Annual and Cumulative tidal capacity in European and the RoW 2010 to 2019[105]



Source: OES (2020)

NI is estimated to have a significant potential for tidal generation. Strangford Lough was previously home to the world's first commercial scale tidal power generation installation. The SeaGen project was awarded a marine licence in 2008, and was decommissioned in 2019, having come to the end of its lifecycle. During this period, it exported an estimated 11.6GWh of electricity to the gird.[106]

According to the most recent OREAP progress update, the following developments are occurring in tidal energy in NI:

[103] OES, International Levelised Cost of Energy for ocean energy technologies (May 2015) https://www.ocean-energy-systems.org/documents/57387-cost-of-energy-for-ocean-energy-technologies-may-2015-final.pdf/

[104] OES, Ocean energy: key trend and statistics 2019 (March 2020) https://www.oceanenergy-europe.eu/wp-content/uploads/2020/03/OEE_Trends-Stats_2019_Web.pdf

[105] *Ibid*

[106] SIMEC Atlantis Energy, Atlantis successfully decommission 1.2MW SeaGen tidal system industry first (26 July 2019) https://simecatlantis.com/2019/07/26/meygen-operational-update-3-2/

- Fairhead Tidal Array: in 2017 an application for a marine licence for a proposal to install a 100MW tidal array off the Antrim Coast was received. Public consultation on this licence request *'raised some fundamental issues around the landfall of the cable and seascape / landscape issues around surface piercing technology and the requisite electricity substation'.* A revised marine licence will be required should the project wish to continue. As of the OREAP 2019 update, published in March 2020, this had yet to be received.
- Torr Head Tidal Array: a marine licence was issued to Tidal Ventures Ltd in December 2016. The company dissolved in January 2019. According to the OREAP 2019 update, the company has proposed using a different company Open Hydro Ltd, which is currently in liquidation to progress the project. As such, the status of this licence is unclear and, as of the OREAP 2019, the DfE and the DAERA are *'considering their options'.*

3.2.8b What are the potential impacts of ocean energy?

As noted in subsection 3.2.9b, the lifecycle emissions of was 17gCO_2/kWh,[107] which suggest that it has less of an emission than the majority of other generation type examined, apart from onshore and offshore wind and nuclear generation.

The broader environmental effects of ocean energy are the same as those outlined in Table 2, which can be found in subsection 3.2.2b. These include, but are not limited to, impacts: on wildlife; noise pollution, potential contamination; and changes to coastal processes; and, increased vessel traffic during construction and decommissioning.[108]

3.3 Summary and key questions

The analysis throughout Section 3 has shown that renewable electricity technologies vary in their global capacity, cost and environmental impact.

Subsection 3.1 demonstrated that on a cost and emission basis, the majority of renewable technologies examined compared favourably with fossil fuel generation. All had significantly lower emissions. All, but the less mature technologies, had broadly comparable estimated costs on per kWh basis.

[107] Schlömer S., T. Bruckner, L. Fulton, E. Hertwich, A. McKinnon, D. Perczyk, J. Roy, R. Schaeffer, R. Sims, P. Smith, and R. Wiser, 2014: Annex III: Technology-specific cost and performance parameters. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf

[108] Department for Enterprise, Trade and Investment, Offshore Renewable Electricity Action Plan 2012-2020 (March 2012) https://www.economy-ni.gov.uk/sites/default/files/publications/deti/Offshore%20Renewable%20Energy%20Strategic%20Action%20Plan%20%28ORESAP%29%202012-2020.pdf

Subsection 3.2 demonstrated only some of the technologies examined had significant levels of penetration in NI (onshore wind, solar and bioenergy). Other technologies, notable offshore wind, ocean energy and geothermal are yet to make an impact in NI.

Subsection 3.2 also demonstrated that each technology brings with it a range of potential impacts that require management and mitigation. They also bring economic benefits.

Energy Strategy - key issues:

- How will the NES seek to further develop the more mature renewable energy generation technologies in NI, whilst minimising their impacts and maximising their economic benefits?
- How could the NES support less developed and pre-commercial technologies, through supporting innovation within the sector?
- How will the NES mitigate the impacts of continued renewable electricity development?
- How will the NES promote cross government working to mitigate the above impacts?
- How will the NES link up with NI's Economic strategy to maximise the economic benefits of renewable energy development?

4 Renewable heat technologies

The following subsections utilise information from a range of sources, to provide an introductory overview of a range of renewable heat generation technologies. The section is organised as follows:

- Sub-section 4.1 looks at the global penetration of different renewable heat technologies, utilising information published by the IEA;
- Subsection 4.2 provides a brief overview of renewable heat penetration in NI, largely reiterating information already outlined in subsection 2.2 of this paper. It is included here for contextual reasons.
- Subsection 4.3 takes a closer look at different renewable heat generation technologies. It draws of a range sources to define each technology type, providing greater details on its global capacity, and, where available, provides indicative information of technology costs and estimated emissions.

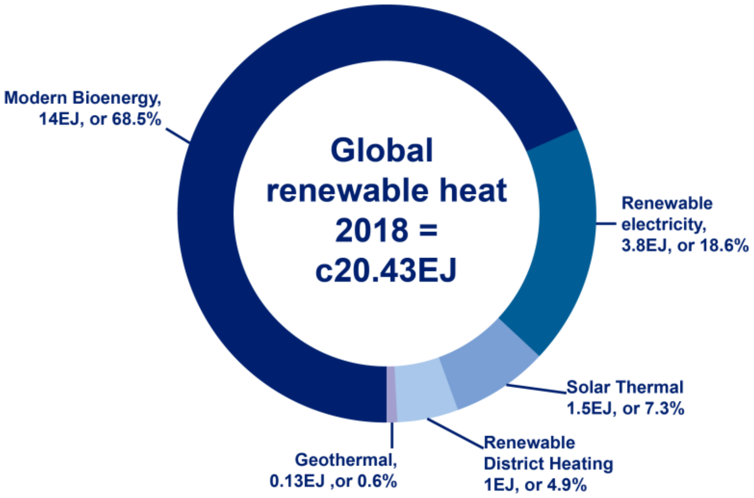
4.1 Renewable heat global penetration

This subsection uses IEA data to provide an overview of renewable heat penetration globally.

According to the IEA heat consumption accounted for 50% of final energy consumption in 2018. This made it that largest single form of energy consumption globally. In the same year, heating accounted for 40% of global CO_2 emissions.[109]

Fossil fuels continue to be the dominate form of heating. As of 2018, 'modern' renewables met only 10% of global heat demand. This figure excludes the traditional use of biomass. Figure 7 below provides a breakdown of global renewable heat generation by type. As can be seen from the Figure, modern bioenergy was the largest form of renewable heat globally accounting for 14 exajoules (EJ) of heat in 2018. This was followed by electric heating, powered by renewable sources. Smaller amounts of solar thermal, renewable district heating and geothermal are also in place globally.[110]

Figure 7: Renewable heat share 2018, by technology type[111]



Source: IEA (2019)

4.2 Renewable heat in NI

As noted in subsection 2.2 of this paper, insufficient data is available at a NI level to carry out a detailed analysis of renewable heat penetration. The DfE's 2019 call for evidence on its NES does provide some indication of levels of renewable heat penetration in NI. The RHI led to the installation of approximately 4,5000 biomass boilers. In addition, NI was home to 90 heat networks in 2016. The majority of which are communal heat networks in social housing. Oil and gas remain the predominate forms of heating in NI.

The ONS provides an estimate of the renewable heat sector's contribution to the NI economy in its *'Low Carbon and Renewable Energy Economy Estimates'* publication. According to this publication, in 2018, the renewable heat sector in NI had an estimated

[109] IEA, Renewables 2019, Market analysis from 2019 to 2024: Heat (October 2019) https://www.iea.org/reports/renewables-2019/heat

[110] *Ibid*

[111] *Ibid*

turnover of £5m (rounded to the nearest £500,000). Data on employment and estimated export value was not available. [112]

The renewable combined heat and power sector had an estimated turnover of £69m (rounded to the nearest £500,000). The sector had employed an estimated 200 people (on a full-time equivalent basis, rounded to the nearest 100). Exports from the sector were estimated to be valued at £36m.[113]

4.3 Renewable heat technologies

This subsection at renewable heat technologies in greater detail. Specifically, it examines the five types of renewable heat that contributed to global renewable hear capacity and are included in Figure 7:

- Modern bioenergy
- Renewable electricity powered heat;
- Solar thermal;
- Renewable district heating; and,
- Geothermal.

In addition, the decarbonisation of gas networks is also considered, as is explicitly featured in the DfE's call for evidence on its NES.

The subsection makes use of information from a range of sources, notably the IEA, IRENA and the Houses of Parliament, Parliamentary Office of Science Technology (POST). This information is used to define each technology type, providing greater details on its global capacity and, where available, indicative information of technology costs and estimated emissions. The subsection is intended to provide an introduction to these technologies. As such, it is not intended as a comprehensive assessment of each, as such an assessment is beyond the scope of this paper.

4.3.1 Modern bioenergy

Bioenergy for heat works on the same principles as bioenergy for electricity generation, except that the heat or converted gas/oil output is used for heating purposes, rather than power generation. As noted in subsection 3.2.7a:

> *Modern bioenergy technologies include liquid biofuels produced from bagasse and other plants; bio-refineries; biogas produced through*

[112] ONS, Low Carbon and Renewable Energy Economy Estimates (Jan 2020) https://www.ons.gov.uk/file?uri=%2feconomy%2fenvironmentalaccounts%2fdatasets%2flowcarbonandrenewableenergyeconomyfirstestimatesdataset%2fcurrent/lcreedataset2018.xlsx

[113] *Ibid*

anaerobic digestion of residues; wood pellet heating systems; and other technologies. [114]

Globally, bioenergy is the largest renewable heat source. As of 2018, the majority (86%) of bioenergy was used in industry, mostly in sectors that produce biomass and waste residues (such as pulp and paper, or wood products). In buildings, direct and indirect uses of bioenergy accounted for approximately half of all renewable heat consumption globally in 2018. The IEA expects overall bioenergy to increase by 12% (or 1.7EJ) over the period 2019-24.[115]

The wider environmental impacts of bioenergy as outlined in Table 6 in subsection 3.2.7b also apply to the technology when used as a heating source. According to a 2016 published POST research briefing, the estimated emissions output of biomass boilers range from 5-200gCO_2/kWh (the study notes that most boilers' estimated emissions are below 100gCO_2kWh). Bio-sourced gasses, when used as heating source, were estimated to have an emissions output of between 20-100gCO_2/kWh. The ranges were all below the estimated emissions ranges for oil (310-550gCO_2/kWh) and gas (210-380gCO_2/kWh) heat generation.[116]

4..3.2 Renewable electricity power-to-heat

According to IRENA:

Renewable power-to-hear refers to technologies that use renewable electricity to gnat useful het for buildings or industrial processes (i.e. via heat pumps of electric boilers). Electric boilers use electricity to het water, which is then used through pipes of disseminated with fan coils to provide space heating, or stored in hot water tanks for later use. Heat pumps use electricity transfer heat from the surrounding heat sources (air, water, ground) to buildings. Heat pumps can fulfil both heating and cooling requirements by using heat in the ambient air, water or ground as the primary source energy and a small quantum of auxiliary energy to drive the process.[117]

Globally, renewable electricity power-to-heat accounted for 4EJ, or around 19% of all renewable heat in 2018. The technology's use is expected to grow significantly over the period 2019 to 2024, with IEA estimating a 41% (1.6EJ) over this period.[118]

114 IRENA, Bioenergy (accessed 16 April 2020) https://www.irena.org/bioenergy

115 IEA, Renewables 2019, Market analysis from 2019 to 2024: Heat (October 2019) https://www.iea.org/reports/renewables-2019/heat

116 POST, Carbon Footprint of Heat Generation (May 2016) https://researchbriefings.files.parliament.uk/documents/POST-PN-0523/POST-PN-0523.pdf

117 IRENA, Renewable Power-to-Heat, Innovation Landscape Brief (2019) https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Power-to-heat_2019.pdf?la=en&hash=524C1BFD59EC03FD44508F8D7CFB84CEC317A299

118 IEA, Renewables 2019, Market analysis from 2019 to 2024: Heat (October 2019) https://www.iea.org/reports/renewables-2019/heat

The emissions and broader impact of power-to-heat technologies depends on the renewable energy used to generate the power used in the power-to-heat system. Table 7, source from POST, compares the lifecycle emissions of heat pumps and electric boilers in three UK electricity generation emissions scenarios:

- **Current – 370gCO_2/kWh**: the average electricity emission in the UK as of 2015;
- **Reduced – 250gCO_2/kWh**: the CCC's recommended level of emissions in 2020; and
- **Low – 100gCO_2/kWh** the CCC's recommended level of emissions in 2030.[119]

As expected, as the estimated emissions of the source power decreases, so too does the estimated emission of the heat-to-power technology. As can be seen from Table 7 below, the estimate emissions range of both ground source and air source heat pumps is below that of electric heaters.

Table 7: Emissions estimate of heat-to-power under three electricity generation emissions scenarios[120]

Technology	Electricity emissions scenario	Technology emissions range (CO2/kWh)
Electric heaters	Current	~370
	Reduced	~250
	Low	~100
Ground source heat pumps	Current	70-190
	Reduced	50-125
	Low	20-50
Air source heat pumps	Current	90-250
	Reduced	60-170
	Low	30-70

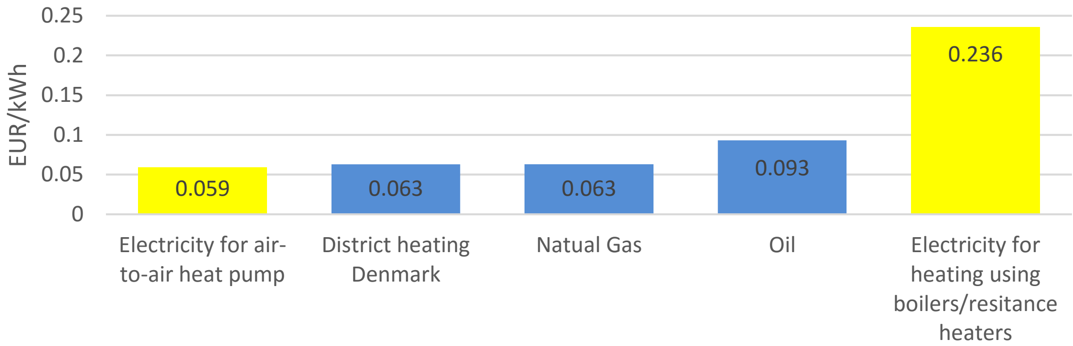
Source: POST (2016)

IRENA also has produced a levelised cost of heating (LCOH) analysis, which compares renewable power-to-heat technologies to oil and gas fired heat, as well as district heating in Denmark. This is shown in Figure 8. It should be noted that IRENA's analysis did not include ground source heat pumps. As can be seen from Figure 8, the LCOH of heat pumps compares favourably with the other technologies examined. The LCOH of electricity heaters/boilers compares unfavourably with the other technologies examined.

[119] POST, Carbon Footprint of Heat Generation (May 2016) https://researchbriefings.files.parliament.uk/documents/POST-PN-0523/POST-PN-0523.pdf

[120] *Ibid*

Figure 8: LCOH cost comparison of power-to-heat to oil, gas and Danish district heating[121]



Source: IRENA (2019)

4.3.3 Solar thermal

As is the case with the other solar technologies, solar thermal converts energy from the sun to other purposes, in this case heat. More precisely:

> *Solar thermal systems (STS) convert solar radiation into heat. These systems are used to raise the temperature of a heat transfer fluid, which can be air, water or a specially designed fluid. The hot fluid can be used directly for hot water needs or space heating/cooling needs, or a heat exchanger can be used to transfer the thermal energy to the final application. The heat generated can also be stored in a proper storage tank for use in the hours when the sun is not available.*[122]

Other forms of solar heating systems are available. These systems, which tend to be used for industrial purposes, include more basic systems for drying food to lengthen shelf life, to solar concentrators, which utilise vacuums to deliver temperatures of 150 to 400 degrees centigrade.[123]

At a global level, solar thermal heating systems contributed approximately 7.3% (1.5EJ), to the total renewable heat generation in 2018. The majority of solar heat installations in 2018 were small-scale thermal systems for domestic water heating. Solar heat for industrial purposes had limited uptake as of 2018, contributing less than 0.02% of total industrial heat demand. The IEA forecasts global solar thermal consumption, to increase by more than 45% over the period 2019-24.[124]

[121] IRENA, Renewable Power-to-Heat, Innovation Landscape Brief (2019) https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Power-to-heat_2019.pdf?la=en&hash=524C1BFD59EC03FD44508F8D7CFB84CEC317A299

[122] IRENA, Solar heating and cooling for residential applications (2015) https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_ETSAP_Tech_Brief_R12_Solar_Thermal_Residential_2015.pdf

[123] IRENA, Solar heat for industrial processes (2015) https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_ETSAP_Tech_Brief_E21_Solar_Heat_Industrial_2015.pdf

[124] IEA, Renewables 2019, Market analysis from 2019 to 2024: Heat (October 2019) https://www.iea.org/reports/renewables-2019/heat

POST has estimated the emissions range for solar thermal space and water heating to be the 10-35gCO_2/kWh range. This compares favourably to oil (310-550gCO_2/kWh) and gas (210-380 gCO_2/kWh).[125]

4.3.4 Renewable district heating

According to IRENA, district heating and cooling:

> *… is defined as the centralised heating or cooling of water, which is then distributed to multiple buildings through a pipe network.*[126]

IRENA, also notes that, as of 2017, most district and heating systems in use globally utilised fossil fuels. In a number of countries, notably Denmark and Switzerland, renewable energy provided up to 40% of district heat supply in the same year. Where district heat utilised renewable technology, this tended to be based on waste and biofuel generation, with solar heat and geothermal playing a much more limited role.[127]

As of 2018, renewable district heat accounted for 4.9% of total renewable heat consumption.[128]

The emissions impact of district heat will largely depend on the source chosen to fuel the heat generation. This also will impact the cost associated with the technology.

4.3.5 Geothermal

Geothermal heating uses heat extracted from the water or rock underground. This then can be used in a district hearing network.[129] As noted in the introduction to this section, geothermal heating met only a small amount of global heat demand (0.6%) in 2018.[130]

The technology has a low emissions impact. With the POST estimate, this is to be around 10gCO_2/kWh.[131] This would make it the lowest of the technologies examined here.

4.3.6 Decarbonisation of the gas network

Decarbonisation of the gas network is achieved by replacing natural gas with an alternative gas with a lower carbon content. According to 2017 POST published

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[125] POST, Carbon Footprint of Heat Generation (May 2016) https://researchbriefings.files.parliament.uk/documents/POST-PN-0523/POST-PN-0523.pdf

[126] IRENA, Heating and cooling (accessed 21 April 2020) https://www.irena.org/en/heatingcooling

[127] *Ibid*

[128] IEA, Renewables 2019, Market analysis from 2019 to 2024: Heat (October 2019) https://www.iea.org/reports/renewables-2019/heat

[129] POST, Carbon Footprint of Heat Generation (May 2016) https://researchbriefings.files.parliament.uk/documents/POST-PN-0523/POST-PN-0523.pdf

[130] IEA, Renewables 2019, Market analysis from 2019 to 2024: Heat (October 2019) https://www.iea.org/reports/renewables-2019/heat

[131] POST, Carbon Footprint of Heat Generation (May 2016) https://researchbriefings.files.parliament.uk/documents/POST-PN-0523/POST-PN-0523.pdf

research, there are currently two methods of doing this in a UK context. The first involves using biomethane a purified for of biogas. As of 2017, biomethane supplied less than 1% of gas within the UK gas network. Biomethane may be produced through anaerobic digestion or in bio synthesis plants, which can produce the gas through process dry organic material, including landfill waste.[132]

A second method of decarbonisation of the gas network is through the use of hydrogen. Hydrogen combustion produces no greenhouse gases. Hydrogen must be produced. This production, however, may result in the production of emissions. As of 2017, hydrogen did not supply the UK gas network. Though it had been utilised to supply industrial users in European and North America.[133]

Depending on the production technique, POST estimated emissions; biomethane to range from -50 to 450gCO_2/kWh. This compares to 232gCO_2/kWh natural gas. The estimated range for hydrogen was negative to 300gCO_2/kWh; but again depending on production technique. The lower estimates for hydrogen are a result of production techniques that involve carbon capture and storage.[134] This technology remains in the early stages of commercialisation.[135]

The POST briefing notes that the process of decarbonising gas networks will be one of transition. This will involve increasing the biomethane in the network to achieve up to 4% of supply by 2030. Hydrogen may be used post 2030, to increase the emissions savings, but *'urgent research and trials to understand the costs of and technical issues posed by a hydrogen gas grid'* are required.[136]

4.4 Summary and key questions

The analysis in Section 4 shows that renewable heat is in less developed than renewable electricity on a global scale. Subsection 4.1 demonstrated that bioenergy is the most developed technology currently in operation across the globe. Subsection 4.2 shows that it is not currently possible to provide a robust picture of renewable heat in NI. However, there is evidence that the sector has had a positive economic impact. Subsection 4.3 provided a brief overview of a range of renewable heat technologies. It demonstrated that these technologies were at various stages of development globally, and that each could reduce emissions relative to fossil fuels under certain circumstances.

[132] POST, POSTNOTE No. 565, Decarbonising the gas network (November 2017) https://researchbriefings.files.parliament.uk/documents/POST-PN-0565/POST-PN-0565.pdf
[133] *Ibid*
[134] *Ibid*
[135] IEA, Carbon capture, utilisation and storage (accessed 21 April 2020) https://www.iea.org/fuels-and-technologies/carbon-capture-utilisation-and-storage
[136] POST, POSTNOTE No. 565, Decarbonising the gas network (November 2017) https://researchbriefings.files.parliament.uk/documents/POST-PN-0565/POST-PN-0565.pdf

Energy Strategy - key issues:

- What renewable heat technology or mix of technologies has the greatest potential for NI, and how can will the NES facilitate development of renewable heat technologies?
- How will the NES support innovation in the sector?
- How will the NES minimise the any environmental impact of renewable heat development in NI?
- How will the NES link with NI's economic strategy to maximise the economic benefits of the renewable heat sector's development for the NI economy?

5 Concluding remarks

NI is about to set out a NES, which will set out the policy for framework for NI renewable development for up to 30-years. This policy will be shaped by the UK target to reach net zero carbon emissions by 2020.

This paper has shown, that to date, renewable energy development in NI has had both success, in the development of renewable electricity (driven by onshore wind), and some failures, in the development of renewable heat.

It has also raised a number of questions regarding the future of renewable energy development in NI, in particular:

- What renewable electricity and heat mixes are correct for NI?
- What renewable electricity and heat targets are required?
- What support, if any, is required to further develop renewables in NI?
- How can renewables be further developed while mitigating the risks and maximising the economic impact?
- How will the NES, and renewable policy interlink with NI's economic and climate change policies going forward.

Annex 1: Note on units of measurement

Throughout this paper, when referring electricity capacity (power), generation and electricity consumption (energy) a number of different units of measurement are used. This note provides a brief overview of these units of measurement.

Power refers to the rate at which energy is transferred, used, or converted from one form to another (power = energy/time).

It can be used to measure how much energy a device needs to operate satisfactorily. In the case of electricity generation, it is used to measure the rate at which coal, gas, oil, wind, or sun etc. is converted into electricity.

The basic unit of power used when referring to electricity is the Watt.

There are a number of terms used to describe multiples of watts:

- 1000 Watts = 1 kilowatt (kW);
- 1000 Kilowatts = 1 Megawatt (MW);
- 1000 Megawatts = 1 Gigawatt (GW); and,
- 1000 Giga Watts = 1 Tera Watt (TW).

The amount of energy created or consumed is typically measured in kilowatt hours. It measures power over time (energy = power x time). It is used, for example, to measure and bill consumers for the amount of electrical energy delivered to their home.

A 1kW system will consume or produce 1 kilowatt hour of energy in 1 hour. A 10 kilowatt system will produce or consume 1kilowatt hour in six minutes.

There are a number of common multiples:

- 1000 Watts or 1 kilowatt for 1 hour = 1 kilowatt hour (kWh);
- 1000 Kilowatt hours = 1 Megawatt hour (MWh);
- 1000 Megawatt hours = 1 Gigawatt hour (GWh); and
- 1000 Gigawatt hours = 1 Terawatt hour (TWh).

To put the above into context, 1 kWh will illuminate a 100-watt light bulb for 10 hours.

Heat generation in this paper is measured in exajoules. A joule is the basic energy unit of the metric system. An exajoule is equivalent to one quintillion joules. One exajoule is equal to 27,778GWh.