

The Role of Net Zero in Reducing Food Greenhouse Gas Emissions

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Declaration

I hereby certify that the material, which I now submit for assessment on the programme of study leading to the award of M.Sc., is entirely my own work and has not been taken from the work of others save to the extent that such work has been cited and acknowledged within the text of my own work. No portion of work contained in this thesis has been submitted in support of an application for another degree or qualification to this or any other institution.

A handwritten signature in black ink, reading "R Cunningham". The letter "R" is large and stylized, with a long vertical stroke extending downwards. The word "Cunningham" is written in a cursive script.

Richard Cunningham

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Abstract

Net Zero is a very topical subject across all sectors of society at the moment. It refers to the balancing of carbon emissions produced from human activity. Many governments and corporations are making commitments to achieving Net Zero by the year 2050. Despite the food industry making strides towards getting to Net Zero there is significant changes required if it is to get anywhere near Net Zero. Agriculture remains one of the biggest offenders particularly looking at a country like Ireland where agricultural emissions are the largest source of carbon emissions of any sector. The study seeks to understand the major causes behind carbon emissions and how to negate this in achieving Net Zero. The Agricultural impacts will be examined in both Ireland and globally, looking at causes of emissions along with successful examples of mitigating emissions in achieving Net Zero. The Study will examine potential technological advances that give hope for achieving Net Zero. There is a detailed review on how policy makers look to tackle this issue and how that relates to the food industry. There are many studies highlighting how Net Zero is perceived by both individuals and their impacts from shifting to a more plant-based diet along with sectors in the food industry in implementing changes that will allow them to achieve Net Zero. The study is an overall review in how Net Zero can be achieved in the food industry for a more sustainable and waste reduced circular model.

Abbreviations

GHG	Greenhouse Gas
kgCO ₂ e	Kilograms of carbon dioxide equivalent = - Used for measuring carbon footprint
tCO ₂ EQ	the unit that measures the environmental impact of one tonne of these greenhouse gases in comparison to the impact of one tonne of CO ₂
CCC	Climate Change Committee
CO ₂	Carbon Dioxide
O ₂	Oxygen
Mha	Million Hectors per year
CO ₂ eq	Carbon Dioxide Equivalent
FLW	Food Loss & Waste
Agri	Agriculture
GT	Gigaton
WHO	World Health Organisation
NET	Negative Emission Technologies
MTCO ₂ E	Metric Tons of Carbon Dioxide Equivalent
CWT	A Hundredweight

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Chapter 1

Introduction

The focus of this thesis is to determine the damage level and effects of the food industry from where food is produced, all the way through supply chain and right to the consumer. The food industry is one of the largest contributors to GHG, Greenhouse Gas emissions globally and in Ireland. If we analyse GHG output and look at what can and is currently being done to reduce this specifically in Ireland, but also looking at what's been doing in other countries. Net Zero is to negate the GHG produced by human activity compared to what would be zero emissions or Gross Zero effectively stopping all emissions. Gross Zero appears to be unattainable as it would involve living in a manner most people would unlikely conform to which is why Net Zero appears the more realistic goal. One of the biggest challenges in moving to Net Zero is trying to switch from a linear model to a circular model from every aspect of how we live, from the waste we create to the produce that's created and to the packaging and all its processes. The entire Net Zero and lowering of emissions is a hot topic for many industries at the moment, however none of these quite touch our lives quite like the food industry which is at a fundamental level one of our primary functions as a species to obtain nourishment. The thesis will define the various causes and potential developments that aid the industry in getting to Net Zero and looking specifically at what the Irish food companies specifically in the agricultural industry, an industry that was valued at €13.6 billion in 2018 and rising. The Agri-industry is a vital component to the Irish Economy, and we will look at what it is doing to lower its emissions (Sustainable food systems Ireland, 2020). The climate is changing, and it is a complex issue to deal with, to make positive changes will involve collaboration of nations, governments, society, companies, and individual actions to be opened to doing things differently and be open to the change required.

The main objectives of the report are to examine what is the situation at present regarding emissions from food with a focus on the Irish Agricultural industry, to look at possible methods of lowering our emissions and getting to Net Zero through technology and implementing change and to examine if we likely achieve our Net Zero targets. The report looks at what can be done to tackle this mountainous task that has been set by industries and governments across the globe

The introductory chapter will outline some of the key elements in the discussion like cultural food links and how this has evolved into everyday norms and how they are once again evolving with alternative options however facing the many challenges.

The report also looks at why it is so important to reduce emissions in food and how not doing so will in itself negatively affect food production. There is an obvious ironic link in the output of emissions from the food industry and the direct impacts of these emissions in our

food chain. If humans can successfully reduce the impact in the future this in turn will lower the risk on both animal and plant life having to adjust and adapt to the pressures of a changing climate in both land and oceans.

1.1 The Concept of Net Zero Overview

The Concept of Net Zero first began in the early part of the 21st century when there was a realisation that carbon emissions were increasing our planets temperature. From the scientific stance regarding changes in the atmosphere, evidence was beginning to appear on the correlation between how the level of planet warming begins to decrease when CO₂ emissions from human caused activities like fossil fuels and agriculture decrease. The effects in recent years have been so severe that what is required to reverse the effects of GHG emissions and global warming need to be swift but sustainable over the decades to come. Although there is a significant level of information from papers published on the Net Zero topic there is no specific defined level of exact emission reduction for companies and countries alike. So, for example with the Paris agreement, no one standard has been set and this leaves individual states to self-determine the course and of reducing emissions and the measurement tools in which they define how they are doing (Fankhauser, S., Smith, S.M., Allen, M. et al, 2021).

1.2 Food Culture

When trying to understand climate change, it's important to be clear on how it is understood in modern life and why it appears to be the younger generation so concerned about its effects. It is now beyond any reasonable doubt that climate change is happening, the simplest description is that there is a change in weather patterns and increasing temperatures on the planet that is going to have a negative effect for all life on the planet. The major causes for this shift are Energy, Agriculture, Transport, and Industry (UN, 2020). In recent years there has been a shift in pockets of the population to reduce our emissions in general from electric cars, more efficient lifestyles and of course the types of foods we consume. Typically, we see this shift in the younger generation that has been categorized as Millennial and Generation Z the generation born from 1981- 1996. In this cohort of the population, you are more likely to find them opting to have more plant-based food diet than the older generation. In the US over 8% of Millennials and Gen Zs are categorized at Vegan/Vegetarian and in the over 50's this

figure stands at only over 2 % (Statista, 2018). This information shows from an age demographic how this can have a positive impact on emissions when we look at the difference in a plant-based diet over an animal-based diet when looking at the carbon output of each.

There is now mounting pressure for change coming from seemingly all sections of society. From a simply practical point if we can consider the efficiency for food growth and production. If we take for example crops, it is more efficient to grow crops for human consumption to instead grow crops, then use the food to feed animals that in turn requires a whole range of energy sources from time, land, water, and energy to go into the production of animal meats that can then lead to the production of methane gases being released in the atmosphere. We can see from some of the research the negative aspects of eating animal - based foods which can cause increasing emissions, this does not however mean we need to stop eating meat. If we look at western society like Europe and North America we can dissect that we are simply eating too much meat, not specifically from an emissions point of view but rather if we look at the health implications of doing so if the global population at large wish to continue to expand the current rate whilst feeding the masses there is a need to reduce the pressures on the eco system through a range of measures like reforestation and not adding already mounting pressures to global warming (The Lancet Commissions, 2019).

The scientific community have been warning about the need for change for years and the IPCC the intergovernmental panel on climate change have had numerous reports on the danger of doing nothing. This has fuelled society wanting change which in turn has put pressure of governments to do more to influence business and socio-economic factors that have huge influences on emissions and really show now that there is mounting pressure for change (Jacobs, M. 2016). This pressure may not be the defining factor into achieving Net Zero but can definitely only further the cause.

1.2.1 Promoting Positive Cultural Change

Looking at what can encourage the population at large to making a switch to a more plant based rich food diet is using a more health benefit approach. Most plant-based foods contain less saturated fats and are not as highly intensively processed. So rather than simply dictating a dietary change and instead explaining the health benefits this could be a way to encourage plant-based consumption, lowering animal-based food intake and in the process having a positive impact on emissions (Theresa M Marteau, Nick Chater, Emma E Garnet, 2021).

If we try to understand what good looks like, can it be used as a template for other companies. One example of a company trying to be more sustainable alluding to the obvious cultural pressures are McDonalds. In December 2021 McDonalds opened its first ever entirely Net Zero restaurant. They have done this through a range of measures using building materials like insulation from sheep's wool, stones from recycled plastic bottles and renewable power from solar power and wind turbines. This is a major development as McDonald's plan to use this as a blueprint for future stores, since McDonalds feeds 1% of the planet it can be seen as a major positive shift in reducing emissions and promoting a cultural shift towards a greener way of conducting business in the bigger picture (McDonalds, 2021). Many countries are planning to promote the use of solar panels in new builds, this is in both of homes and business premises. There has been a question mark of the cost of solar panels particularly within the retrofit sector of updating older buildings. A frequent obstacle was always how many years of energy savings this would take in order to break even and making a savings. Since the war in Ukraine broke in February 2022, energy costs have skyrocketed globally along with rising inflation. The likely outcome of investing in solar panels for businesses will likely be a prudent one from the point of reducing energy costs and in the process having made a positive effect on Net emissions. What will likely trigger an increase in uptake of adding solar panels will be a focus on tax reduction in policy in tandem with achieving emissions goals that will make it more attractive for businesses (Massihi, N., Abdolvand, N., & Rajae Harandi, S, 2020).

1.2.2 The Covid Cultural Shift

If we look at what happened in 2020 when the Covid Pandemic hit the world we saw a situation where the society's behaviour changed. The Pandemic changed the way people thought about things and the fact that disruption in commerce was caused by factory shutdowns and a realisation of the dependency to global trade. This can be attributed to various factors. People found themselves having more time on their hands as they were working at home so cooking at home became more common. Initially when the restrictions in Ireland came into play, there was a rush of panic buying. This was then followed by people reducing the number of times they visited shops and led to a surge of online shopping. Why was all of this important? It led to a situation where people thought a lot more about the food they ate regarding how much they wasted and the psychological shift in highlighting the importance of food in our lives which will be an imperative connection required for the

changes needed in becoming more carbon conscious in the future (Rachel F. Rodgers, Caterina Lombardo, Silvia Cerolini, Debra L. Franko, Mika Omori, Jake Linardon, Sebastien Guillaume, Laura Fischer, Matthew Fuller-Tyszkiewicz, 2021).

1.2.3 Shocks to the world

As we saw with the Covid Pandemic and are still seeing at this point in time that the only thing that can be certain is uncertainty. The war in Ukraine is inevitably going to have long-term effects on the cost of food as both Russia and Ukraine make up almost one third of international wheat sales combined. This is at a time when the industry is still vulnerable from the Pandemic shock and currently experiencing unprecedented inflation around the western world. At the world economic forum this was discussed at length highlighting how food systems are way behind the energy sector for reliability and technologically. There were five main points highlighted as areas for attention in order to shifting the world to Net Zero.

- Reducing Food waste which causes not only waste of the end product itself but needlessly wastes GHG emissions
- Healthier food promotion
- Encouraging a switch to Plant-Based food sources
- Getting Agriculture on a more sustainable path
- Having zero hunger around the world through aid packages (World Economic Forum, 2022)

1.3 Climate Neutrality

If we consider the move not just in the food industry but in general practices across all industries, there is move towards becoming climate neutral. Climate Neutral is a concept that is at its essence about being Net Zero. It simply relates to emitting less in relation to carbon emissions and absorbing more carbon from the atmosphere. If we think about emitting less there are a range of examples in achieving this. This can be shifting towards using more efficient processes, polluting less into the atmosphere by switching fuel types to greener energy uses. Consumers have a huge role to play by the lifestyle choices and reducing our own individual impacts. Emissions need to fall, that is something there is consensus on in the scientific community however the reality is that some emissions are unavoidable. This is where neutrality comes into play in achieving Net Zero. This means there is a need to absorb as much CO₂ as possible in order to negate the unavoidable emissions. This can be achieved by a range of methods. We know our forests and oceans are capable of absorbing CO₂ and

this needs to be encouraged and policy needs to be fostered in a way that promotes absorption (European Council, Council of the European Union, 2019).

In 2019 the European Commission introduced the Green Deal which included a variety of measures that would assist climate neutrality. There are some key measures that have been introduced in order to enhance the chance of climate neutrality. These include investing heavily in environmental technologies that can limit and absorb emissions. Supporting innovation that could produce the new ideas in offsetting the current trajectory. Improving transportation through more greener forms like public transport and the take up of electric vehicles. Most importantly to work with other stakeholders and larger countries like the US and China to try and improve standards in different parts of the world where there is limited influence on policy for reducing emissions. Although there are many who say the Green Deal is yet another example of creating long term targets that have little accountability, the EU have put an ambitious aim of spending 30% of its overall budget from 2021-2027 to tackle the effects of climate change which is a key indication of how serious they view this threat (European Green Deal, 2019).

1.3.1 Emissions Management

Origin Green have developed a hierarchy to managing emissions following very simple principles. The first step is actually understanding what the carbon output is. If you consider generic methods in reducing emissions, there are all vital steps but it's difficult to look for an answer if we don't know the problem. Companies in the food industry must understand what their emissions are and how they can be measured if they are successfully going to reduce them. There is a calculation devised in doing so $GHG = \text{Emissions Data} \times \text{Global Warming Potential}$. $GHG = \text{Activity Data} \times \text{Emission Factor} \times GWP$, or $= \text{Activity Data} \times GHG \text{ Conversion Factor}$. This allows a company to have an understanding what its challenges are. This is followed by general principles in managing the emissions.

1. Transparency, looking at facts, disclosing all relevant information from every available source of information
2. Relevance, making sure GHG emissions information are appropriately relevant and reflected for decision making
3. Accuracy, ensuring that emissions are accurately calculated and not above or below the true number.

4. Completeness, use all available information and document for any reason to exclude any sources of data.
5. Consistency, be consistent in the methods being applied, and highlighted any changes regarding methods used.
6. Conservative, if unsure err on the side of caution in terms of results produced opting for the most onerous result (Origin Green Guidance, 2021).

Measures like this seem simplistic and obvious. What's worrying though is it doesn't seem to be an industry standard. There was a poll taken in the UK looking at 1000 small and medium sized businesses (SMEs). Although not specific to the food industry it gives an insight to the lack of understanding in business at tackling their carbon emissions. The worrying findings are that only 1 in 10 were measuring their carbon footprint. Many of the businesses had no idea how to measure. With one observation from the findings showing a correlation that the smaller the business then there was a lower likelihood of undertaking measuring GHG emissions. This can be attributed to culture, importance, and the fact that in the UK there is no legal requirement to measure GHG emissions showing an obvious shortfall in policy. The UK Government have released guidance for SMEs to measure GHG emissions however it would appear this needs to go further as the results of the poll are ominous for the future. (EDIE, 2021)

1.3.2 Science Based Targets

Science based targets are clearly defined paths to getting companies and institutions to follow a more measured method for measuring emissions and reducing GHG's. There has been a lot of development into science-based targets and differentiating the types of emissions into clearly defined categories. This can be also known as getting companies on the net zero standard. Firstly, splitting the types of emissions into sections known as Scope 1, 2 and 3 emissions.

- Scope 1 emissions can be identified as direct emissions from resources owned by the company as are released as a direct result of the company operating, for example the CO₂ emissions from a company vehicle.
- Scope 2 emissions can be identified as indirect emissions, using power from an energy provider for example the electricity and heating purchased from a utility company.

- Scope 3 emissions can be identified as indirect emissions but not owned. These represent the larger share of emissions produced by an organisation and have a much wider scope. Various examples of scope 3 emissions are the emissions from purchasing or selling goods or services, the commute an employee makes to get to work, the waste disposal or the transportation, distribution, and product manufacturing (Plan A Academy, 2020).



Figure 1.1 Graphical representation of Scope emissions

As scope 3 emissions have a wide encompassing possibility due to so many variables there is a need to calculate as best as possible managing any areas of uncertainty. There is a lot of streams of information, and this can lead to incorrect calculations. There is the potential of unreliable data arising from various sources, and until the time of more specific and accurate data, many methodologies are reliant on predictive assumptions rather than reliable exact scientific data (Gireesh Shrimali, 2021). Science Based Targets will be a very useful mechanism in getting companies and corporate attentions in focusing on their climate responsibilities. There is a need to expand this out for more of a defined standard across all food industries. There is a potential weakness in the fact that this may be seen as the standard in achieving Net Zero when really it is only the first step in a much bigger challenge for the food industry as a whole.

Chapter 2

Agriculture

The situation with the depreciation of our eco environment across the world and the many threats facing farmers across the planet has increased in recent years. What has become a challenging environment for many with aging farmers and an industry that seems to move from one crisis to another with prices and the natural environment in which ironically has been impacted from an industry that relies upon it. There seems to be one very glaring and obvious culprit in challenges faced in getting to net zero in food production and that is Agriculture was responsible for 37.1% of all GHG emissions in Ireland in 2020 see figure 2.2 (EPA 2020). What may differ to Ireland compared to other countries is as an industry agriculture is so important to Ireland both financially and culturally. Agriculture has a huge amount of the population working within it, if we take dairy farmers in isolation there is about 17,000 dairy farming families and as a whole and the agriculture industry employs 265,400 people as per CSO statistics in 2016 which represented approximately 5.5% of Ireland's population (CSO, 2018). It is important when looking at the agriculture landscape in Ireland when looking at ways in reducing emissions that there are certain societal and economic realities that need to be faced that change cannot just be thrust upon an industry that lives through their work and have done so for generations.

Ireland has always been an innovative country when it comes to technology, and it may well be the case that technology is one of the driving forces around modernising our agricultural industry in order to help us achieve our Net Zero objectives.

We can see in a wider sense outside of just Ireland at what is happening now, in the EU there are already failings as when the World Health Organisation recently set recommended levels of meat consumption in Europe specifically the EU we are consuming double the recommended amount. Although this varies country to country and is very much a highly discussed topic, in this part of the world, Ireland is a negative outlier with the increase in animal-based food consumption like dairy and poultry (Net-Zero Agriculture in 2050, 2019). The study provides examples of smaller agricultural businesses being innovative with doing business differently along with larger multi national's trialling new ways to achieving Net Zero.

If we look at Agriculture in rural Ireland often made up of a network of smaller farms it may be difficult to implement a widespread standard of doing things efficiently for Net Zero, so in order to give rural farmers the tools necessary to assist them in becoming more carbon efficient supports will need to be in place. This could be in the form of a Green Scheme that offers not just financial supports in upgrading facilities but also the skill sets and expertise for example soil testing supports or digital assistance (Dave S. Reay, 2020).

2.1 The Circular Economy

When looking at reducing the carbon output of all aspects of producing food then it's important that all areas of the supply chain be as efficient as possible from production to packaging. One example of a company taking a more circular approach is with Saltrock farm in Wexford. Saltrock farm have their own pasteurising unit avoiding transporting the produce to be pasteurised elsewhere. Their product is non-homogenised which is less processed and contains a higher protein level than traditional milk produce. The milk is available to customers a few hours after production through the channel of a mobile vending unit that allows its customers to fill their own milk through a mobile vending unit. They have also introduced flavoured milk options to differentiate themselves even further from the traditional marketplace (Wexford food family, 2021).

Biodiversity appears to be one of the tools at the disposal for modernising agricultural. A good example at how this is being trialled is Farm Zero C this was a UCD led project in agriculture and won €2 million in the zero emissions challenge. In the Farm Zero C example which involved the Carbery Group who deal with cheese, protein products, bioethanol Carbery process, flavours, the Shinagh Farm a dairy farm in County Cork part of the West Cork co-op. They recognised that there is a need to develop a carbon neutral farm and are using biodiversity as one of the tools in their arsenal to get closer to this. The project is a strive forward for a carbon neutral dairy farm. For context there is a difference in being carbon neutral and Net Zero where carbon neutral refers to balancing CO₂ emissions from what is emitted to being what is absorbed, Net Zero refers to all GHG's like Methane and Nitrous Oxide. There are significant challenges facing the project like the fact that approximately 65 % of all emissions in agriculture are coming from enteric fermentation (cows burping). There are progression plans going forward to work with 10 other farms over the next two years that will be replicator farms that will begin to implement some of the measures that have been developed in the project but the long-term goal of this blueprint is to scale this up to over 5000 farms so this can have a national positive impact on reducing GHG emissions. Some examples of what is being implemented regarding biodiversity replicating and expanding hedgerow areas along with growing different species of plants that have the ability to trap nitrogen like clover that takes the nitrogen from the air meaning it requires less fertilizer by approximately 50%. Also looking at the feed for cattle breeding and how this can be tackled. Simple but effective measures like these have potential. In terms of energy creation implementing solar panels on milking parlour roofs meaning the farms won't have to

purchase electricity from the grid but can also return electricity to the national grid having an economic benefit to the farm (Farm Zero C, Science Foundation Ireland, 2022).

Looking at the science foundation of Ireland who are connected to farm zero c and are also researching areas that they hope will lead to progress for science to do its part in reducing emissions. There is a designated science group Biorbic or Bioeconomy SFI Research Centre have been researching areas they feel can have a huge impact in emissions reduction. Specifically, they have been looking at high emission sectors like marine and agriculture in Ireland that typically are high level emitters. They have partnered with many food producers like Glanbia and Nuritas. Ultimately their goals are to develop and deliver expertise on new technologies and processes to help make the industry more sustainable in the long term. They are looking to collaborate with the industry in order to not only become more sustainable but in the process increase regeneration in rural areas along with reducing dependency on imported goods that will organically have a positive environmental impact (Biorbic, 2021)

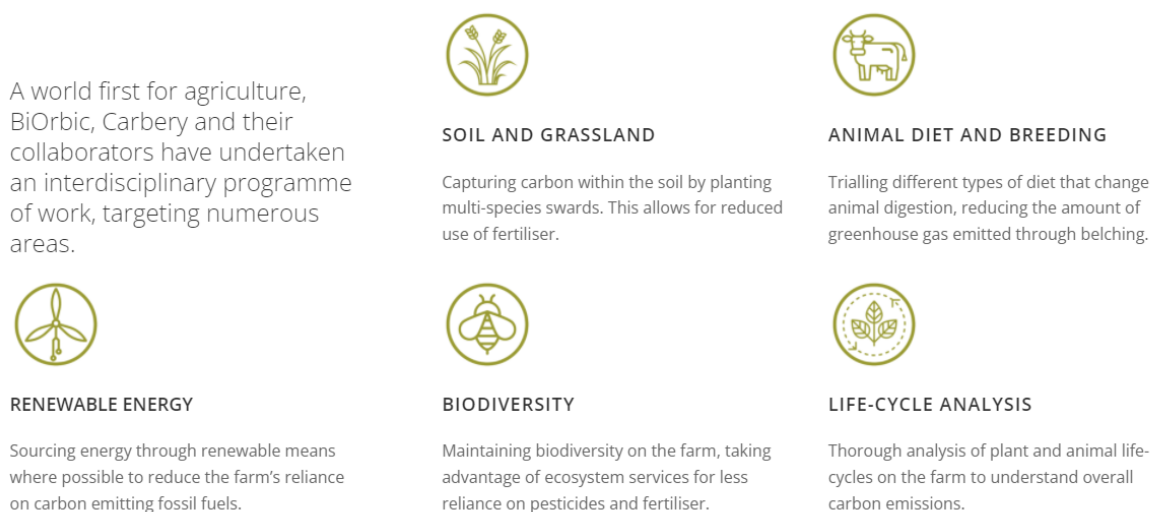


Figure 2.1 Farm Zero C Key Strategies

Looking at the emissions produced from agriculture in Ireland it is clear it owns a significant level of the overall output and is going to be one of the more challenging areas to tackle as it is responsible for more than a third of the overall carbon output

2.2 Threats to Change

Although from most of the literature regarding agriculture and net zero there is recognition that the processes mainly for meat production are generally damaging in relation to carbon emissions. An important point to be made is not everyone wants change. If you look at agriculture and the ramifications the Net Zero movement has for it, there's much to lose. If we can consider what happened with Exxon secretly lobbying government in the US to undermine the science about climate change in order to kill reform. It's reasonable to expect the same type of lobbying by the Agri-industry. There have been highlighted examples of this regarding analysis of documents from the Agri-industry in order to delay or quash reform in policy that could potentially hurt their bottom line. As with many industries like banking and fossil fuels, the corporate arm of the Agri-industry poses a significant threat to change (Theresa M Marteau, Nick Chater, Emma E Garnet, 2021).

There have other examples of the Agri-industry trying to implement barriers to the plant-based industries. Such recent examples in Ireland where Pat McCormack, president of the Irish Creamery Milk Suppliers Association had lobbied policy makers to introduce legislation to ban the use of words like sausages and burgers for non-meat-based products and similar for almond milk not to be labelled as milk. There has been measures in countries like France and Belgium already to implement such legislation. The justification for such a proposal was it was not acceptable for the plant-based industry to piggyback on the labels from the meat industry that had been long established (Irish Independent, 2022). Although this could be seen as far less sinister as lobbying government to undermine scientific evidence around climate change, it's clear to see that there are forces within the agricultural industry that are trying to hinder and limit change that they see as a threat to their industry and profit margin. There are obvious deliberate barriers to getting to Net Zero however there are also some challenges where the barriers are not so deliberate. If we consider the food industry has many SME businesses as part of its overall industry particularly in a country like Ireland. Lloyds Banking group in the UK published a report which was a practical guide for SME's. The report itself highlighted the significance of the overall SME sector in the UK and that getting to Net Zero would be a failure without the SME sector on-board. The findings outline the challenges and also the opportunities for the SME sector. 40% of the SMEs surveyed in the report had stated that the high costs of implementing the required change was the main barrier to change. This was in spite of huge long-term savings that would be made and the commercial gains with going green as consumers are found to be more likely to spend where

there is a green initiative. Also, the report highlighted measuring emissions is an area of huge concern as most companies find it difficult to understand and measure their emissions impacts which we have already looked at in detail (Llyods Bank, 2021).

2.3 Agriculture and Net Zero

If we look at the agricultural industry and ask the question, why set an agricultural net zero target? If we look at what agriculture contribute to GHG emissions see in figure 2.2 below in Ireland it will be almost impossible to getting emissions to Net Zero if Agriculture doesn't have a significant reduction in number of emissions, it produces.

Agriculture was responsible for 37.1% of greenhouse gas emissions in Ireland in 2020

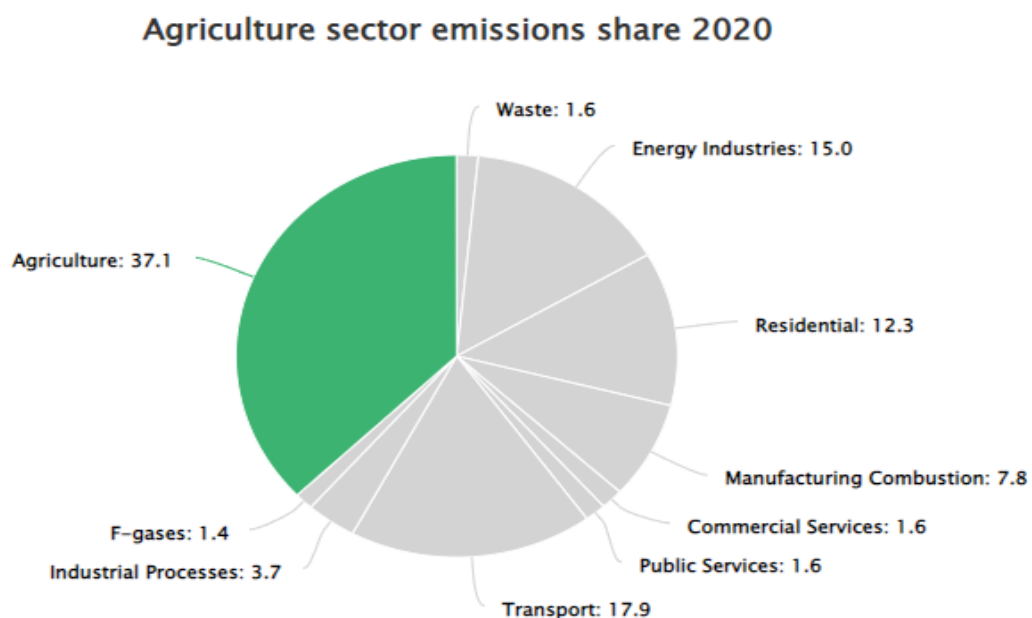


Figure 2.2 Irish Agriculture GHG emissions 2020

This is significant as it is an extremely sensitive cultural issue. Irish Farmers feel they are being vilified in the pursuit of lowering carbon emissions. The reason the agriculture industry has such an impact is that many of its processes mainly for the purpose of food creation is carbon heavy like the management of manure, enteric fermentation (cows and other livestock that produce methane) and the agricultural soils. When looking at Methane in isolation it can be described as cow's belching out methane gas. Methane gas is the second only to CO₂ when discussing emissions. Cows and then Sheep are the largest emitters of Methane gas with 58% of Irish Agricultural emissions that can be attributed to both Cow and Sheep

emissions (Teagasc, 2021). The harrowing situation is that GHG emissions rose by 1.4% in Irish agriculture, and this is down to many drivers like the removal of the milk quota in 2015, the increase in the national herd size for the tenth consecutive year in a row and increased use of fertilisers and liming (EPA, 2020). At a time when Ireland needs to be reducing its national herd size the reality of the situation for the dairy industry is it has gone in the opposite direction for Ireland since the abolition of the EU milk quota. Ireland has made the commitments to lower its emissions but, on the ground, very little appears to be happening in terms of achieving those goals. The reality of the situation and the fact Ireland has continuously missed emissions targets is that if we take the dairy industry in isolation, from 2015-2020 dairy farms have dramatically expanded no longer being bound by quotas. This has led to Ireland needing to import more feed for larger herds and requiring the use of chemical fertilisers with the overall result being an increase in emissions from all areas of the supply chain in increasing dairy production. So by increasing the national herd for milk production this has caused an increase in emissions, one way to counteract this would be to try and have the herd made up of cows that are genetically bred to yield larger and more frequent milk supply (Doris Läßle, Colin A. Carter, Cathal Buckley, 2020).

There is likely going to be major challenges with the reality of huge changes required to lower emissions that will require farmer engagement in the decision making as it will likely require a reduction in the national herd size. Farmers need to be part of the discussions in change and given the reasons why such change is necessary. If legislation is implemented and the required education is not in place there is huge potential for conflict as there is likely the perception in the farming community that they have been excluded from the decisions that are going to influence their livelihoods. Scepticism will likely arise from perceived motives and interests also coupled with a lack of understanding and education if the farming community have not been included in discussions for change (Henchion, M.M.; Regan, Á.; Beecher, M.; MackenWalsh, 2022).

Ironically, beef is generally considered the highest GHG emitter regarding the energy costs of bringing a cow to maturity for slaughter and yet it is the beef farmer who has the lowest average net income per hectare in Ireland which means it is going to be a difficult task requiring huge governmental backing to reduce emissions in this area.

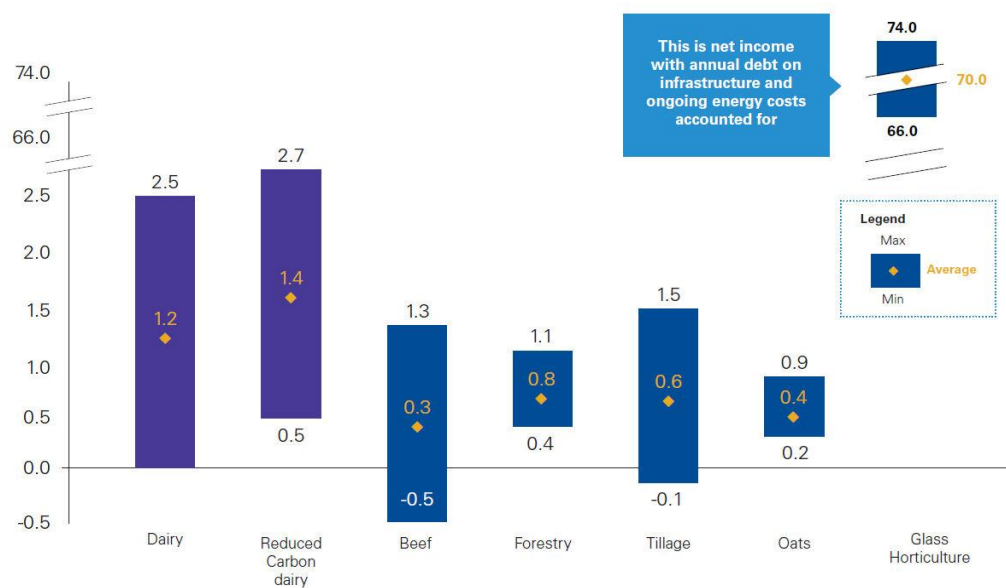


Figure 2.3 Illustrative annualised net income by farmland use, €'000 per hectare, Ireland averages, inclusive of grants (KPMG, 2022)

With Ireland having committed to targets for being net zero by the year 2050 (gov.ie 2021) with the Low Carbon Development Bill which would in reality require a 7% per annum decrease for the next ten years for this to become a reality and with the agricultural industry at large in the country not even sustaining current levels of output, this seems like a target set to be missed. The government have clearly outlined what they expect from farmers and businesses however there doesn't seem to be any specific strategies in place onto how this can be realistically achieved as a lot of the "goals" contain an element of robust sounding narrative and some very strong rhetoric on how this needs to be achieved but like a lot of policies in contemporary politics it seems lacking in clearly defined substance and if Ireland is going to be successful in reducing emissions it won't be because of vague targets (gov.ie, 2020). One specific form of government support announced in 2022 in Ireland is that there has been confirmation of a 60% grant under the targeted agricultural modernisation scheme (TAMS). This has been coupled with a 100% tax write off for the year of installation which can be seen as a very concrete measure in supporting farmers and agriculture in improving their facilities to be more Net Zero. The IFA had conducted a study prior which the results indicated that in order for the investment to be feasibly viable this level of grant was necessary. This is an important step to catch up with the average renewable energy generation in the EU. Out of the 27 member states in the EU, Ireland is placed number 23 with only 2.6% renewable energy generation in the agricultural industry compared with the EU average of 12.1% highlighting much still needs to be done in this area (IFA, 2022).

What does this mean going forward, is Ireland doomed to fail on their target of reducing GHG emissions due to the agricultural industry's intense output. Are there more emission friendly ways to produce and not negatively impact production?

2.3.1 Deforestation

An area that has gained a lot of attention of late is that of deforestation which can have a doubly negative impact for emissions. On one side you have now lost a lot of forest area that has the capability to absorb CO₂ and return O₂ into the environment. What has replaced the forest has then a contributing factor in increasing CO₂ levels with what can be infrastructure or worse with what is taking place under Jair Bolsonaro in Brazil with the Amazon being deforested and replaced with agriculture (Markus Kröger, 2019). Unfortunately for Net Zero targets, Deforestation has ramped up in recent years in the Amazon to make room for agricultural farming as part of Brazil's plans for economic expansion. This is also the case amongst other areas of the planet like other areas of South America and DR Congo (BBC, 2021).

Ireland has set itself an enormous target of planting 440 million trees before the year 2040. Ireland had one point was 80% forest which dipped to below 1% in 1929, it has increased to 11% but it still has one of the lowest forest rates in Europe. If Ireland is to be successful and increase its forest percentage and achieve its targets its once again going to need to coordinate its plans with the farming community who will likely need to designate a portion of their lands to forestry. This has been a contentious issue for farmers for the fear that if they give up their land for forestry it may then be unavailable for other agricultural uses in the future. There have been criticisms of the forestation section of the government's climate action plan for various reason like lacking in biodiversity. Forestation does appear to be a more affordable mechanism in mitigating the risks associated with emissions and helping sustain our Net Zero targets in the near future (Treehugger, 2020).

Looking at Ireland for example where there are plans in place to reduce deforestation and planting trees. If as a consequence of this there is, then an uptrend in deforestation elsewhere then this is having no significant effect in the overall goal of getting to Net Zero and effectively all that is happening is outsourcing Deforestation to another location. Such examples of this can be seen with waste disposal sending their waste to other typically poorer countries effectively exporting the problem (Dave S. Reay, 2020).

There have been calls to end deforestation or what is known as Zero Deforestation of any kind, but in reality, this is highly unlikely due to the need for lumber in society. What has become more of a likely outcome if we want to sustainably look after our forests is what's known as Zero Net Deforestation. Zero Net Deforestation is a more measured way of removing forest for lumber and land use but in the process offsetting that loss by a process of reforestation elsewhere. As seen in Brazil and other areas of deforested locations around the world there is a direct correlation with deforestation and agriculture. This is why there is a move to eradicate all human generated GHG emissions from deforestation by the year 2030, this paper produced by the WWF in 2009 had also hoped for Zero Net Deforestation by 2020. This is another example of how goals are consistently missed in the challenge of getting to Net Zero. (WWF, 2009).

2.4 Biodiversity in Food

Like Deforestation, there is a significant effect with the loss of biodiversity on the planet. There are direct links with the unsustainable practices in our food production systems that are responsible for 60% terrestrial biodiversity loss and overfishing on the planet to the same unsustainable food practices responsible for increased GHG emissions. Although damaging for different reasons, the loss of plant life has a corresponding connection to the increase in GHG emissions. Biodiversity is a key component to basic human security regarding food. There are other indirect links that may not be evident, if biodiversity continues to worsen this could have significant negative effects on crops and animals within the eco system (World Food Prize Foundation, 2017). Along with being important for nutritional purposes it has a massive importance regarding food security. There is the link that short sightedness in damaging practices have never worked in producing a sustainable model for any industry. There are actions that can be taken in order to improve and mitigate the risk in biodiversity that have direct parallels with getting to Net Zero in the food industry.

1. Remove any incentives in food production and consumption that may have a negative impact on biodiversity. This can be achieved by identifying incentives, developing plans and measures to mitigate this and to redirect any subsidies to programs that are related to sustainable practices.
2. Reduce food waste within the supply chain. Implement a system or a tool mechanism that can account and report and be a standard for food loss that can be an index to

measure loss and identify ways to introduce combative measures, an index for all companies to report food loss.

3. A certified system for sustainability standards. Governments, public and private entities to require minimum sustainability standards in order to be certified as so. Having food producers to sign up to policy standards in order to being compliant.
4. Promote sustainable diets, more diverse diets that involve a higher level of plant-based foods can lead to a reduction in demand of certain food types which could lead to a lowering in overfishing or intense farming. Indicators of this can be countries with guidelines that involve health and sustainability.
5. Strengthen governance for sustainability, Implement a legal framework of laws and policies at government level. This will require transparency, enforcement and funding for policing bodies that will create a system that deters practices deemed damaging for sustainability (Izabela Delabre et al, 2020).

2.5 Global Agriculture and Net Zero

Although Ireland has and disproportionately large share of GHG emissions attributed to the agricultural industry the situation on a global scale is not much better. 23% of GHG emissions can be associated with Agriculture and Forestry meaning that it is of significant importance in the overall Net Zero challenge not only in the food industry but for the wellbeing of the planet as a whole (Net Zero Climate, 2020). The industry is also the leader in Methane emissions which is particularly damaging. If we analyse the situation regarding how agriculture is reacting to the shift towards Net Zero on a more global scale we can see the proposed emphasis on change has been met with hesitation. There had been a study taken in 2020 looking at 35 of the biggest agricultural companies in the meat and dairy industry around the world. Out of the 35 companies across the world only 4 had made a pledge to a reduction in emissions and achieving Net Zero by the year 2050. The findings in the report highlighted that the 3 biggest offenders of which two are based in the US (Tyson and Cargill) have not implemented emissions targets. Some of the findings were stark showing that 9 of the companies based out of the US are responsible for 6% of total emissions in the US and this is likely to grow to 9% by 2025 indicating that the emissions are moving in the wrong direction. This highlights the power of these large corporations in terms of stifling reform as the top 10 US companies consistently lobby the US Congress and the EPA to block legislation that might restrict their production. These companies have spent in the region of

\$200 million in lobbying fees since the turn of the century. One parallel that might be drawn is that of the big tobacco companies in the 80s and 90s in terms of how the meat and dairy industry act in what appears to be a collective coordinated defensive lobbying. The analysis concluded that the most likely result going forward is that emissions are likely to increase if existing practices don't change which currently show no signs of doing so and that the effects of Methane which is actually considered a more potent GHG emission is particularly prevalent in the meat and dairy industry. The report was unique as it looked at the big agricultural corporations in isolation and could be viewed as a microcosm of the entire industry with the findings showing portentous signals for the future of the industry if the situation doesn't alter its direction (Lazarus, O., McDermid, S., & Jacquet, J, 2021).

Chapter 3

Methods and Materials

3.1 Methods - Study Design

This section outlines the methods used to determining the benefits of consuming food that is locally produced for the purpose of lowering GHG emissions. The method used in research has been based upon a desk-based study of published journals, peer reviewed papers and sources of information from government and non-government organisations. When looking up Net Zero food in google scholar the results found 1,630,000 million results so this required a more specific search for research and then when adding Net Zero Food Ireland there were still had 154,000 results. When further narrowing the search to Net Zero in food industry emissions agriculture in Ireland I reduced the results to 17 giving me more of a specific scope in researching the areas specific at appropriate research and avoiding generic information.

3.1.1 Thesis Outline of Research

There are numerous amounts of papers available that outline the consequences of Net Zero in various sectors of society, the damage agriculture causes to emissions. The topic of research presented in the thesis looking at the role of Net Zero in reducing food greenhouse gas emissions is encouraging the awareness of causes, preventative measures, and outcomes of getting the food from source to mouth to a balancing of its GHG emissions. Chapter 1 examined what is Net Zero and how is it defined, looking at examples of cultural impacts like age, geography and the impacts of changing consumer demands effecting how corporations want to be viewed. Also trying to define methods of measurements based in science at determining the specific emissions that are being created from processes. Explored in Chapter 2, the effects of the agricultural industry were delved into looking at Ireland in isolation but also referring to global issues within the agricultural industry effecting emissions. The potential for change and the threats faced for an industry that has endured challenges on an ongoing basis. Chapter 3 has given a framework the materials and methods employed to examine the topic of research. Chapter 4 will detail the results and discussion around these studies and topics relating to the findings specific to Net Zero in food issues across all areas of the chain from grower, producer, retailer, and consumer. Chapter 5 will be a synopsis of the overall findings within the thesis and review the main findings looking at the issues raised and drawing conclusions based upon the findings. Chapter 6 will list out references used throughout the thesis.

3.1.2 Data Comprisal

The Data comprised in the study was sourced from previous studies on industries like the craft beer industry and on individual participant studies sourced from peer reviewed papers observational studies. The data included, has been sourced from the most recent publication, typically within the last five years. There are examples of older data sourced that still has relevance to the topic.

3.1.3 Omissions

Data from non-peer reviewed sources has been omitted for review data.

3.1.4 Scope

The scope of the research topic on the role of Net Zero in reducing food greenhouse gas emissions, focusing on the consumer and industry cost to the planets rising temperature, cultural issues, and the ramifications of what happens if nothing changes. The scope will explore the agricultural industry at length, which is one of the main causative factors of GHG emissions.

3.1.5 Statistics size cohort

Only data from studies, with sizeable data sets with a substantial and applicable subject matter have been included relevant to the specific data that has been used. Studies typically included over 400 subjects, with the exception on the study of craft beers that had a narrower focus. There was no statistical analysis carried out as the data provided from existing sources included would be more accurate on relevant to the topic. Within the material used for the research study, they include statistical analysis which produced data within the studies outlined within the research material.

3.2 Materials

3.2.1 Global Community

Within the thesis there was a specific review in Ireland particularly regarding the agricultural industry along with referencing what is happening internationally at a global level. There are examples of successful Net Zero examples from Farm Zero C and McDonalds Net Zero restaurant in the UK, both trials in the area proven to be successful.

3.2.2 Individuals and Entities

Data relating to individuals in how they perceive Net Zero along with Data from Industry regarding what they are doing to achieve Net Zero has been included. There is a mix of studies and general information on each topic describing the differences in what can be done by individuals and what can be done by entities like government, policy makers and stakeholders in the food industry.

3.2.3 Scientific Material

Scientific data that has been trialled to varying levels has been included. This is due to various hypothesised alternative solutions that haven't been proven to any relevant level to be included for discussion.

3.2.4 Exclusions

Unproven theories relating to hypothetical solutions regarding getting the food industry to Net Zero have been excluded from the thesis as there is no scientific base to include them.

Chapter 4

Results and Discussion

4.1 Carbon output of foods

If we look at the different types of food that we consume in life regardless of what that is, there is a carbon output. This however drastically varies from the types of food we consume. If we look at the data and compare the different outputs of foods one glaring observation is that the output of plant-based food sources is incomparable to animal-based foods. Below we can see (see figure 4.1) how different types of food sources produce varied levels of carbon output take beef for example looking at the most efficient and at the extreme scale of 30-70 kgCO₂e and comparing that to foods like potatoes, wheat and peas which are generally more plentiful from an energy source for human consumption and only produce between 1-3 kgCO₂e.

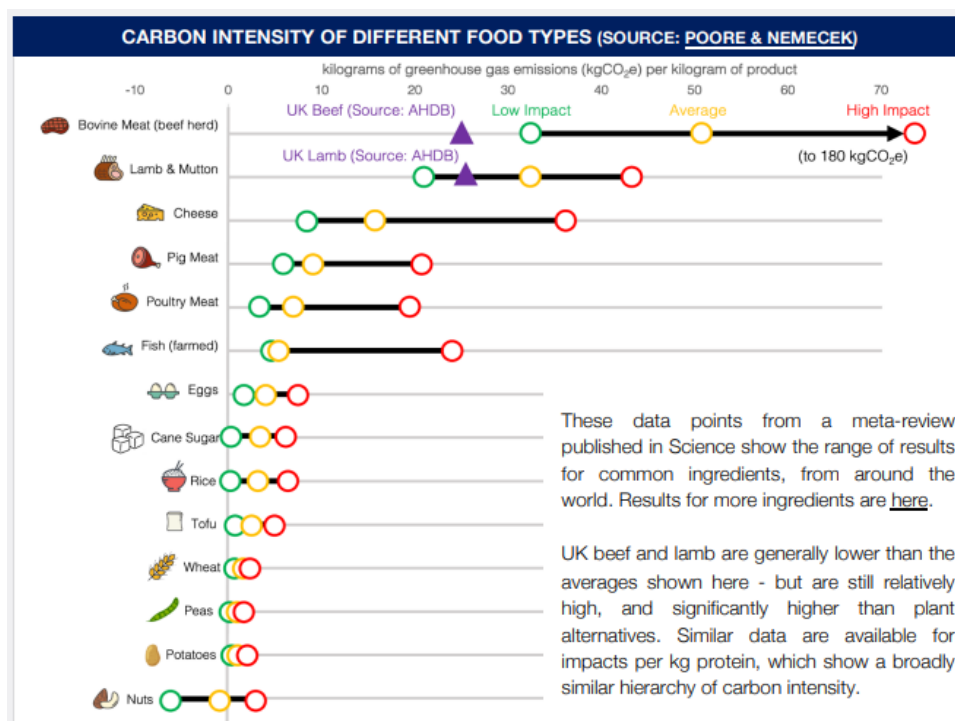


Figure 4.1 Carbon intensity of different food types.

The above data is based on global results hence the wide variances between for example the output in beef showing there are ways it can be produced more and less carbon intensely. Surprisingly, the findings do not make a recommendation to switch the diets to a vegan diet and more focuses its recommendations on alternative productions methods for food (Poore & Nemecek, 2018). It will likely take a blended approach as mitigation appears to be another possible weapon in the arsenal that won't on its own achieve desired results.

If we look at a wider sense of society at large, most people think their own impact on GHG emissions are modest at most. This trend is down to our behaviour and self-determining decisions of the food we eat. In a study undertaken to ascertain the GHG emissions regarding food and the energy that is required, in all estimates the participants of the study underestimated the impact of the food. If we consider beef for example, the lack of understanding to the level of how carbon intensive it is to produce may contribute to being a factor in society being unwilling to move away from it. We have labels on food to tell us how many calories there are in the product and how much sugar is contained. One proposal being tabled is if we had labels that outline the GHG emissions information in a simple way to help consumers choose products that reflect their own preferences for the environmental impact of their choices (Camilleri, A. R., Larrick, R. P., Hossain, S., & Patino-Echeverri, D 2018).

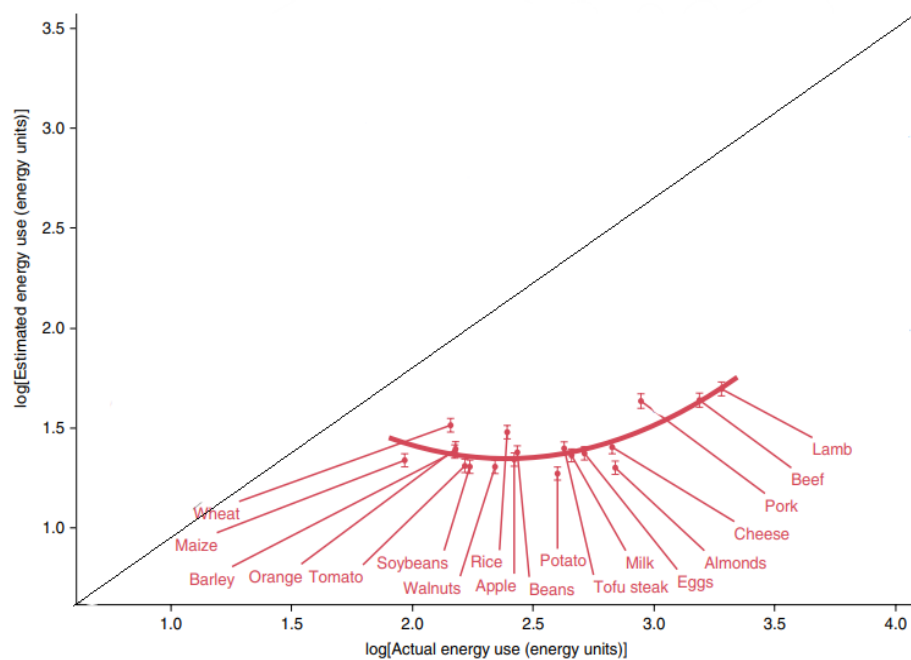


Figure 4.2 Participant estimations of emissions versus actual emissions

As shown above in figure 4.2 is the mean results of 518 participants and highlights on the line in red the estimated for the energy consumed for 19 food types. If the food types were accurately depicted, they would be along the 45° line in black. However, in the study it found that for every single food type the participants grossly underestimated the amount of energy required in the foods life cycle in order to have it prepared for consumers. This highlights a disconnect between what people perceive to the way things actually are. If you take for

example that lamb was considered more energy intensive than potatoes and although that is true the reality is the differential between the two is huge, yet the answers given by participants reflect only a modest difference between the two. The results highlight that people are unaware of how they could have such a huge influence on emissions if they chose foods that were much less carbon intensive compared to carbon heavy foods produced which are typically animal-based like beef and lamb (Camilleri, A. R., Larrick, R. P., Hossain, S., & Patino-Echeverri, 2018).

4.2 The Craft Beer Sustainability Study

4.2.1 Craft Brewery

If you look at recent years with the explosion of craft beers, we can see a model based more on the Small medium enterprise (SME). It is an industry made up of a cohort of smaller business than the traditionally larger beer industry. A consumer selecting a craft beer over a multinational corporation could somewhat mirror the selection of local foods from a farmers' market over choosing a supermarket product. The products are seen to be more locally produced and try and differentiate themselves over mass produced beers but are often more expensive. In 2017 online searches were used with words like craft beer and sustainability, green craft beer and environment and beer which then generated the first 100 hits used to identify what could be viewed as the most sustainable. 70 breweries were identified mainly from the US and the remaining from the UK, Canada, South Africa, Australia, and New Zealand. There were detailed investigations carried online on all the breweries. There were 12 topics used to categorise like Climate, Energy, and water Etc. and further then through broader headings institutional/strategic, environmental, and socioeconomic whilst highlighting breweries who were promoting what were deemed noteworthy initiatives for sustainability, an example of which can be seen in table 4.1.

Area	Guiding Question
Institutional/Strategic	
<i>Sustainability tab</i>	Does the brewery website contain a separate section for sustainability (or similar)?
<i>Sustainability report</i>	Has the brewery produced at least one sustainability report?
<i>Certified B Corporation</i>	Is the brewery a certified B corporation?
Environmental	
<i>Water conservation</i>	What measures does the brewery take to improve water use efficiency or promote water conservation?
<i>Energy/climate</i>	What measures does the brewery employ to decrease energy use or use renewable energy?
<i>Spent grain reuse</i>	Does the brewery promote the use of brewing grains for other purposes?
<i>Other Solid Wastes</i>	Does the brewery place emphasis on solid waste handling or belong to a solid waste program?
<i>Containers/packaging ingredients</i>	What measures has the brewery used to decrease the impacts of beer packaging? What measures are used to for more sustainable ingredient use, including both beer & restaurant activities?
Socioeconomic	
<i>Employees</i>	What schemes are employed to improve the working conditions of employees?
<i>Gender & equality</i>	Does the brewery explicitly partake in measures to seek a gender balance and promote equality at the brewery?
<i>Community measures</i>	What actions does the brewery carry out to support and engage itself in the community?

Table 4.1 Brewery sustainability criteria

Identifying if the company have a section for sustainability outlined the company's aims in these areas, then looking at reports to further determine this. The Certified B Corporation is issued by a 3rd party by a non-profit organisation requiring certain criteria like transparency, social sustainability, and environmental standards.

The environmental section specifically looked at areas that would be related to net zero criteria in terms of energy, waste and water conservation as brewing can use a lot of energy and water which have obvious climate implications which would ascertain the measures to promote a more renewable method of processing. Also, with an emphasis of waste regarding by-product waste and wasted grains and looking at packaging which in all food and beverage industries can be one of the most environmentally damaging areas. Also, and emphasis was placed on looking at ingredients free from GMO's.

There was also an area for socio economic factors but as this is not relevant to environmental issues therefore this is not relevant for the topic.

4.2.2 Craft brewery results

Using the data an example in below in table 4.2 which showed 43 out of 70 or approximately 61% of the sites gave special mention to sustainability however this was to varying levels from website to website.

Area	Web score	Guiding Question
Institutional/Strategic		
<i>Sustainability tab</i>	43	Sustainability Web page with multiple tabs for examples of sustainability work
<i>Sustainability report</i>	10	30 Page Sustainability Report
<i>Certified B Corporation</i>	11	Certified since 2010
Environmental		
<i>Water conservation</i>	32	Water recapture system for returnable water bottle system
<i>Energy/climate</i>	41	10,000 + panel solar array to run the Brewery
<i>Spent grain reuse</i>	30	Business offshoots to produce dog biscuits and energy bars from used grains
<i>Other Solid Wastes</i>	28	Construction material reclamation; no-waste certification
<i>Containers/packaging</i>	27	Wheat-based, 80% tree-free paper pa
<i>ingredients</i>	29	All beers 100% certified organic; on-site ingredient farming
Socioeconomic		
<i>Employees</i>	20	100% employee-owned company
<i>Gender & equality</i>	4	Main business mission to balance the gender representation in the industry
<i>Community measures</i>	43	Support of different cycling initiatives in the community

Table 4.2 Brewery sustainability scores

Out of the 70 brewery's 14% had a report available to view on sustainability. The detail varied on these considerably regarding specifics on detail. Similarly, over 15% of the companies were B-Corporation Certified showing the industry has a strong emphasis on sustainability.

If we examine the results of the areas relating to sustainability which are Water Usage, Energy, Grains, Solid Waste, Packaging, and Ingredients we can see what the results delivered.

Looking firstly at water, almost half the companies place an emphasis on conserving water with 32 out of 70 of the companies implementing processes to reduce water wastage for example using technology for the reclamation of water to reduce waste during the brewing process, using a rooftop system to harvest rainwater and installing dry toilets throughout facilities. An innovative system was seen in one of the companies where water which was

used to clean the inside of bottles was recaptured, sterilised, and reused to clean outside of bottles lowering the overall consumption considerably.

Obviously the reduction of energy usage in business operations are good for the balance sheet, looking at the 70 breweries the results indicate that 41 of them had made positive moves towards using renewable sources of energy regarding the type of companies that provided their energy along with a range of measures. These measures included the use of natural lighting where possible, constructing net-zero energy buildings, biodiesel powered vehicles and various other programs that would reduce energy requirements. 13 of the breweries had solar panel systems that's powered in house battery storage systems.

Looking at grains the results showed that 30 breweries made a strong effort to implement reusing grains that were already used for production and could be then repurposed for animal feed. Some other alternatives were implemented by a few of the breweries using spent grains for use in production of dog biscuits and energy bars fit for edible consumption. These examples show that strong efforts were made to not have unnecessary waste which in itself could cause additional expenses.

Waste and recycling was a notable feature with 28 of the breweries implementing a recycling system including solid waste and organic waste composting. With one brewery going a step further reusing building materials from the premises they took over to be repurposed for a brewpub.

Packaging for 27 of the breweries showed an emphasis on more sustainable packaging for beer containers. This was done through a range of different methods and differed from company to company. Some of the sustainable types of packaging were bottles made up of mainly recycled glass or very light weight bottles, also some had a system of reusable bottles and beer kegs. One example showed a wheat-based packaging for a 6-pack container which was 80% free of conventional paper.

Ingredients were a prominent marketing tool for the craft beer industry. There was an emphasis on local produce and organic. In 14 of the breweries they used certified organic ingredients, with one brewery highlighting that the beers they produced were 100 organic and certified, this would be very unusual in the beer industry.

The study was very useful in determining what useful practices can be incorporated into food and beverage companies to lower their emissions. However, it must be said an obvious weakness of the study is that it is comprised mainly of online internet searches and not what could be considered truly academic articles in the traditional sense. There was data present on other mediums from the company's social networks, however this data was not taken into

consideration for the study. The study was also very specific to the microbrewery industry, so it doesn't give much insight into what the bigger players in the industry are doing for sustainability purposes. An obvious weakness to this study is it only involved countries in English speaking countries which does limit the scope for a holistic view on the industry dismissing companies from around Europe and all around the globe in the craft brewing industry, this was done for obvious reasons as the study was based upon an online search however it does highlight a glaring limitation.

The study did highlight that the industry has a proactive emphasis on sustainability which can be considered one of its differentiating factors from beers produced by multinational corporations. There is significant room for further analysis of the craft brewing industry with perhaps the scope to not just review microbreweries but take in some of the larger macro breweries and examine if there is the same emphasis on sustainability as within the microbrewery industry. If this study was to be expanded on going forward it would be beneficial to look at more data sets than online websites and in other non-English speaking countries to give a more thorough examination to how craft brewing as a whole is preparing for Net Zero (Barry Ness, 2018).

4.3 Local Government study on emissions

4.3.1 Local Government Study

There is obviously a need for governments to be the driving force in changes in emissions however there is also a need for local government at grass root level to be consistent with the wider message that emissions need to reduce.

In a study which looked at data in the climate emergency the data was captured and looked at UK local authority records. It then took a sample of these local authorities and examined them to see what was happening in order to combat climate change regarding the investment, strategy, and the engagement with the public. There was then a database constructed which looked at the authorities that had stated there was a climate emergency. What was found from the database was that out of the 408 local authorities in the study there was approximately 75% of the local authorities who had uploaded information which the database created allowed for data capture see table 4.3. This obviously comes with its challenges for reliability sources as each local authority has the ability to upload their own data onto the database, there is a potential for inaccuracy, and it relies on each local authority to upload data which some may or may not have done either by choice or by not being aware of the process.

Once the data was collected a sampling strategy was used to determine the data with 42 authorities selected from the overall data and a search commenced with the individual council websites and databases to examine each looking at specific financial records and the individual commitments made. The goal of the study was simple, to examine the local authority's commitment to reducing emissions and the actions they took to achieving their goal.

Data	
Local Authority	English County Councils, English District and Borough Councils, English Unitary Authorities (including Isles of Scilly), English Metropolitan Councils, London Boroughs Councils, City Corporation, Scottish councils, Welsh councils, Northern Irish councils
Region	Southeast, Northeast, Scotland, Northern Ireland, East, Yorkshire, Northwest, South West, West Midlands, London
Political party affiliation	Conservative, Labour, Liberal Democrat, Green, Plaid Cymru, No Overall Control, Independent
Date declaration passed	The date that a Council committee, usually the Full Council or Cabinet, met and approved a motion to declare a Climate Emergency
Target date	The date set to meet the scope of the Climate Emergency Declaration

Table 4.3 Local council database

4.3.2 Local Authority Results

As mentioned, approximately 75% of Local Authorities have made special mention to a climate emergency. The respective authorities did have the same access to available evidence in all regions but use different ways to interpret the info. The Greater London Assembly was referred to as a zero-carbon city compared to the greater Manchester Combined Authority which as the aspiration for becoming a carbon neutral city. The results indicate that the

majority of local authorities have the aspiration in placing an emphasis on the climate which in turn will feed into local implementation of policies that can help get closer to Net Zero. This has a significant impact with how local businesses particularly in food and agri sectors carry out their business, highlighting the importance from buy in at local level. Obviously a lot of the pressures on local authorities stem from targets set at national level however it is important that it is being made a priority for what is happening on the ground and targets are set in the long term to achieve real practical change that will have a wide reaching impact across the country and can be seen as a template for other countries in getting buy in (Gudde, P., Oakes, J., Cochrane, P., Caldwell, N., & Bury, N, 2021).

4.4 History of Food Emissions

If you look in detail at the way humans created food throughout history, it was generally small-scale agriculture with the vast majority of the food we ate coming from produce grown in the ground. If we look at this simplistic yet low emission form of production which served humanity well until the Green Revolution in World War II. In the 1940's food production experienced its own Industrial Revolution with a dramatic increase in production capabilities fuelled by oil fuelled pesticides and fertilizers (Daisy A. John, Giridhara R. Babu, 2021). When globalisation started to really ramp up in the 1980s and 1990s what resulted was a situation where food prices dropped and made up a smaller amount of our expenditure. The result being it was cheaper to import food from other countries than to produce it in the country it was being consumed. The monetary cost may have decreased, however the emissions cost was not contemplated. With food being transported from Brazil to Europe or from China to America, this was adding miles to the emissions to the life cycle that were never present in previous times in history.

4.4.1 GREET Model Study

If we look at model created by the Argonne National Lab who are a research centre for engineering and science looking at energy and the environment. The Model was named GREET short for GHG's, Regulated Emissions and Energy used during Transportation. The GREET model was used to measure CO₂ emissions between local and imported foods. The GREET software had a focus on the transportation of foods however there was a focus on the energy, resources and fuels required to produce the food along with transporting it. If we look at the example from the study comparing Tomatoes grown in California and estimating the difference in emissions from tomatoes which have in Florida that have yields of an average of

366 cwt per acre with inputs included of 173 lbs. per acre of nitrogen and 0 phosphate, 302 lbs. per acre of potash, and 181 lbs. per acre of sulphur in 2014 resulting in 4.22 g of nitrogen, 7.37 g potash, and 4.42 g sulphur per kg of tomatoes respectively figure 4.3 below.

Drag and Drop Inputs below			
Nitrogen		Water	
Quantity	422g	Quantity	2526.90 kg
Source	Pathway Mix	Source	Primary resource
Pathway Mix	Pathway Mix: Nitrogen Ave.	Pathway Mix	Pathway: Distributed U.S.
Potassium Oxide		Sulfuric Acid	
Quantity	737 g	Quantity	442 g
Source	Single Pathway	Source	Single Pathway
Pathway Mix	Pathway: Potassium Oxide	Pathway Mix	Pathway: Sulfuric Acid Pro

Figure 4.3 GREET model for Florida Tomatoes

The information was extracted from USDA data and ultimately the findings estimated that although the production emissions of Tomatoes grown in California and eaten there were generally in line with the Tomatoes grown in Florida. There was a huge difference with the overall associated emissions from the Florida tomatoes as this required transportation from one state to another across the country (Bradley Striebig, Eric Smitts, Samuel Morton, 2019). This highlights the associated emissions from transportation within a country. If we consider this and how more extreme examples of international movement of produce will have a much greater output. In theory however unlikely to happen is that if produce came from local sources alone there would be substantial emissions benefits from transportation alone before implementing changes that could benefit production emissions. This could have a negative impact on the choices of food available in a particular location for example in Ireland it would not be feasible or productive to grow avocados that are mainly grown out of Mexico and North America so in order to have access to such foods there is a need to import certain types of produce.

	Tomatoes	
	Local	Florida
Production	19.21	19.7
Transportation	5.53	29.12

Table 4.4 Tomato transportation emissions versus local tomatoes

GHG Emissions per KG of Tomato per Region

This study is brief and based between two states in America, but it could be defined as a microcosm of the issues with globalisation and the detrimental effects of transporting food over long distances on getting to Net Zero. If packaging clearly outlined the origin of foods this may have an impact on consumers choosing to buy more locally and helping them make in making educated decisions. This could however limit the variety of food people have come accustomed to in recent years. An obvious weakness of the GREET model is that its findings are mainly limited to the transportation and doesn't examine other factors like refrigeration or indirect emissions of labour force.

4.5 Alternative Methods for Carbon Removal

4.5.1 NETs

One hypothesised method in tackling emissions is the use of NET's (negative emission technologies). These are common practice in places like energy plants that compensate positive emissions that are elsewhere in the chain. One possible example of this would involve the use of Biochar which is similar to charcoal and is made from burning organic agricultural waste. The below table highlights the likely advantage and disadvantage of such an application (Nair S. Bhasker Nair, Raymond R. Tan, and Dominic C. Y. Foo, 2020).

Type	Example	Description	Advantage	Disadvantage
-Indirect Capture of substance	-Biochar	-slow pyrolysis of biomass under an oxygen deficient environment	<ul style="list-style-type: none"> –the solid form of biochar may be utilized for soil reinforcements –lower CO2 emissions from the agriculture sector due to reduced fertilizer usage –emission avoidance via the substitution of fossil fuels with biofuels 	<ul style="list-style-type: none"> - uncertainty of large-scale implementation -lack of understanding regarding the interaction of biochar with various kind of soils

Table 4.5 Biochar as NET

There have been some concerns regarding Biochar from studies like land erosion and the risk of contamination of worm life posing the question that looking at NETs like this in the use of agriculture could quite literally open up a can of dead worms we hadn't anticipated.

4.5.2 Biochar

In one study on the use of Biochar and how it would affect soil properties and the impact this would have on crop yield see table 4.5 as this is an area that has been frugally explored outside of a lab environment. The study explored agricultural pressures of soil degradation that occurred under the growing pressure of increased productivity due to population increase. Biochar is being explored to mitigate the risks of unsustainable agricultural practice involving high use of environmentally damaging pesticides and fertilisers. The findings from the report show that Biochar increased crop yield and the overall health of the soil particularly in highly degraded soils. The report did indicate however that although this is a promising development there needs to be more comprehensive field trials and studies to produce reliable data that can further ascertain the exact efficiency of Biochar on different types of soils and crops, for example the results indicated Biochar was more effective in tropical regions with poorer soil quality. The use of Biochar may offer the chance to further mitigate the risks of climate change particularly in the agricultural industry (Vijay Vandit, Shreedhar Sowmya, Adlak Komalkant, Payyanad Sachin, Sreedharan Vandana, Gopi Girigan, Sophia van der Voort Tessa, Malarvizhi P, Yi Susan, Gebert Julia, Aravind PV, 2021).

Looking at recent literature on methods and a model in reducing emissions we can see examples which may lead to a pathway in achieving results with reducing Ireland's agricultural impacts of GHG output. There has been various methods like The Irish TIMES (The Integrated MARKAL-EFOM System) a system which was created by (UCC) and the (ESRI), from March 2009–November 2011 (The Integrated Markal-EFOM System) using this system it analyses GHG emissions and energy required with raw materials and was extracted from the Pan European TIMES model of Europe and was then updated and modernised looking at and more comprehensive data specific to Ireland and in the study of programs aimed at reducing GHG emissions from energy and material use. It calculates the financial costs of a variety of climate mitigation initiatives (Madden S, Ryan A. Walsh, 2022). It is likely that it will take a range of modelling and systems designed specifically to lower emissions if there is going to be any progress made. When using at these models for simulation the aim is to look at the everyday life and the challenges and intricacy issues that can occur and how systems can be implemented in practice and how coupling techniques are affected and the how reducing emissions can occur from practical measure.

4.5.3 Enhanced Weathering

If we take normal weathering a process where rock weathering absorbs CO₂ emissions naturally. This occurs in our planet where acidic rain absorbs Carbon Dioxide from the earth, it then reacts with rock forming bicarbonate and ends up in the seas and oceans. Although this has a positive effect for CO₂ reduction in emissions it is a drop in the ocean to the scale of the problem. Enhanced weathering is a process that ramps this up. Increasing the level of natural weathering. The issue with the concept is there is little research or studies where enhanced weathering is the main focus of the study. There have been trials done that have produced results showing that unweathered rock reacts much more potently than weathered rock like basalt and are proposed for use in enhanced weathering. Lands normally used for agricultural have been proposed for enhanced weathering as there are plant roots and fungus which have already got infrastructure in place that could allow for the powder of unweathered rock to be applied over large areas that have the potential to enhance weathering on an agricultural scale (Andrews, M. G., & Taylor, L. L, 2019).

4.5.4 Ocean Based Carbon removal

It may not appear obvious that our oceans similarly to our forest have a huge role to play in removing CO₂ from the atmosphere. Currently approximately 30% of all CO₂ emissions are removed by our oceans. There are currently studies looking at ways to increase this. One example is that enhancing marine alkalinity in order to assist in its removal of CO₂ or adding synthetic materials that could induce an increase in the electrochemical processing that is responsible for removing emissions and can be classed as a chemical approach. There are potential barriers to interfering with the natural processes with our seabed. There are legal barriers that predate the concept of carbon removal which means that there may be a requirement for laws to be changed to allow this type of research (World Resources Institute 2020). Although there is a lot of excitement on various technologies being formulated to fight climate change and help the planet get to Net Zero. The fact the ocean is already such an enormous remover of carbon would mean it likely has a huge role to play in the future of any Net Zero strategies.

4.5.5 Genetically Modified Crops

GMO's, genetically modified organisms are already commonplace in society. If crops yields can be maximised this will require an increase in food production arising from lower energy input. GMOs have been mentioned sparingly in most literature on reducing emissions.

Traditionally the process for genetically altering plants were seen as a mechanism to fight off diseases in crops like potato blight reducing the risk of crop loss. There is now mounting evidence that modified crops have the potential for increasing efficient crop yields from 15-40% based on 3 individual studies from the National Science Foundation from 2016-2020 (The Breakthrough Institute 2021). In recent years there has been major developments in the creation of new food types. One highly publicised example of this is green super rice. In one study it highlighted the benefits in the creation of green super rice varieties and how this led to strains of rice that produced a vastly more nutritional rice variety and was more resilient in crop production in rain fed conditions. This was achieved through cross breeding various species of rice by systemic phenotypic selection also allowing for the crops to be grown more successfully that would not traditionally yield successful crops. What is promising in the results for creating super green rice varieties are that the research is still in its infancy and has the potential for even greater innovation and may yield results that can be used as a benchmark for other food types which in turn may be another key ingredient in achieving Net Zero in food (Zilhas Ahmed Jewel, Jauhar Ali, Yunlong Pang, Anumalla Mahender Bart Acero, Jose Hernandez Jianlong Xu Zhikang Li, 2019). Although there are what can be described as many benefits and possible advantages to GMO crops, there are opponents to GMO development. Some negative proponents to GMO use have indicated that there are concerns in using GMO foods in widespread crop creation. The main reason for the concerns is the long-term unknowns. There are genuine fears that engineering genomes for widespread use may have the possibility of negatively effecting health both for human consumption and biodiversity of wild plant population. This can be the creation of allergens that are not currently present in naturally occurring crops and this may cause an indirect danger for food security that hasn't been contemplated in the creation of such bio engineered seed and plant creation. There is also a perceived risk there may be the creation of non-target organisms (Ruben O. Morawicki* and Delmy J. Díaz González, 2018).

4.5.6 Direct Air Capture

There are some exciting new technologies that could have a major positive effect for Carbon emissions in general for example Direct Air Capture (DAC). The process involves the capture of CO₂ normally emitted into the atmosphere. The DAC take in air which reacts with a liquid solution to absorb the majority of the CO₂ and can then be used to form calcium carbonate pellets which can then be heated and captured as a pure CO₂ gas. There is also the potential to follow on to this with air to fuel technology which is a tech still in its early stages but does

give hope to the potential for technology playing a major part in tackling the climate problems at a significant level. The current issues with DAC technology are that it is very expensive and for this reason it is currently infeasible for companies to roll out DAC technology at their plants for industry. The hope is similar to electric vehicle battery technology, that necessity is the mother of invention. As the need grows greater the emphasis on innovation and technology will catch up to fill the need. Ultimately the DAC process has the capability of increasing energy from existing fossil fuels whilst lowering the output of emissions as the energy produced by the process is far less aggressive for emissions (Fuhrman, J., McJeon, H., Patel, P., Doney, S. C., Shobe, W. M., & Clarens, A. F, 2020).

CO2 capture by direct air capture in the Net Zero Scenario, 2020-2030

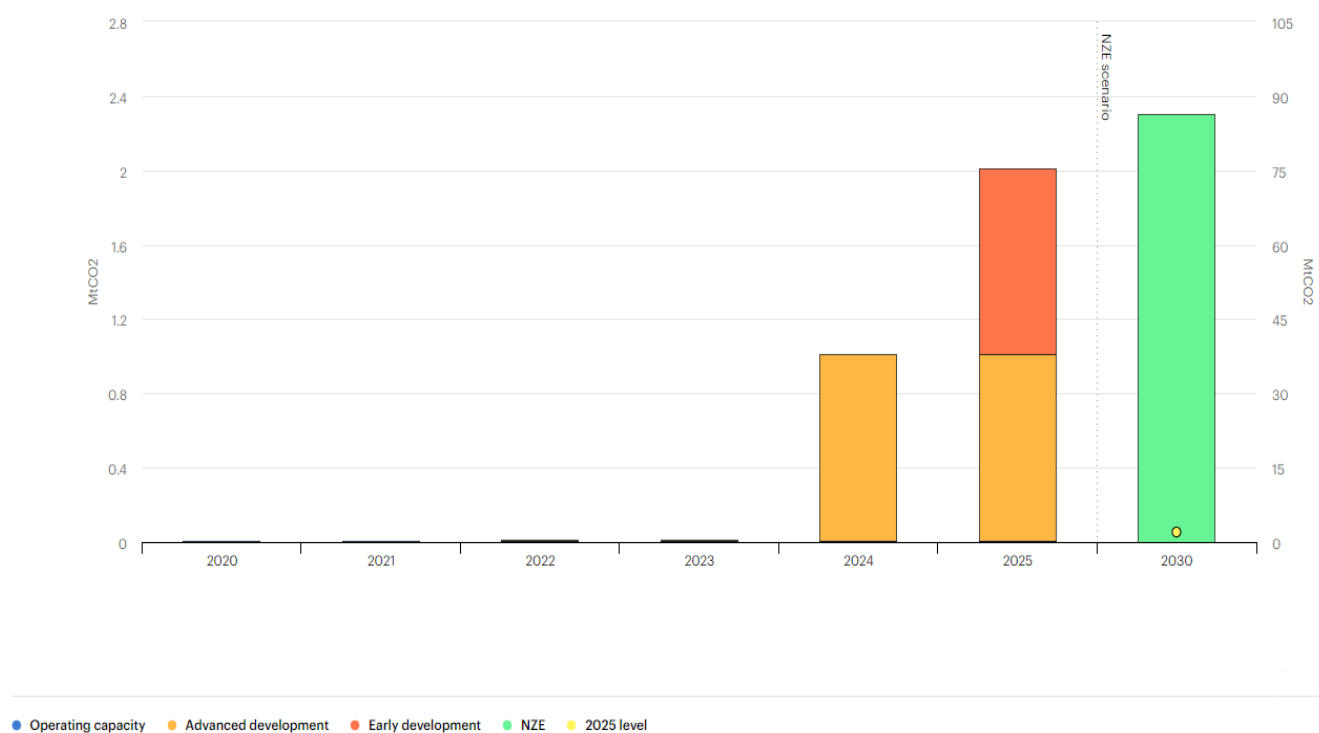


Figure 4.4 shows the CO2 capture by DAC in net Zero Scenario from 2020-2030

If we take what is happening with DAC currently. There are only 19 DAC plants in operation in the world today which capture 0.01 MTCO2 (Metric Tons of Carbon Dioxide) every year. There is currently a plant being developed in the United States that is in the advanced stage of development that will have the capability to capture 1 MTCO2 per year and with more and more advances by both companies and states looking to reduce their emissions, DAC technology does look like a positive development with the potential of being a strong weapon in reducing emissions and getting closer to our targets for Net Zero. Although it's not specific

to the food industry, as technology improves, and costs reduce it is a technology large food companies could implement at their own manufacturing plants and predictions of the increased roll out of DAC technology is evident from see figure 4.4 (IEA, 2021). There are many benefits in using artificial technology like DAC compared to natural CO₂ removing mechanisms like reforestation as it does require much land use or water. What is likely to be required is a blended approach employing a range of carbon removal methods.

As DAC has the potential to be revolutionary in reducing emissions there are drawbacks as with any new technology, costs are significant. Like when solar panels were first introduced and initially expensive as advancements in the technology are made it will likely reduce the costs and make it more appealing to be implemented. DAC like other measures for reducing emissions will likely be one of many measures that will help in achieving Net Zero.

4.6 Protein Alternatives

One drawback to eating less meat and consuming a more plant-based diet is the obvious reduction of protein in foods requiring those who switch to diets to eating a range of different types of foods to ensure they get the required protein levels from their diet. There are a range of options for someone to get the level of protein needed to meet their health requirements. This could be in the form of eating a range of different foods from beans, peas, nuts, seeds, and vegetables. What is likely required to make the transition for society to get on board are meat alternatives. Some of these alternatives have already started to appear to meet the demand of current nonmeat eaters. Products from the Beyond Meat company have started to surface in supermarkets and fast-food chains like McDonald's this was likely in response to Burger King introducing their own plant-based burger option trying to tap into the trend towards eating less meat (McDonalds, 2022). As the technology in this sector advances to meet demand it is likely that more meat alternatives will come to market. The Beyond Burger is for example a good source of Protein however it's not a food product that you wouldn't recommend it being eaten regularly as it has a very high level of salt content more so than a beef burger (Beyond Meat, 2022). If governments could however use a meat tax as a deterrent to reduce meat consumption and use the funds generated to help research and development into further possible meat substitutes that would give healthy alternative options that would in turn reduce the emissions. There are significant corporate investment strategies being employed for the alternative protein markets. Originally this was being strategized as a niche in the vegan market however this has now branched out and has been employed in

areas like precision fermentation which uses the rapid generation of microorganisms to produce ingredients for alternative proteins. There have been major advancements in areas like cellular agriculture in which cells are derived to create lab grown meats like beef and poultry compared to rearing livestock. The potential ramifications of such produce if it can be rolled out in mass production mean that it could positively offset the need for mass agriculture and potentially have massive positive consequences for GHG emissions particularly methane gas from cows. The market for protein alternatives have grown year on year in recent years and have become more diverse not just following plant-based protein options see figure 4.5 (Alex Money and Julian Cottee, 2021).

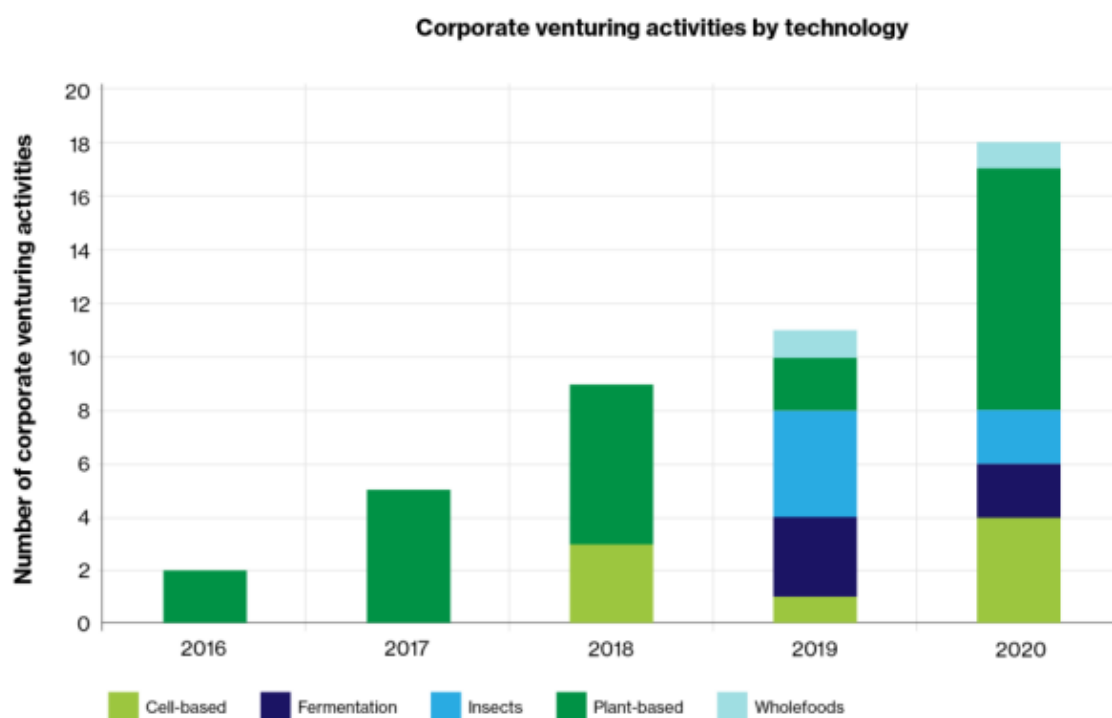


Figure 4.5 Corporate venture numbers and types for alternative proteins

4.7 Practical Alternatives

Looking at more practical alternatives in general one obvious observation is that plastic packaging is almost everywhere. The production of plastic itself is highly carbon intensive. In 2015 in the supply chain, the carbon emissions released into the atmosphere from plastic packing production alone which was in the vast majority for the food industry which were estimated to be approximately 1.7 GT of emissions. These emissions are seen all the way in the chain from harvesting plastic pellets out of raw materials from oil to refinery and then

many plastics are then disposed of in incinerators having negative carbon effects all through their lifespan (Maocai Shen, Wei Huang, Ming Chen, Biao Song, Guangming Zeng, Yaxin Zhang, 2020). If we can adjust our supply chain for more reusable forms of transporting when you consider something like beer that is stored in steel kegs it averages a CO₂eq of approximately 20 grams per litre and if you compare that to glass that has been recycled which averages 300-750 grams of CO₂eq but if we look at plastic bottles that end up in landfills there is a stark 450-2500 grams of CO₂eq which indicates there is mitigation potential for packaging but ultimately this can come down to the balance sheet if there is to be any success in implementing such positive change (Poore & Nemecek, 2018).

4.8 Mitigation

When looking at mitigating the impacts of Net Zero it may be perceived as an industry or Government Issue, however there are positive effects that can be procured from actions we take today from society, governments and individual choices and changes in diet. If we think about ways to mitigate the risks at large there are what obvious measures that can be taken. Rather than just looking at deforestation for example, there is an opportunity to invest in our eco system with reforestation and are known widely as natural climate solutions. If we focus on what an individual can do we can see massive consequences in changes something as simple as a diet. When we eat, this has a carbon effect regardless of what food it is. The different types of food we consume all have a very different carbon output particularly when comparing plant-based diets to animal-based diets the data below figure 4.6 highlights such benefits regarding carbon output differences in various diets. The benefits of this can be seen by simply looking at the different types of diets and how that is linked to the carbon output of such diets for example if we look at the typical tCO₂EQ of a Mediterranean diet that is high in plant-based food types and the majority of meat-based food sources are sea-foods we can see the average tCO₂EQ is approximately 0.6 for mitigating carbon output and if a diet is switched onto vegan the average tCO₂EQ is approximately 0.9.

The below graph figure 4.6 looks at 10 peer reviewed papers and the varying types of consumption options, it highlights negative values in red with individual dots plotted showing a different study and the average being identified as x for annual mitigation options (Diana Ivanova, John Barrett¹, Dominik Wiedenhofer, Biljana Macura, Max Callaghan and Felix Creutzig, 2020).

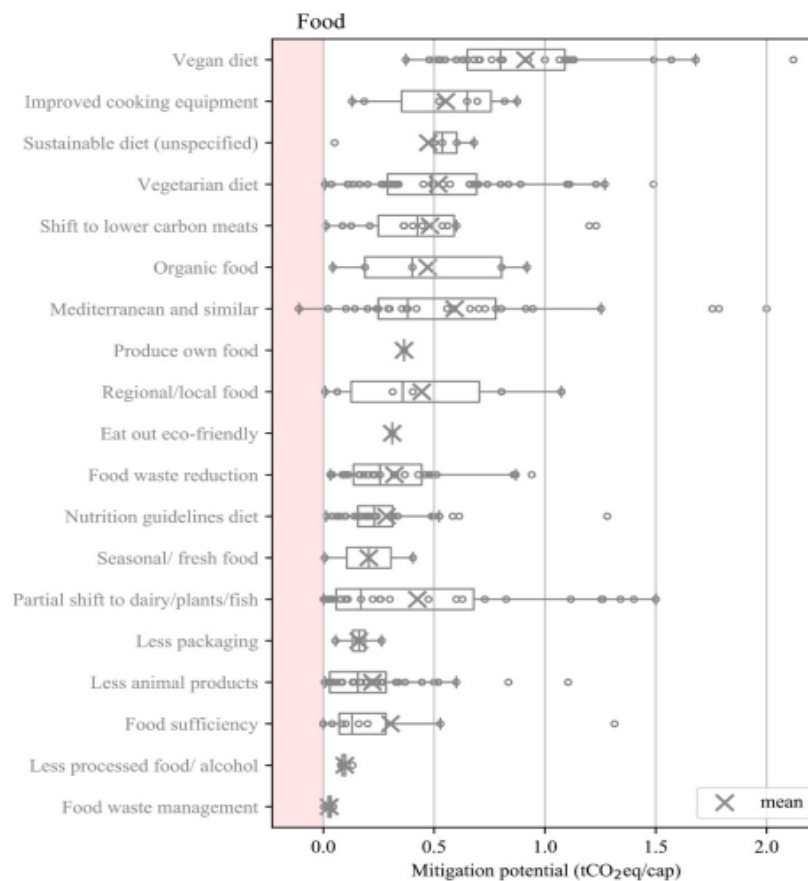


Figure 4.6 Mitigation factors of diet

There are mitigation measures that can be taken all across the food industry. If we examine some specific examples we can see practical changes that can be taken that will make significant differences. Firstly, if we look at the costs associated with refrigeration, 40% of all foods produce across the world requires some level of refrigeration. If we consider that all refrigeration requirements across the planet use 15% of the world's electricity consumption then it is evident that this is an area that could produce significant benefits in the Net Zero challenge. There are various measures that could be taken to improve this situation. Certain foods will require refrigeration so could there be further investment into R&D into making refrigeration less energy intensive. Also, could there be more practical measures involving a cultural change, only eating foods that are in season in order to avoid and reduce the need to use refrigeration for certain food types. Secondly if we take processed foods, many processed foods involve processes that are energy intensive. If you look at processes like refining for foods like oil or syrup, they require a lot of energy. There are many measures that can be taken to reduce the problem, one is reduction in the intake of such foods, another would be to develop improvements in the processing procedure that would not only save energy but

would reflect on a fiscal saving for food businesses (Niles, M. T., Ahuja, R., Barker, T., Esquivel, J., Gutterman, S., Heller, M. C. Vermeulen, S, 2018).

4.9 Governance and Policy

In the most recent report from the IPCC in April 2022 it left for grim reading. The report has stated its imperative that action is to be taken now otherwise the outlook is bleak. Although it wasn't specifically targeting the food industry it has highlighted that every sector including food must now change dramatically and rapidly. What is highlighted in the report suggests that governments need to do far more than what's been done. If Governments can clearly align finances to tackling the problem it is still achievable and can be successful. Certainty from financial institutions like central banks and the relationship they hold with private sector investment banks have the potential to encourage and develop technology and help reduce the financial burden of making the changes necessary. This will also allow investment opportunities and create wealth in the process. Unfortunately, at the current trajectory there are still plans to introduce infrastructure in fossil fuels development and this needs to be halted (IPCC, 2022). When we look at strategies, targets, and goals it's one thing to set where we want to be in terms of achieving them in the future however it's an entirely different matter than actually doing what is required to achieve said desired results. It's well acknowledged when planning for lowering emissions, it is a long game, but with many goals in politics and governance it's easy to make the promise. If we examine the situation specifically in Ireland and also what is happening across the world we can see firstly if we look globally there is a lack of global standard with many countries and jurisdictions implementing their own version of what they feel is appropriate of popular to sell to their voters. When it comes to targets there is a sense that these are often vague and not subject to being proven right as the results will be many years from now and this could be the root cause to why as a whole the hopes of getting the food industry globally are likely to fail (Joeri Rogelj, Oliver Geden, Annette Cowie & Andy Reisinger, 2021). In 2021 in the COP26 agreement in Glasgow, almost 200 countries agreed to cut emissions, importantly the US and China who are the largest emitters made a pledge to cooperate and switch to a greener energy source. This is although not specific to the food industry has been seen as a positive development. The concerning issue once again is the lack of specificity and accountability and the ramifications for the failure to not achieve targets are non-existent. China and India are likely future world superpowers and are going to find it more challenging than the US and

Europe as they are further developed and have a much smaller population comparatively (United Nations 2021). If you look at India in Isolation the future most populous country in the world, they have been vague with the concept of Net Zero saying their target of reaching Net Zero is 2070. This is a precarious situation with such a chunk of the world's population doing little to nothing in addressing their emissions and a half century target means very little to those who make it (Bloomberg, 2022). When it comes to signing up to obligations and setting targets for which the cost is uncertain, Governments hate to make these choices. What is surprising is although a country like China who is the biggest emitter of CO₂ on the planet, there has been a surprising development in countries like Brazil and China who have made significant investments in renewable energy and looked to restructure how they consume energy as they see this as an important tool for improving their economic standings in the world who have identified the link in negative emissions and income as drivers for renewable energy in other G7 countries (Ruhul A. Salim, Shuddhasattwa Rafiq, 2012).

It is admirable that countries are looking to lower emissions and making the move to Net Zero however if we are being realistic and really want to get to the nub of the problem certain realities need to be realised. Countries need to agree on exactly what Net Zero means from a practical point, moving away from heaviest emitters and rethinking licencing for gas and oil producers in our waters. Questions that need to be asked to stake holders to why Net Zero targets are pushed almost decades ahead when they will no longer be accountable for decisions made today. Global warming estimates state that if we don't cut emissions by 50% by 2030 that the planet will have risen in temperature by over 1.5 Degrees. Are Governments risking everything in the hope that technology will save us and prioritising economic expansion over taking the difficult decisions now that may save the planet in the future by simply kicking the can down the road and is a risky bet as the worst outcome could be detrimental to human life (Steffen, W., & Bainbridge, 2021).

Looking at companies, Ireland's role on the international exports, Ireland has an image as a more grass fed producer when it comes to beef. When looking at what Ireland is exporting to other countries with the produce being economically valuable to Irelands economy is it practical to raise cattle in Ireland then have it shipped all over Europe by boat and lorry to be consumed in other countries. Table 4.6 shows the amount of cattle exported across Great Britain and Europe

	2021	2022	Change - head	% Ch
Total United Kingdom	14300	8831	-5469	-38.2
Great Britain	221	434	213	96.4
Northern Ireland	14079	8397	-5682	-40.4
Total Continental EU	28501	35118	6617	23.2

Table 4.6 Irish Live Cattle Exports – head

4.10 Ireland and Bio Energy

Looking closer to the situation in Ireland and what is the plan in getting to Net Zero and more specifically the food industry we can see with the Climate Action Plan 2021. The Irish Government have set what can be seen as an extremely audacious targets to reduce emissions by 51% and more specifically agriculture by up to 30% by the year 2030. Very little detail has been provided in the way of how this will be achieved but the government has stated that they plan to incentivise farmers to make changes adding additional income streams for farmers to support renewable energy mechanisms and requiring farmers to use less chemical nitrogen and looking at herd genetics for improved productivity meaning lower numbers required. The Government also hope to encourage diversification among Irish Farmers through afforestation and bioenergy however this remains cloudy on detail and there is likely sceptics in an industry that already feels squeezed through inflation (Climate Action Plan, 2021).

If the government are serious about encouraging farmers at operating their business in a more carbon friendly manner then it needs to be more specific in the measures it plans to introduce. The measures regarding support for farmers financially and educating them on the benefits which may cause scepticism. Looking at data from a report on Anaerobic Digestion for

Energy Production in Irish farms which simply used manure to create biogas energy (gas from grass) amongst other new technologies that could reduce not just emissions but costs. The report undertook a survey for Irish farmers being willing to uptake and implement the technology for a variety of reasons and when looking at the results we can see various responses from Likely, Possible and Non-Adopters.

Table 4.7 survey responses below were in connection with looking the farmer's likely motivations to implement new technologies for Anaerobic Digestion for energy production. We can see using a Likert scale which is a survey to ascertain opinions and attitudes for data gathering, with 1 being very important and 4 being unimportant the summary of the various responses using the mean and standard deviation.

The results indicate that 41% of those asked would be open to AD technology in the next 5 years and most of the respondents who were likely to take up the technology held a higher level of education than other respondents. Looking at AD technology in the wider sense it would appear that it offers the opportunity to reduce the negative emissions that take place in Ireland's agricultural landscape to produce onsite energy and in turn require less use of oil based fossil fuels (Sean O'Connor, Ehiase Ehimen, Suresh C. Pillai, Niamh Power, Gary A. Lyons and Josh Bartlett, 2020).

Category	Responses	Likely	Possible	Non-Adopters	a p-Value
To improve farm profitability	1.49 ± 0.69	1.34 ± 0.55	1.48 ± 0.68	1.76 ± 0.90	0.0628
To reduce greenhouse gas emissions	1.92 ± 0.91	1.82 ± 0.85	1.93 ± 0.81	2.17 ± 1.27	0.3028
To add another revenue stream	1.57 ± 0.64	1.48 ± 0.57	1.57 ± 0.63	1.82 ± 0.87	0.1626
To reduce farm pollution	1.80 ± 0.62	1.69 ± 0.59	1.82 ± 0.39	2.09 ± 1.04	0.0959
To reduce farm business costs	1.67 ± 0.73	1.61 ± 0.61	1.63 ± 0.61	2.00 ± 1.25	0.1248

Table 4.7 a p-value results for t-test comparisons between non-adopters and other adopter types

Agricultural farms from the small to medium size range using Anaerobic Digestion for energy use can have a huge influence on the overall emissions considering the makeup of the agri industry is made up of many smaller farms. There are obvious obstacles to implementing such measures with start-up costs being significant and will require significant upfront investment that will have to be encouraged through subsidies and mechanisms to get credit to farmers. The positive outlook is that there appears to be a large section of farmers who are open to change, and this could potentially increase if proven successful creating a precedent for a more efficient and profitable business model that others could and would want to replicate with a double impact of reducing emissions and producing energy.

In the UK they have identified that agricultural emissions are likely to increase and already account for 11% of the overall GHG emissions. To try and mitigate the effects of this the UK government have outlined a three-prong approach system that they hope will help reduce the effects of increased emissions.

- Switching to plant-based sources where possible from animal-based sources
- Introducing evidential approach to encourage improved options
- To tackle food waste by seeing what has worked up until now create incentives where possible through fiscal policy measures (Alice Garvey Jonathan B. Norman, Anne Owen, John Barrett, 2020).

Effective measures like these have demand-side change in mitigating the emissions around food consumption. Although a lot of stock has been placed on technology, there remains significant upside potential for dietary change that could yield significant results and it would be prudent for policy makers to encourage its population to get on board with making changes towards a more plant-based diet. There is potential to employ organisations in the health and environmental sectors to help get the message into the domain. Looking outside just legislation from the state and looking into state bodies such as Bord Bia who launched Origin Green back in 2012. Ultimately Origin Green is a programme aimed at increasing sustainability in the Irish food and beverage industry and is seen as one of the Governments tools in getting to Net Zero by 2050. Origin Greens membership has increased dramatically in the past few years with over 90% of the industry approximately 300 food and beverage companies in Ireland who have signed up to the programme. There are significant advantages from a reputational stance when selling produce abroad with the Bord Bia sign of approval feeding into a €13 Billion export industry (Bord Bia, 2021). This is a strong indicator that companies are open to change as they see it as a long term benefit but this change needs to be

feasible and will require governmental fiscal backing however Origin Green promotes advice and measures that can be affordable and not only help companies lower their carbon footprint but also save companies money with expertise on installing heat exchangers, wind turbine technology and sky lights all with the aim of lowering energy costs and ultimately leading to a more sustainable enterprise.

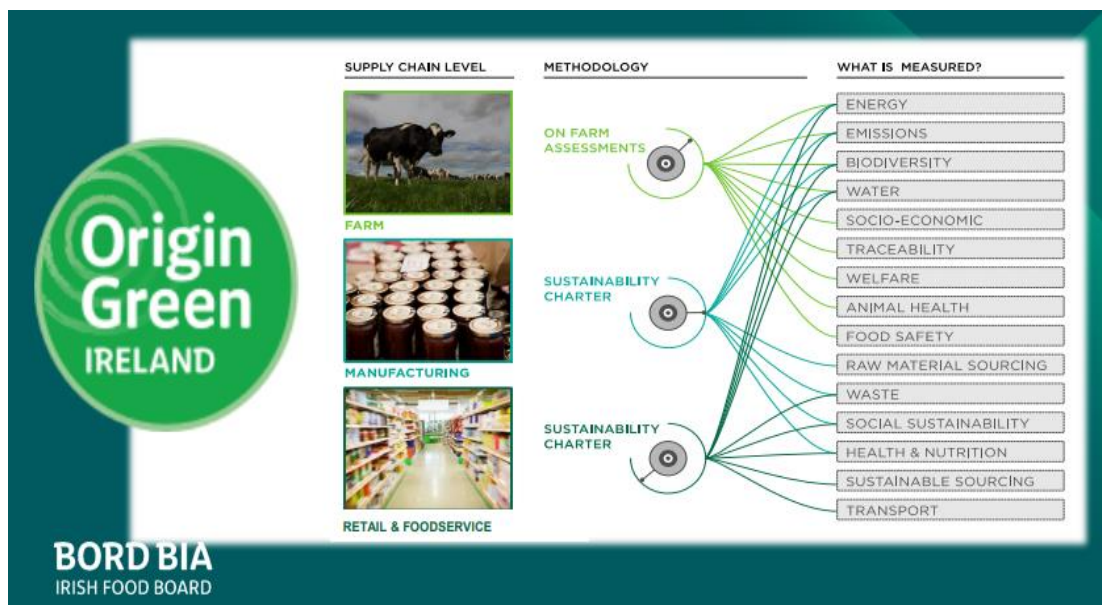


Figure 4.7 Bord Bia methodology

This shift in companies becoming more sustainable in Ireland is something that is welcome and not unique to Ireland. All over the world governments and jurisdictions are introducing legislation on carbon emissions in places like the state of California and countries like New Zealand and very recently in the EU sustainability targets are being rolled out to member states along with very specific legislative directives set down by the EU for the purpose of reducing plastic packaging in food banning specific typed of plastic packaging altogether and single use plastics used for drinks products like plastic straws (Directive EU 2019/904 2019) that not alone have a high carbon intensity but also have the added problem of ocean pollution which in itself has its own negative environmental issues.

It can be seen as a very positive shift that legislation is being implemented to promote improving the culture of the industry at large, however it may be crusade doomed to failure unless the proper supports are introduced in conjunction with required standards. If these measures are to be properly enforced it will also require the agri sector along with other food industry sectors in the food and beverage industry to commit to the development and implementation of methodologies. If these measures are to be long lasting and sustainable it

will likely require the support of the scientific community with incentive schemes to aid industry in making strides towards necessary progression. This must be done in a way that is feasible for companies to still be profitable whilst following science-based targets in lowering emissions (Nayla Bezares, Gabriela Fretes and Elena M Martinez, 2021).

4.11 Waste

There are many opponents to change in the industry claiming that with a growing population there is a need to increase food production in order to alleviate food security for the most vulnerable. There is however a very stark counter argument to this. The fact is if food waste was drastically reduced there would be no need to increase production as what is currently being produced is sufficient to deal with the growing population however this requires a change in culture (Bérénice Dupeux, 2021). It may not appear obvious how the effects of waste actually feed into the effects of GHG emissions. If we waste less and consume more of what we produce then we need to produce less. This has a positive effect everywhere in the supply chain from the origin all the way to the consumer. It is a shocking statistic that 10% of all GHG in the world come from food that ultimately ends up in the thrash. To put that into context of actual figures there is an estimation that approximately 1.2 billion tonnes annually which is enough to take up to over 800 million people out of food insecurity in the world. Ultimately there is a strong cultural element in this from western nations due to the abundant levels of food in society but nonetheless this is going to require a shift in how we think of food as something that is disposable to something that is the essence of our lives. (WWF, 2021). In 2021, the Earthshot prize competition was launched to run annually with a £1 million prize. Although the competition itself is for environmentalism one of the first prize winners was for reducing waste in food with the City of Milan Food Hubs who simply redistribute food. The model in essence was simplistic but requires a volunteer force looking at food that would be discarded by supermarkets and companies. It has been a major success having reduced food waste in Milan by 130 Tonnes annually whilst feeding those in need. It has been seen as a blueprint that can be scaled across the world in reducing food waste (Earthshot, 2021).

When looking at the agricultural industry specifically in Ireland and examining FLW, Food Loss and Waste. The difference can be seen as subjective with food loss generally seen in the processing and production stages and food waste generally seen at the end of the chain generally discarded for whatever reason. Looking at research for waste of where

approximately 9,817,861 tonnes of food was created for consumption with a FLW of 189,508 tonnes representing almost 2% of all food. We can see the details of where food loss and waste occur from the different sectors of the agri Industry. We can see from the figures below in table 4.8 that aquaculture whilst representing a small percentage of total edible food production it has an extremely high FLW percentage (Tracey O'Connor, Rosanna Kleemann, Jennifer Attard, 2022).

Production Sector	Total edible production (t/a)	Loss (t/a)	Waste (t/a)	Total FLW (t/a)	FLW as proportion of total edible production (%)
Total	9,817,861	119,093	70,415	189,508	1.9
Animal Husbandry	8,951,732	45,011	900	45,911	0.5
Horticulture	602,286	58,953	67,270	126,199	21.0
Tillage	181,057	11,372	1130	12,502	6.9
Aquaculture	13,468	3757	941	4698	35.0
Fisheries	69,318	0	174	174	0.3

Table 4.8 Food loss and waste in different sectors

We have seen measures introduced in the Farm Zero C example of ways in which an agricultural business can be more efficient in many areas of its processes and measures. In the chart below it gives context to the amount that food waste contributes to the planet in comparison to actual GHG emissions compared to overall emissions from the highest GHG emitting countries on the planet.

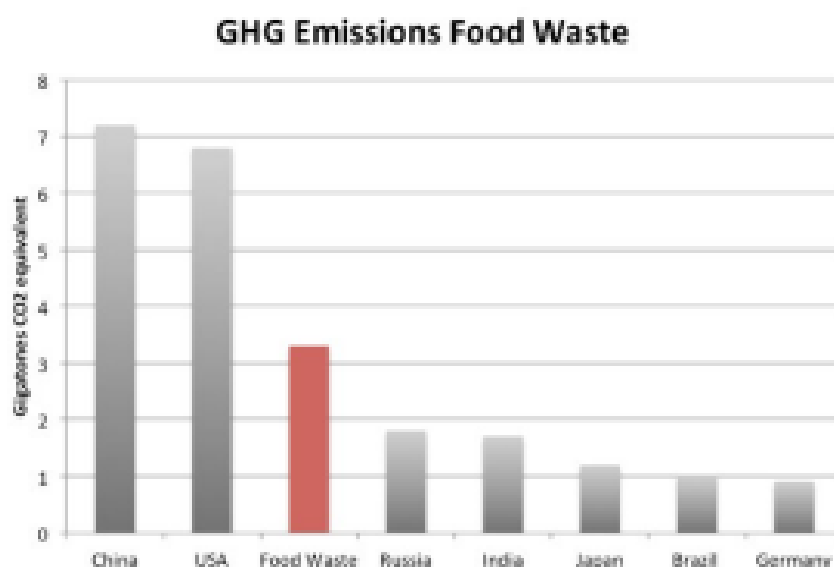


Figure 4.8 Total GHG emissions of top 8 of countries (year 2005) vs. Food wastage

When we try to analyse the practical steps, we can use to reduce food waste as we can see with the above with Milan food hubs, it may not be a case of requiring new tech in order to revolutionise how we tackle the problem. There are what could be described as quick win options to utilise the food we produce to its maximum. The food we buy should not have to have the appearance of perfection; a bendy carrot is as nutritious as a straight one. There are of course technological measures that can aid us in the battle to avoid wastage. If we take more developing countries like India and in Southeast Asia, investment at both governmental and local level smaller scale natural refrigerants like the use of Ice for evaporative cooling in the transportation of food produce, this can reduce spoilage and extend the life cycle of food (National Geographic, 2015).

There is a reality that the price of food is a likely influence on the type of food purchased. When we consider that many countries are currently in the process of introducing carbon taxes mainly in connection with energy usage in order to promote green energy consumption. If society were to apply the same criteria to meat-based food types in order to reduce the amount of meat consumed and promote a more prevalent plant-based diet then this may present an opportunity to indirectly reduce emissions. This action may incur a cultural backlash by consumers and producers so is discussion that needs to be addressed prior to introduction. If both health and environmental issues are tied together in order to gain a level of acceptance of such a measure. We can see evidence of high-income nations having a higher level of metabolic syndrome attributed symptoms like heart disease, stroke and diabetes this can be seen as a justification for such a tax similar to the sugar tax introduced in Ireland that would benefit both health and emissions and may lead to a reduction in food waste (Funke, F, Mattauch, L., van den Bijgaart, I., Godfray, C., Hepburn, C., Klenert, D., Springmann, M. & Treich, N, 2022).

What appears obvious from the reams of studies and information available is that no one thing can solve the GHG emissions problem in getting to Net Zero. When we consider the mitigation options available we can look at it from a three-prong approach. There are gains to be made through a measure of means.

1. Food consumption – there is a plethora of evidence on the benefits on reducing emissions by changing diets. This does not mean society needs to go vegan or even vegetarian but rather if there was a significant reduction in meat and animal-based foods this would yield massive reductions in emissions. This will require a change in how people eat today. There will be opposition to this based on cultural norms but

nevertheless there is massive potential for improving the situation by altering the types of foods we eat.

2. Food production – there is a need to intensify the sustainability models for production in the food industry. This will require buy in from all in chain. Farming to industrial activities. There are ways production can be assisted by science if we consider the potential for crops like GMO food types which have the potential to be resistant to climate variances. Physically upgrading farms and industry on a global scale to more efficient means involving renewable energy has the potential to reduce emissions.
3. Technology- R&D will require considerable investment if it is to yield the necessary scientific breakthroughs regarding genetic modifications in crops allowing for highly nutritious food to be produced in regions not normally capable of providing such crops. Selective animal breeding that could prove to lower methane gas emissions but still allowing for the necessary production of animal-based foods (Climate Change: Science and Solutions, 2021).

There is an abundance of guidance and companies are getting a better understanding to what it means to become more sustainable an in line with Net Zero guidance. A worrying very recent development is on the 22nd of April 2022 EY released information on a survey of Irish businesses. The survey reveals a rather bleak outlook for the Irish business sector. It indicated that 4 out of 5 Irish businesses have low confidence in meeting carbon neutral targets in 2030. At a time when businesses need to be overachieving on carbon targets it appears that like with many long-term targets, they will be missed. On the positive side, awareness on sustainability increased from 61-64% but the number one motivational factor in being sustainable was so companies would be compliant, this was then followed by environmental factors. This highlights two very important issues. Firstly, that companies have still not fully bought in to the idea of being sustainable for the overall environmental factors and secondly the importance of governance and regulation which has been found to be the real driving force behind companies implementing changes based on regulations. There is an obvious disconnect with seeing value in sustainability with only 40% agreeing that being sustainable has a positive impact on the balance sheet (EY, 2022).

Chapter 5

Conclusion and Further Study

5.1 Conclusion

In conclusion, when reviewing the role of Net Zero in reducing food greenhouse gas emissions it's clear from the research and the available data that to prevent the worst effects of climate change the food industry has a massive part to play. If the planet will meet the 1.5 °C target by the mid-century then Net Zero has to be successful. Governments and the general population should have really got serious about addressing carbon emissions years ago, but the past can't be changed. We are where we are, and emissions have gone up not down. This is the reason why a blended approach is now urgent, and the requirement of NET's are so vital in securing success. The technology is not anywhere near the level it needs to be but the positive thing is there are potential methods that can be a cause for hope. One thing that is evident is what is required to have any chance of success is change and significant change. It is a complex problem that will require a range of measures in order to be successful in addressing. If globally we continue to function in the belief that we can maintain our current path, and this will be without consequence then the bleakest outlook will become reality. As the data included reveals as people we don't grasp the full significance to the decisions made, and the underestimation to the impacts from the choices that are made. If a cultural change could sweep society to make the choice of more locally produced and more plant-based rich diets, these would have considerable influences on industry and the changes would follow. This will also mean changes in how life is lived not just the food that is eaten but the levels of waste that is created.

Governments and policy makers around the world need to not only virtue signal but put in effective legislative processes that will require both society and industry to do what is required to achieve a Net Zero society for food. Setting goals for decades ahead is required but it is easy to make promises with no accountability in the long term. Action is required immediately over sound bites. There appears to be a bet that technology will come to the rescue and those who make the decisions are unable or unwilling to make the tough decisions. If you really wanted to apply criticism you could say the generally countries that make commitments and goals around Net Zero have continually not reached them and largely broken the promises that have been made, the same can be said about Ireland specifically since ramping up milk production since the EU quota was abandoned in 2015.

Technology will be a key tool in mitigating the effects of what is likely to come. As the data shows there are a range of promising developments from purely removing CO₂ from the

atmosphere, this could be one of the key weapons in the reduction of CO₂ in the long term and there appears to be a hope that necessity is the mother of invention.

The agricultural industry needs to upgrade its practices and limit its emissions. This needs to happen in many ways, reducing deforestation and increase practices like reforestation. Adopt emissions technology anywhere possible. This will likely require substantial fiscal supports which could help in ways like switching to machinery that is powered by electricity rather than traditional fossil fuels and generating electricity on site that won't create emissions through solar and wind power. It is very unlikely that the agricultural industry will achieve Net Zero in its specific sector. There is simply such a large scale of emissions that it appears improbable at best. The most likely way of achieving Net Zero in the food industry as a whole will be through a combination of limiting emissions and employing negative emissions technology that itself will offset emissions generated from areas that are unable to get to Net Zero in their own right.

Net Zero is appealing to those who pursue it, obviously it's something most people agree is necessary. It is however extremely complex and challenging. Countries really need to start setting more short term measured targets in order to keep them accountable for the longer-term goal sometimes decades out. There is going to be a need for richer more developed nations to assist the developing world in achieving their targets, however with richer countries struggling themselves it appears this looks unlikely. Countries like India may need to be pressured into making climate change something their government takes seriously as a lot is at stake and responsibility rests on their shoulders due to sheer population.

The cost of getting to Net Zero is undoubtedly going to be high but the cost of not getting to Net Zero will be paid in more than just money and for generations to come.

5.2 Future Research

As discussed in the paper, there is currently being significant advances in technology for methods regarding Direct Air Capture. This technology although currently expensive, offers the possibility to have the potential to neutralise emissions in not only the food industry but in other industries like energy, transport, and the effects of fossil fuels.

There remain significant unknowns regarding this technology as it is relatively new which does suggest the potential for advances could create a new era in how we perceive the danger for rising GHG emissions. The current lack of data on DAC around the world will cause many to be sceptical on its use in the wider sense. It would therefore be relevant to develop a

wide data base of all major DAC units around the world with a detailed evaluation on cost, effectiveness, wider use and roll out potential for tracking GHG positive emissions.

Secondly relating to the original topic of the role of Net Zero in reducing greenhouse gas emissions, it's important to note that there are significant limitations to the the analysis of the topic as there are very little evidence in any of the studies that reach Net Zero emissions.

Hence, it makes sense to investigate future potential of Net Zero emissions e.g., DAC and other carbon reducing technology like Biogas to quantify if an approach towards net-zero emissions by the mid-century is actually possible.

Chapter 6

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