The relationship between climate change and agriculture is a contentious, complex and important one. In this series of twelve blogs, UCD Adjunct Professor Frank Convery will explore the context, challenges and potential solutions for dairy, beef and sheep farming in Ireland. Each blog presents key evidence to underpin informed debate and the series seeks to help plot a sustainable future for the sector.

Responses are invited via earth.institute@ucd.ie and the UCD Earth Institute will host a workshop in association with the UCD School of Agriculture and Food Science and the National Economic and Social Council at the end of the series to discuss the evidence and its implications.

Professor Tasman Crowe, Director, UCD Earth Institute

11. Climate Performance by Irish Ruminant Farming: Innovation

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"Ireland will become a **world leader** in Sustainable Food Systems (SFS) over the next decade. This will deliver significant benefits…and will also provide the basis for the future competitive advantage of the sector".

Food Vision 2030[1]

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Some Key Points

Climate innovation is about finding new and better ways to reduce greenhouse gas emissions and store carbon at scale and at low cost. There have been giant strides in doing so in energy industry and transport, but the process is only beginning for ruminant farming. As rich countries that export most of what they produce, Ireland and New Zealand have a particular responsibility to find the ways that work to do so for pasture-based farming. Incremental gains in carbon efficiency are useful, but on their own will not be anything like enough to meet the challenge.

Small countries can make a big difference: Denmark (population 5.8 million) showed the world how, with innovation, wind can produce electricity that, under certain circumstances, is commercially competitive with fossil-based sources; a small offshore island (Ireland) incubated the largest airline in Europe (Ryanair) and the creation of a dairy based drink (Baileys Irish Cream) that is one of the world's favourites; the Netherlands fostered the development of the only additive (Bovaer) licensed to reduce enteric methane.

Small countries can lead the world when the innovation ecosystem is in place to do so - crisis; courage and entrepreneurial talent; smart and persistent policies; sense of mission; research and development; outsiders; global reach and large potential commercial rewards; luck. However, there is no funding source at EU level for farming comparable to the Innovation Fund that supports finding new ways to reduce carbon emissions at scale.

We begin to see promising developments in New Zealand (e.g., Ruminant BioTech CALM, Atkins Farms) and in Ireland at research (especially genetics), demonstration (Devenish, Farm Zero C, start ups such as MILJO etc.) and company levels, and learning by doing by farmers (Signpost etc.). But will these be sufficient to deliver the needed breakthroughs for pasture-based farming as regards: reducing enteric methane emissions at scale, integrating tree farming and cattle farming, and biodiversity and emissions reduction? I don't think so: when change is necessary, it is necessary to change. The key characteristics that maximize the prospects of successful innovation are: crisis, good policies that are sustained, mission focus, learning by doing, relevant research and development, direct 'outsider' involvement, global reach, luck. We should see to emulate them.

Introduction

The drive to create alternatives to carbon-emitting fossil fuels by the energy sector began over 50 years ago. It was triggered by a sense of crisis and achieved by innovation: The escalation in oil prices and associated strategic concerns following the Arab Israeli War in 1973 was an important early stimulus to both policy and technical innovation directed at reducing import-dependence on fossil fuels, and the associated encouragement of renewables. In the US, California was a first mover to support renewables, providing tax breaks and other incentives which provided a very important market for wind turbines from Denmark (see more below). Later, Texas became a leader.[2] Renewable portfolio standards (RPS), also referred to as renewable electricity standards (RES), are policies designed to increase the use of renewable energy sources for electricity generation. In the US, 38 States have developed and implemented polices that drive renewables integration into electricity generation, with Renewable portfolio standards (RPS), as a key driver. These require or encourage electricity suppliers to provide their customers with a stated minimum share of electricity from eligible renewable resources. In Europe, a number of member states acted to encourage renewables, and the feed-in tariff – a guaranteed price for electricity produced by renewables - emerged as the preferred support instrument. In 2012, EU subsidies for solar, wind and biomass amounted to €34 billion,[3] distributed as follows: wind (€11 billion), solar (€15 billion) and biomass (€8 billion). The large subsidies to consumers in the US, EU and elsewhere, combined with other policies to drive down costs over time, were as follows:

Table 1. Costs of Solar and On-Shore Wind, per kWh, 2010 and 2021

Source	2010	2021
Solar	0.38	0.07
On-Shore Wind	0.086	0.053

Source: World Economic Forum, 2021. *Fostering Effective Energy Transition*, Figure 2, p. 9

Note that, notwithstanding large subsides, the dramatic cost reductions experienced by solar and wind energy do not seem to have happened for biomass. At EU level, there is a guaranteed, dedicated source of funding, financed by ring fencing a share of the auction revenues from EU ETS – the Innovation Fund - which will provide around €10 billion of support over 2020-2030 for the commercial demonstration of innovative low-carbon

technologies, aiming to bring to the market industrial solutions to decarbonise Europe and support its transition to climate neutrality. It focusses its expenditure in four areas: **highly innovative technologies; big flagship projects; innovative low-carbon solutions;** and **small-scale projects** that can bring on significant emission reductions.[4]

The two main points are that: a crisis is an invaluable stimulus to create new and better ways to address an existential challenge, and secondly, innovation is a policy instrument – you don't have to wait for something to show up – you can design and deliver policy that increases the prospects of doing so. Until recently, neither a sense of crisis and urgency, or the associated effort to find new and better ways to reduce emissions from ruminant farming at scale, has been in evidence. This is now beginning to change.

In the 'evidence' section, I use a few case studies to illustrate what it takes to maximize the prospects of a successful innovation strategy generally, and then turn to what is emerging internationally and locally to fill the innovation gap for climate policy addressed to ruminant farming. In the 'assessment section' I summarize what the evidence says to me and explore its implications for Irish policy and practise.

Evidence

As discussed in the venture capital section of Blog 8 (Companies) successful innovation is incredibly hard, as exemplified by the early efforts (2006-2011) of venture capitalists in the US to achieve transformation of the energy system. It can also be very expensive; the early wave of investors lost ~€12.5 billion. There are 3 broad lessons: it takes enormous courage to go where no one else has been before; persistence is essential – many of those who failed in the 2006-2011 period have since succeeded; learning by doing is the best way to learn.

Innovation as a Policy Instrument[5]

Below, I touch on a few cases where innovation has played a pivotal role is shaping outcomes, show how it happened, and conclude with a summary of the conditions that usually need to be met to do so.

Innovation as a Policy Instrument 1 - the Development of Wind Energy in Denmark (Population 5.9 million) – small countries can make a big difference.

At the time of the OPEC Oil Embargo (1973), Denmark was 80-90% dependent on imported oil for its energy needs. The government decided that this was a national emergency. It radically revised its energy policies to directly reward energy innovation: supported renewable-focussed R&D (Risø National Laboratory); subsidized the harvest of renewables, regulated companies, instructing electricity utilities to develop and deploy 100-MW wind power by the year 1990. In 1987, close to Vordingborg in Denmark, the largest wind farm in Europe at the time was connected to the grid (five turbines at 750 kW each). Technologies for wind power generation at sea were evolving rapidly, and in 1987, the Government Committee for Offshore Wind was established; the first offshore wind farm in the world, Vindeby Offshore Wind Farm (11 turbines at 0.45 MW each), was connected to the grid in 1991.[6]

On the entrepreneurial front, Peder Hansen and his son Finn in the 1960s were manufacturers of hydraulic cranes, who turned their attention to wind turbines. In 1978, their company (Vestas) produced its first wind turbine. At this time Vestas was the only company producing wind machines that were sufficiently durable and reliable to stay standing in California's conditions. Jim Dehlen (Zond) purchased 150 of them.

Later, market support in Europe was crucial. With the passage of the Feed-In Law in 1991 (which was followed by the much more ambitious Renewable Energy Law, 2000), Germany emerged as the key global market for renewables. In February 2023, Vestas was valued at €31 billion.[7]

Innovation as a Policy Instrument 2 – Covid Vaccine in the UK

The innovation policies Denmark applied to wind energy were very similar to what we have observed in the UK as regards vaccines for Covid. There was an emergency. The critical constraint to progress at scale was identified– absence of a vaccine. It was recognized that new choices were needed at scale (innovation) to address this constraint. The policies and procedures were put in place that would maximize the prospects of relaxing this constraint as quickly as possible; a key was payment up front for potential suppliers, and guaranteed payments later for vaccines that worked.[8] This progress was greatly enabled by the fact that the federal government in the US had initiated its 'warp speed' programme to encourage R&D and supply of vaccines.

Innovation as a Policy Instrument 3 – the Development of Bailey's Irish Cream

In 1973, Tom Jago, head of a British company (IDV) with an operation in Ireland, became aware of an initiative by the Irish Department of Finance, whereby export earnings from a new Irish alcohol drinks brand would be tax-exempt for 10 years. David Gluckman (South African) and Hugh Reade Seymour-Davies (British) were asked by Jago to help create a new Irish alcohol drinks brand for export; Gluckman had been on the team which established the Kerrygold brand in the 1960s. He asked: "Is there something in Ireland's reputation for dairy produce that we can apply to an alcoholic drink – all those lush green, rain-sodden pastures and contented cows?" Seymour Davies replied: "What would happen if we mixed Irish whiskey and cream? - that might be interesting." Research followed, and the product was launched in 1975. On December 3rd, 2007, Diageo announced the sale of the billionth bottle of Baileys.[9]

Innovation as a Policy Instrument 4 – Enteric Methane Inhibitor in the Netherlands (Population 17.2 million) – Bovaer

Royal DSM is a global, purpose-led company in Health, Nutrition & Bioscience founded in the Netherlands in 1902. In 2007 it started a companywide initiative called 'Climate Change Induced Innovation' within which reducing methane emissions from ruminants was an early ambition. In 2008, Mark Kindermann joined DSM as head of the R&D programme for 'Clean Cow.' In an interview he noted that: When I joined DSM in 2008, I had no animal nutrition background and hence was something of a "clean slate" without preformed opinions on this matter. When I began working with a small team on this challenge, I was trying to understand the molecular details behind ruminant methane formation, thereby approaching it from a very different perspective than others before me." The research resulted in the development of 3-NOP (Bovaer®) during 2010.[10]

Over the past 10+ years, 50 on-farm beef and dairy trials across 14 countries and in various feeding systems have been conducted: "These trials showed that Bovaer® can consistently achieve an enteric methane reduction of on average 30% from dairy cows, and on average 45% from beef cattle. Just a quarter teaspoon of Bovaer® per cow per day suppresses the enzyme that triggers methane production in a cow's rumen. The additive takes effect immediately and is safely broken down in the cow's normal digestive system into compounds already naturally present in the cow's stomach. As soon as it is no longer fed, full methane production resumes and there are no lasting effects in the cow".[11] It has been approved for use by the European Food Safety Agency 'as safe for dairy cows at the maximum recommended level.'[12]

JBS Foods is the largest beef producer globally. It is partnering with DSM to implement a programme to reduce the enteric methane emissions from cattle on a global scale, using Bovaer to improve the greenhouse gas footprint in the beef production value chain.[13]

As regards Irish trials, the Irish Farmers' Journal reports that: "Teagasc has completed a study on beef and cattle indoors, but the results are yet to be published. It plans to assess the use of slow release of Bovaer® pellets in dairy cows grazing grass and clover swards at Moorepark in the autumn".[14]

Innovation as a Policy Instrument 5 – Ryanair the largest airline in Europe

An enduring memory of my early experience in the 1980s working with the EU was the trips with Aer Lingus from Dublin to Brussels and back: the air fares were incredibly expensive, almost everyone on the flights – mainly civil servants and MEPS, with a sprinkling of business folk and academics – were having their fares paid by someone else, and there was no airline choice – either you travelled with Aer Lingus or you didn't travel at all. This was a product of policy: After the second world war, a decision was made to restrict competition and effectively limit air traveller access to state airlines, who acted as a cartel, deciding on flight frequency and capacity (supply) and managing both so that fares were kept high. The same model – but with commercial rather than state airlines – was applied to interstate travel in the US. This was changed in the US with the leadership of President Jimmy Carter; in 1977, he appointed Fred Kahn as chair of the Civil Aeronautics Authority (CAB) with the singular mission of deregulating air travel across state lines; working with congress, President Carter signed the Airline Deregulation Act in 1978.

A key beneficiary of this policy was Southwest Airlines, which was started in 1971 in Texas by Irish American Herb Kelleher, who noted: "I knew nothing about airlines, which I think made me eminently qualified to start one because what we tried to do at Southwest was get away from the traditional way that airlines had done business," he told NPR's Guy Raz in 2016. "I think that was very helpful."[15] A key to his success was his forensic control of costs – only snacks were served, planes and staff were scheduled for more flights each day, flying to smaller airports where it could negotiate cheaper landing charges, and reducing maintenance costs by flying only one plane type (Boeing 737). The deregulation allowed him to expand across state lines and achieve huge economies of scale and scope, which allowed him to further reduce costs and fares.

Ryanair was founded in Ireland in 1985 but struggled to make profits. Micheal O'Leary joined the company in the early 1990s and went to Southwest to learn about their business model. When O'Leary saw how Southwest was making money, it was a "road to Damascus moment," he says, "it was blatantly obvious that this was the way forward."[16] In January 2023, Ryanair had a capital value of $21.79 Billion,[17] and is recognized as the largest airline in Europe based on passenger numbers. Analogous to the case of Southwest, a critical enabler of success at scale was the creation of the European Single market and the subsequent open skies agreement. The ingredients are familiar: huge courage and skill, enabling policies ('open skies'), research (learning from Southwest), learning by doing (ancillary services), global reach, 'outsider' status which made the inconceivable doable. There is no reason why such a company should have been incubated and then expanded in Ireland, with its peripheral location and tiny local market. But when the foregoing conditions are met, smallness per se is no barrier.

Shared Characteristics of Successful Innovation

Caveat: Drawing definitive conclusions from a few case studies that came somewhat randomly to my attention lacks rigour. The shared characteristics listed below should be regarded as suggestive, rather than generalizable truths.

The shared characteristics overlap and include: crisis; courage, smart and persistent policies; sense of mission; research and development; outsiders; global reach and large potential commercial rewards; luck.

Crisis

'Necessity is the mother of invention'. The Danes faced a desperate need to find replacements for oil, the UK faced a desperate need for a Covid vaccine, the Irish food and drinks industry faced a desperate need to diversify. Ryanair faced a desperate need to make money. The exception here is DSM – it did not face a crisis but saw an opportunity.

Smart and Persistent Policies

The Danish government provided a guaranteed market for electricity generated from renewables, and it in parallel invested in R&D and in enabling infrastructure, and this was followed by market support at scale across the EU. The UK policy for a covid vaccine was also simple – singular ambition, pump-priming of the most promising prospects, and guaranteed market at scale for those who succeeded. The policy that was essential to the creation of Bailey's Irish Cream was simple in its ambition – create a new alcoholic drink – and in its reward – exemption from taxes on exports for ten years. For Ryanair, the EU's open skies policy was a key enabler of economies of scale and scope.

Sense of Mission

Failure is often the product of unwillingness to prioritize, to focus on achieving a specific outcome work back to find how best achieve it and act accordingly. All five cases were mission focussed and they prioritized actions accordingly.

Research and Development

In all five cases, this was an essential pre-requisite, but they never conflated R&D with innovation. The former is necessary, but not sufficient, for the latter. The essence of good science is readiness for the surprise, famously captured in Alexander Fleming's observation in 1928 of the unexpected death of bacteria near the mould of a fungus-contaminated petri dish, which led to the discovery of penicillin and other life-saving antibiotics, but this openness should not preclude mission focus.[18]

Courage and 'Outsider' engagement

In Demark, Peder and Finn Hansen made the leap from building hydraulic cranes to creating wind turbines. In the vaccine world, messenger RNA (mRNA) became the key to the rapid roll out of the most successful vaccines (Pfizer and Moderna). In the case of Bailey's, it took two 'outsiders' – David Gluckman (South African) and Hugh Reade Semour Davies (British) to create the alchemy that became Bailey's. In 2007, 13 years before the Commission published Farm to Fork, DSM anticipated that methane emissions from cows was going to become a key policy issue and invested accordingly; new comer Mark Kindermann focussed on understanding the molecular details behind ruminant methane formation, and this made all the difference. Neither Herb Kelleher nor Michael O'Leary had ever run an airline.

Global Reach

On the demand side: the sale of 150 turbines to California in its early days was very important for Vestas, and the massive global market available to the winners of the covid vaccine process encouraged their engagement. The fact that Bailey's is to be found everywhere around the world, from the most luxurious resort to the meanest shebeen is testament to its global reach; it is clear that DSM aims to find markets for Bovaer around the world; the fact Ryanair carries more passengers in Europe than any other airline tells its own story. On the supply side, a key to progress is finding and mobilizing the best talent, wherever it is be found, epitomized by the founders of BioNTech (Ugur Sahin and Ozlem Tureci) children of Turkish parents based in Germany, whose partnership with Pfizer has been central to the latter's vaccine success.

Luck

Denmark's progress on wind energy was helped by the fact that its grid was already very interconnected with the Nordic system, which provided back up when the wind was not blowing. The certification of Bovaer for use in the EU and many jurisdictions has more or less coincided with the new climate ambitions of the EU, and the emergence of controlling emissions from ruminant farming as a new priority. Ryanair was already well embedded in the UK market before the Brexit fissure happened.

Progress in Ireland

Increasing Efficiency

Ireland has a long tradition of supporting research that improves commercial outcomes from ruminant farming and helping engage with farmers such that findings are converted into outcomes. Inter alia, this results in getting more output per unit of input. We can get a sense of the opportunities in the very short run from the estimates of average direct costs by farm system (Table 2). The largest cost in each case is 'purchased concentrates' and the top 4 [concentrates, fertilizer, livestock (A.I. Vet etc.) and hire of machinery] accounting for over 80% of the total.

Table 2, Some Direct Costs per Farm, by Farming System, Ireland 2021, €

Cost Category	Dairy	Cattle Rearing	Cattle Other	Sheep
Purchased Concentrates	45,790	3,787	7,911	7,530
Fertiliser	15,153	2,462	3,669	3,117
Livestock (A.I, Vet etc.)	14,163	2,427	2,322	3,562
Hire of Machinery	13,204	3,269	3,767	2,646
Sub Total (% of Total Direct Costs)	88,310 (82.8%)	11,945 (85.7%)	17,669 (86.6%)	16,855 (80.1%)
TOTAL DIRECT COSTS	106,647	13,933	20,393	21,036

Source: Dillon Emma, Trevor Donnellan, Brian Moran, and John Lennon, 2022. *Teagasc National Farm Survey, 2021.* Microsoft Word - Final_2021_for_pub.docx (teagasc.ie). p. 37

Depending on prices and the costs of these and other inputs farmers adjust the input mix in the short run, with a view typically to maximizing short term net returns. In the longer term, the stock of land, livestock, buildings, equipment will change depending on relative costs and expected change in outcomes.

How does increasing efficiency convert into climate outcomes? Below is a table copied directly from Blog 1 (Table 8 in: 'Looking Back') which extracted the average emissions by Kg of product from Teagasc's 2020 and earlier sustainability reports.

Table 3. Emissions per unit of product, Average Farm, 2012–2020, Ireland

Sector		Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020
DAIRY	(1)	Kg CO2e/Kg Milk FPCM (LCA)	1.31	1.24	1.14	1.03	1.06	1.08	1.11	1.03	1.04
CATTLE	(2)	Kg CO2e /Kg liveweight beef	13.3	13.5	13.0	11.2	10.8	11.0	11.5	11.0	10.5

SHEEP	(3)	Kg CO2e /Kg liveweight sheep	9.2	9.2	9.4	9.7	8.9	8.7	9.1	7.8	9.7

Source: 2020-Sustainability-Report.pdf (teagasc.ie) pp. 70, 71, 74 for 2015-2020 data. Earlier sustainability reports for 2012-2014

For all three farming systems the data show declining carbon footprint up to 2016, and thereafter stable.

However, the data above, taken directly from Table 1, Blog 6, have been revised in the most recent sustainability report, as shown below:

Table 4. Revised Trends in Carbon Footprint (Kgs CO2e/Kg Product) Dairy, Beef, Sheep) Ireland, 2016-2021

Activity	Unit	2016	2017	2018	2019	2020	2021
	Kg CO2e/Kg product						
Cow milk	Kg Milk FPCM (LCA)	0.91	0.96	0.92	0.89	0.86	0.85
Beef	Kg liveweight	11.9	12.0	12.6	11.7	11.7	12.0
Sheep	Kg liveweight	10.5	10.5	11.3	10.2	11.8	11.4

Source: BUCKLEY AND DONNELLAN 2022. 2021-Sustainability-Report Teagasc October.pdf pp78-83

The revisions show some decline – from 0.91 Kg CO2e 2016 to 0.85 Kg CO2e per Kg Milk in 2021 - in the carbon footprint of dairy, but none for beef and sheep over the same period.

The explanation for the change is found in 'Methodological Updates' in Buckley and Donnellan, 2022, p. ix, which concludes: "Reflecting development of our scientific understanding of the global warming potential of different GHG and our understanding of the composition of the Irish farm population, the revised and updated set of historical sustainability indicators supersede previously published Teagasc Sustainability report data."

Farmers have an ongoing commercial interest in finding ways that work to increase productivity where the returns of doing so exceed their costs, so efficiency gains are likely to continue in the future. What is new are recent developments where contributions to climate and environmental performance are explicitly sought.

Recent Developments

Institutional: There are institutional developments which place a particular focus on addressing the climate and wider sustainability agenda. These include:

1. The creation of an agricultural sustainable centre by Teagasc
2. The Agricultural Greenhouse Gas Research Initiative: This is coordinated by Gary Lanigan (Teagasc) and includes >30 scholars of note in the field.
3. The AgTech Hub Case study: This is not climate or environment-specific, but it could provide an enabling framework for ag-tech solutions relating to public goods. NovaUCD has been awarded €3 million to help turn UCD Lyons Farm into a central hub of ag tech in Ireland, including helping with the launch and scaling of AgTech companies, and providing acceleration programmes and incubation facilities. AIB, Kildare County Council and Kildare Local Enterprise Office (LEO) and several agri-companies and investors including Devenish, Dairymaster, Glanbia, Finistere, the Yield Lab and Atlantic B.

An interesting climate-relevant start-up is MILJO which offers a modular solution which provides optimal nutrition for cattle herds: It can also "aid in the reduction of methane greenhouse gas emissions as research has shown that up to 12% of dietary intake is used to produce methane which could be otherwise used for performance gains as low methane producing animals are more feed efficient".[19]

Research and Demonstration: Ongoing R&D includes:

1. **Devenish:**[20] with HQ in Belfast, it was bought by the current management team in 1997, with the aim of using R&D to develop and produce innovative and specialized nutrition products. Beginning in 2014, it embarked on research and demonstration to find ways that work to reduce greenhouse gas emissions and store carbon, using two farms to anchor the work: The first is based in Meath near the River Boyne; in 2014, it purchased a 91 ha farm of grass, trees an hedges, and baselined soil quality – and by implication its ability to store carbon – and (using Lidar) the amount of trees and hedgerows and by implication, performance and potential to remove carbon. It farms sheep (Suffolk ewes) rotationally grazing with 80 heifers, with the objective to be carbon neutral by 2025, through research into carbon sequestration, soil improvement, multispecies swards and silvo-pasture. The second farm is a beef and sheep farm (100 acres of mixed heavy soil and bog land) on the Sligo-Mayo border. The aim is to take a farm that was idle and unproductive and find a way to produce a carbon neutral beef carcass in 16 months with an eye to informing the future of farming and food in the West of Ireland.[21]

2. **Genetics reducing methane emissions from Beef:** There are encouraging developments in Ireland on understanding that genetic selection could play a key role in reducing enteric methane emissions - "The first large scale characterisation of methane emissions in Irish beef cattle conclusively shows that some beef cattle can produce up to 30% less methane emissions, on average, for the same level of productivity". A senior author Alan Kelly (UCD) is quoted as follows: "These are really encouraging findings for Irish beef producers. Low RME cattle from the national beef herd produced a third less methane for the same level of performance and feed input, with these emission differences recorded for all universally accepted metrics of methane expression, be it daily emissions, methane yield or methane intensity. Going forward, from a research perspective, we need to understand the biology underlying why these cattle are producing less methane."

Farm Zero C: About €2 million has been provided for the development of the Farm Zero C project at Shinagh Dairy Farm which aims to find ways that work to reduce greenhouse gas emissions and remove carbon at scale, and "create a world first climate neutral dairy farm".[22] An important paper - Rubhara, Theresa, Luis Alejandro Vergara and James Gaffney, 2023. "A business case for climate neutrality in pasture-based dairy production systems in Ireland: evidence from the Farm Zero C Project" – was presented at the ENVIRON conference, April 4. It is a work in progress, but its provisional findings are that a mix of measures applied to reduce emissions from a dairy herd of 93 cows on a 66-hectare farm in Cork would be expected to reduce the carbon footprint of milk (Kgs of CO_2e per Kg milk LCA FPCM) by 31%. Over 60% of emissions were a result of use of a methane reducing additive.

3. **New Zealand Innovation**: There is an interesting mission-focussed initiative to find ways that work at scale to reduce enteric methane emissions at scale for pasture feed dairy systems – see Blog 7 New Zealand for details and *Dairy News* 2022 article "Methane inhibitor bolus could reduce emissions by 70%". As also noted in Blog 7 (NZ), there is an IRL-NZ collaborative agreement that provides a framework for collaboration.
4. **Climate KIC Partnership**: The Irish government recently announced this: "The Strategic Partnership would see EIT Climate-KIC apply their 'Deep Demonstration' model of innovation to the entire agri-food and biobased value chain, from soil to farm to fork. This will involve working with stakeholders from public, private, non-governmental and Higher Education sectors to develop a range of strategic and coordinated solutions on climate action that will be tested and demonstrated.[23]
5. **Learning by Doing:** This is the most valuable learning, and the Signpost farmers are showing the way. (See Blog 6 for more).

- *Ben Tyrell* owns a 300 hundred Jersey dairy cow farm in county Dublin. Asked recently on *CountryWide* about meeting sustainability requirements, he noted:

"It's the license to farm isn't it. Open to inspection. The bigger you get, the higher your standards have to be; it has to be done. If you are running a factory, whatever you need to do to comply, you just do it. If you need it, you need it; you just have to comply. It's part of the business. If you can't afford it, you have to look at why you're doing it. When you're at this sort of size, when things go wrong, they go really wrong, so you have to keep on it".

On the innovation front, he has invested in a new bubble system for the aeration of slurry including the separation of slurry and milk parlour washings, because the spreading rules are different, and he sees slurry as a welcome substitute for expensive chemical fertilizer. To produce beef that is saleable, he is testing cross breeding with Belgian Blue (good muscle tone).

- *Jane Shackleton*: Farmer (with parents) in County Cavan. I have seen the 'Tom Crean' play three times, so I am disposed to take anyone with the Shackleton gene seriously. She has advantages of scale (80 hectares), and access to data (she is doing a PhD), and she and her parents have used these resources to simultaneously diversity and specialize. The farm produces organic beef – no concentrates or grains - (Aberdeen Angus, Belted Galloways that provide 'exceptional meat quality with high marbling,') integrated with forestry (oak, birch, larch, ash, hazel, Scots pine and Norway spruce).[24] There are thousands of farmers who planted trees and for whom the premium payments (payable over 15 years) have run out. Their woods are continuing to remove carbon and could be an important part of their business model for the future. Over the 1980-2020 period, over 25,000 farmers and other landowners have undertaken grant-aided afforestation (285,000 hectares).[25]

All-Island Climate and Biodiversity Research Network: Climate policy and performance can be logically linked to the addressing of water quality (nitrification) and air quality (ammonia). There are clear links also with conserving nature (biodiversity) but the symmetry of interest is less clear, the policy instruments and institutions tend to be distinct, as are the performance metrics, and they typically operate in parallel rather than as mutually re-enforcing movements. The Irish Citizens' Assembly on Biodiversity Loss symbolizes the effort to give parity of esteem to biodiversity, and a sense of the perspectives emerging as regards agriculture is available from the submissions to a meeting on 15-16 Oct, 2022. Their full report is available at: Report-on-Biodiversity-Loss_mid-res.pdf (citizensassembly.ie)

6. The challenges are shared across the island, and an important first step towards a more integrated approach has come from the research community.[26]

Assessment

To deliver our ambition to become 'a world leader in sustainable food systems by 2030' we will have to find new and better ways to reduce greenhouse gas emissions and to store carbon at scale, and we now have only 7 years to meet our Food Vision 2030 target. We need to do this for three reasons: it is the right thing to do by our posterity; if we do not match the carbon footprint performance of our competitors in key markets our food businesses and farmers are likely to incur significant commercial losses; and this will spill over to blight the prosperity of rural Ireland and damage Ireland's reputation as a country and people that take their climate responsibilities seriously. Below are my 'conclusions and next steps.'

Conclusions and Next Steps

1. **The key role of innovation – dramatically reduce the costs of emissions reduction and carbon storage at scale.**

Costs are critical. Solar energy was a small scale, expensive boutique endeavour, until (a) demand was scaled up dramatically and (b) costs were sharply reduced.[27] The same was true of battery storage – small scale, limited range, and very high costs initially. Innovation with the following features: crisis, good policies that were sustained, mission focus, learning by doing, relevant research and development, direct 'outsider' involvement, global reach, luck, resulted in the huge reductions in costs for solar, less so, but still significant, for wind energy.

2. **Why we need a *mission-focussed* innovation strategy.**

- You can't have a successful climate policy for the sector and leave ~ 60% of emissions (enteric methane) on the table.
- The high-tech solutions that are emerging e.g., feed additives, may provide a competitive advantage to indoor containment farming systems. We need something that works at comparable for pasture-based systems.
- The commercial incentives to innovate are likely to reward solutions that are patentable, but not do so for changes in farm systems, e.g., integration of beef and woodland farming.

This means *prioritizing.*

In rank order, the priorities that stand out for me are:

1. Finding ways that work to reduce enteric methane emissions at scale for pasture-based farming. More efficiency will help (see below) and should be fostered, but this on its own is unlikely to be nearly enough. The development in NZ by Ruminant BioTech's CALM (Cut Agricultural Livestock Methane) which aims to find ways to reduce enteric methane emissions at scale from pasture based systems is operating with mission and the beginnings of a scale ($16 million) and structure that is credible (more detail in Blog 7 and Home | Ruminant BioTech).

Ireland's efforts - Devenish, Farm Zero C, emissions-reducing genetics directed at beef, etc. - are significant and useful, but lack the funding, scale and other attributes that are likely to deliver a step change in emissions reduction before 2030. The big strategic question we face is whether to depend mainly on external ambition and expertise to find solutions for us, or should we scale up our efforts and aim to become significant actors on the world stage?

2. Since 1980, about 25,000 Irish landowners have been grand aided to plant trees; the top 7 (out of 26) counties in terms of area planted are (in rank order) Cork, Kerry, Claire, Mayo, Tipperary, Galway, and Donegal. Those with this endowment are the place to start with finding ways that work to combine tree culture and animal farming; they have a carbon removal machine already in place on their farms, and some will also have experience with cattle and sheep farming. The new planting grants (See Blog 12) in the Irish government's Forestry Programme 2023-2027and related progress on addressing licensing issues means that new planting is also likely to expand; finding ways that work to make sure that this new endowment helps working farms to integrate carbon removal into their farming practise will be a key priority for an innovation strategy.
3. Integrating an ambitious carbon removal strategy with biodiversity conservation. The location of the Natura 2000 network tells us where the payoffs for investing in the latter are likely to be greatest and the river catchments identified by the Irish EPA where agriculture is the main source of eutrophication provide an important indication as to where the payoffs to greenhouse gas emissions reduction are likely to be greatest. But we need a lot of innovation and associated learning by doing as to how best to integrate these objectives.
4. Wars always have many tragic and odious consequences, but they do create challenges and opportunities. This is the case with the Russia-Ukraine war, where one consequence has been interruption of production, supply chains and flow of inputs, and this has consequences for prices of outputs and inputs. As we see in Table 2 above, for all three ruminant farming systems, the three most expensive input categories in rank order are purchased concentrates, fertilizer and livestock (Artificial Insemination, vet services etc.). Finding new and better ways to reduce these costs while maintaining output would deliver both commercial and public goods outcomes.

3. **Innovation is where small countries can make a huge difference.**

114 of the world's 235 countries have populations less than 6 million.[28] They can all argue – and many do – that 'we are so small, and make such a miniscule contribution to global emissions, that there is no point in them doing much; that's for the big boys to take on'. As the former editor of EAERE Magazine, I made the case myself for climate leadership by the Big Four (China, EU, India, US),[29] but small countries can make a huge difference if they chose to show the way via innovation.

As I write, it has been announced that there are 14 Irish nominees for film Oscars (including an Irish language film, An Cailín Ciúin, in the international category) this year. [30] How can a country of 5.1 million people, comprising a miniscule percentage of the world's film-viewing public, perform to such effect on the global stage? The answer is for the same reasons that innovation succeeds in other arenas – courage and talent, smart and persistent policies; sense of mission; research and development; outsiders; global reach and large potential commercial rewards; luck.

Denmark (Pop 5.8 million) showed the way to make wind a serious alternative to fossil fuels for the generation of electricity, and Ireland (and New Zealand) can do likewise in finding ways that work to reduce greenhouse gas emissions at scale from pasture-based farming.

In Ireland (Population 5.1 million) Bailey's Irish Cream and Ryanair are products of innovation. The first is a favourite of consumers world-wide and Ryanair in 2019 carried more passengers in Europe than any other airline [followed by Lufthansa, IAG (British Airways, Iberia and Aer Lingus), and Air France-KLM].[31]

4. **At EU level, the Innovation Fund provides a ring-fenced guaranteed source of innovation funding for carbon reducing technologies.**

There is nothing comparable available to fund innovation aimed at emissions reduction and carbon removal by ruminant farming. At this (EU) level, we need to find and implement mechanisms that will help fill this gap.

5. **Similarly, at member state level, assess the extent to which the existing mix in Ireland of R&D and innovation, and what is emerging in other jurisdictions, are sufficient to maximize the prospects of achieving reductions of emissions and removal of carbon at scale and delivering global leadership by 2030.**

If, as I suspect, a conclusion is that we need to sharpen our focus, increase the resources, and organize accordingly, we need to do so.

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Biography

Frank Convery has degrees [B. Ag and M.Ag (Forestry)] from UCD. Encouraged by the late Seamus Sheehy, he went to the US and took a PhD in Forestry Economics (State University of New York). After a distinguished academic career in the US (Duke University) he returned to Ireland as research professor at ESRI before being appointed as Heritage Trust Professor of Environmental Studies at UCD where he led the successful application for the funding of the UCD Earth Institute. He chaired the boards of the Sustainable Energy Authority of Ireland (SEAI) (2002-2007), Comhar Sustainable Development Council (2006-2010) and served on the Climate Change Committee (2016-2020) chaired by John FitzGerald, and the AgriFood 2030 Committee chaired by Tom Arnold. The latter produced *Food Vision 2030*. From 2014 to 2018, he was chief economist with the Environmental Defense Fund, New York. His passion is finding ways to bring the weight of learning down to where things are done; his ambition for the sector is the same as Food

Vision 2030's: "Ireland will become a **world leader** in Sustainable Food Systems (SFS) over the next decade. This will deliver significant benefits…and will also provide the basis for the future competitive advantage of the sector".

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