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Connecting innovation and policy to reduce to carbon emissions from manufacturing

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Abstract. Drawing on qualitative case study data from Scottish distilleries and from UK cement production, this paper explores firm- and sector-level responses to the net zero carbon emissions challenge, demonstrating the difference between two pathways: (1) improving existing technologies and processes, and (2) developing and adopting new technologies. For each pathway, our data shows that a distinctive mix of policy and regulation needs to be in place to achieve the desired transition. This holds true across both of our energy-intensive manufacturing cases.: whisky distillation and cement manufacture. For Pathway 1, innovation is passive in relation to policy; i.e. the pursuit of optimisation means that innovations respond to incentives (or disincentives) but do not create the conditions for policy success. For pathway 2, innovation and policy feed off each other in a more dynamic relationship; pushing each other and establishing conditions that support transformative practices and technology-process development. Effective policy mixes must also reflect aspects of place that affect the firm, whether cultural, resource factors, social norms, or governance and political arrangements.

1. Introduction

Responding to the twin challenges of reducing carbon emissions and reducing energy and resource demands is a defining business challenge, with ‘Net Zero by 2050’ being easy to adopt as a strategy but difficult to deliver. Cement manufacture and whisky distillation are both energy-intensive sectors with apparently few options for technological innovation in their core processes. By exploring innovative practices in these two industries, we identify challenges in moving these alternative developments into mainstream practice’, with a specific focus on the role of policy and regulation. This paper uses both theoretical and a practical lenses. On a theoretical level we engage with the innovation and policy debate; on a practical level, we share some lessons summarized from our primary data collection.

Our focus was to explore the following research questions:

- RQ 1: Does policy enable or stifle innovative practices?
- RQ 2: Is innovation a driver for successful policy development?

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While our focus sectors and data are embedded in the UK context, the recommendations relate to broader systems of innovation and policy development and are therefore applicable to other national contexts where manufacturing and carbon-intensive industries are expected to meet transformational carbon reduction targets.

2. Configuring innovation and policy to support pathways to net zero

Achieving 'net zero' carbon emissions requires a global transition from carbon-intensive energy systems to low carbon configurations [2-3]. The path towards net zero requires intentional institutional and policy frameworks that support productivity and innovation across physical, knowledge, human, natural and social capital assets over a sustained period [1, 4-5].

Many of the processes used in the manufacturing and transportation of both cement and alcoholic products are energy-intensive, necessitating measures to transition these industries toward net-zero [6-7]. For cement, transitioning requires integrating advancements in low-CO_2 technologies with policy frameworks that guide and offer stringent emphasis on economic viability and encouraging collaborative efforts [7]. Consequently, the decarbonisation of hard-to-abate industries will need strong policy support and robust policy instruments. These policies will affect the various production, processes, consumption, and disposal within the two sectors and will need intentional instruments that create markets for low carbon products.

Whilst it is clear in the academic literature that policy support and innovation are critical for the net zero agenda, often there is a question as to which leads, and which follows. There is support for two propositions: as policy established with the aim of driving innovation [8-9] and as innovation driving policy [10-11]. However, Schot & Steinmueller (2018) [12] argue that this is not actually a polar debate because there are three innovation policy frameworks: innovations for growth; national systems for innovations, and transformative change. The first two frameworks broadly correspond to the two sides of the policy-first or innovation-first debate. The third framework uses the concept of 'transformational change' of a sociotechnical system. This third framework is useful for topics with a high degree of sociotechnical complexity and dependencies, such as the decarbonisation of industry and the pathways to net zero.

Our research questions, therefore, aim to identify the policy mixes that interact with innovations to strengthen a firm's commitments and capabilities to decarbonize across the value chain [13-16]. Those policy mixes need to exhibit characteristics of consistency, credibility, comprehensiveness, and conciseness (4Cs) to be effective [13]. Trade-offs among environmental, economic, and social effects have to be considered; Nemet *et al.*, (2017) suggest that climate policy design needs to navigate a trade-off between making commitments that are sufficiently credible to stimulate transformation and retaining flexibility to adjust as needed while pursuing a low carbon agenda. [17] We are keen to explore this notion with our data and to examine how policy mixes can achieve alternative low-carbon innovations in our case study sectors.

3. Methodology

We gathered primary data from firms in two sectors: distilleries in Scotland and cement companies in the UK, which were selected because they rely on energy and their embeddedness in UK economic, political, social, and cultural contexts. For example, cement makes up 6.1% of UK GDP, and alcohol is 2.5% of total UK GDP or about 150bn GBP [18-19]. Also, while both have technology-process innovation, each of the focus sectors has distinctive characteristics that allows us to draw useful insights. In the distillery sector, technological innovation was supported through a national Green Distilleries Competition [20]. The cement industry sample was narrowed by contacting key informants who work on improving Portland Cement processes or developing alternatives.

13 interviews were conducted with in the distillery industry and nine interviews from cement, over a three-month period in 2024. The interviews were recorded, transcribed, and processed before data was analysed to identify net zero innovations and practices and the policies that were either in place or were required.

4. Examining policy and innovation in the case studies

To examine the relationship between policy and innovation, we partitioned our case study data between two pathways to net zero: 1) *the improvement of existing technology and processes* and 2) *the development and adoption of new technological pathways*. Data presented here shows the relationship between policy and innovation in these pathways. Subheadings offer one-line summaries of the stories illustrated by each of four case studies.

4.1. Pathway I: improvement of existing technology and processes

The first pathway to focus here on is *the improvement on existing technology and processes.* In this pathway we present two case studies. Both cases are about optimising existing resources. The case from the distillery sector is focused on energy use optimisation, while the case from the cement sector is focused on procurement and development of existing low-carbon alternatives to cement.

4.1.1. Classic energy use: Kingsbarns distillery[1]

The first case illustrated a classical approach to energy use optimisation in a company with limited options on its pathway to net zero. Kingsbarns Distillery is a relatively new distillery, opened in 2014, and founded to follow a traditional style of Scotch whisky-making in Fife, Scotland. The distillery's main products are Scotch whisky and gin.

Sustainability was embedded in the business from its inception, however, there are a great many barriers on the distillery's pathway to net zero. As a small distillery without their own agricultural land, the raw ingredients are obtained from local farmers and a malting house 450km away is used. Both processes require transportation. Distillation is an energy intensive process as is waste disposal. The business has focused on technological innovation and process optimisation in *energy*, *waste*, and *transportation* to reduce their carbon emissions.

In terms of *energy*, Kingsbarns' currently uses renewable electricity providers and has plans to generate low-carbon energy on-site with solar panels, leaving space for a hydrogen power station in the future. The distillery has invested in energy efficiency measures, including a new heat exchanger and recharge tank. *Waste* (sewage) is processed through an on-site reed bed; spent grains from distilling are sent to local farms for animal feed, and other organic waste is piped to a local farm for spreading on the fields. Kingsbarns also up-cycle their glass bottles and oak barrels and also change product design to reduce waste; their new gin bottle "*will use much lighter and thinner recycled glass, which will save on weight and material*." Less *transportation* for flavouring ingredients. "*The new gin has been developed by our distillers to use far more local and home-grown botanicals where possible, to reduce food miles. So, for example, lemon peel has been removed… and*

1 https://www.kingsbarnsdistillery.com/

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replaced with locally grown herbs with citrus aromas," [*Excerpt from an interview*] this is paired with incentives for more sustainable transportation on-site, such as providing electric vehicle charging.

On interaction with policies and regulations, Kingsbarns is a case that shows the optimisation of existing processes where possible to drive change or using available technologies. On this pathway, policies are in a passive relationship with innovation. The distillery optimises to best fit within existing systems. Innovation also extends until reaching the constraints of the system, after which it becomes part of a future plan, as is the case with setting aside space for hydrogen, should hydrogen-driven technologies ever become available. This optimisation pathway is a common approach for many SMEs, due to many reasons, such as limited resources, space, and time, to name a few.

4.1.2. The bird's eye view: AMCRETE UK

AMCRETE UK, an expert independent consultancy supporting concrete technology in clients across the construction sector, illustrates the innovation and policy relationship where there are low-carbon alternatives to cement and the role of procurement, development, and opportunity for the use of these alternatives. AMCRETE UK throughout the UK.[2]

Interview data reveals that the drivers for decarbonisation within the cement sector stem from multiple sources, including regulatory frameworks, consumer pressure, and investor expectations. Therefore, the relationships between policy and innovation in the cement sector are nuanced depending on the situation and actors participating as well as in which part of the supply chain the situation occurs, leading to a complex interplay between policy measures and the realities of cement production. Regulatory frameworks, as a subset of policy instruments, play a crucial role in guiding the cement industry's path toward decarbonisation, and these are not usually directly net zero related. Such frameworks underscore the need for well-considered policies that account for broader economic, social and political factors, examining the supply chain rather than focusing solely on the product or company. An example from the cement industry is the *carbon tax*. Carbon taxation can be studied holistically by examining not only policy, but also the regulation and enforcement of policy.

Another regulatory framework that emerged from the data is the *regulation of the people* – creators, the clients, and the providers. *Creators need* to be encouraged to develop alternatives to Portland cement using incentives that reward risk-taking. Such incentives mitigate financial risks for the creators, and encourage the industry to embrace innovative materials and practices that contribute to carbon reduction. "*Clients have the greatest opportunity to set the standard*" [*Excerpt from an interview*] and drive positive change within the supply chain. *Providers* then can support *clients* by having a shared vision of decarbonisation in the cement industry and collaborating across the entire supply chain, including designers, structural engineers, and cement manufacturers.

This case illustrates a requirement for policy and innovation to be rooted in a strong collaboration across the value chain, since collective efforts are essential for achieving meaningful reductions in carbon intensity.

4.1.3. Pathway I: Revisited

In both case studies there is complex interplay between policy measures and the realities of ingredient use, production, transportation, use, and disposal of materials in both sectors,

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2 www.amcrete.uk

even in a passive relationship to policy. As in both there are optimisation strategies, in that regard that are in line with the existing policies, but not in contention with them. These findings allow us to address our first question, namely *(RQ 1) does policy enable or stifle innovative practices.* We argue that despite positive development in the sector via optimisation techniques, in the case of passive policy relations, policy does not enable or stifle innovative practices. This is important to understand because a persevering view is that if a policy exists, innovation will be related to it either negatively or positively. But we see that as not the case. This perspective helps us understand why despite clear policies and policy mixes, transformations are slow to take shape, even when business interests align with Net Zero approaches.

4.2. Pathway II: development and adoption of new technologies

In this pathway we also present two case studies. From the cement sector, data focuses on the development of a new type of cement in an attempt to drive down carbon emissions. From the distillery sector, data is presented on the development of new bio-methane storage, processing and distribution technologies as a way to address the existing challenges posed by slurries in the UK.

4.2.1. An innovative approach for cement in the UK: the case of CEC[3]

The third case to explore here is that of Cambridge Electric Cement (CEC). In their company's words, CEC focuses on developing a new technology while still remaining "*within the parameters of established industrial processes*." CEC's process replaces lime in steel recycling with recovered cement paste from old concrete. The recovered cement paste is reactivated using electric arc furnaces without disrupting steel production. This process eliminates the energy-intensive kiln emissions of traditional cement production and leverages existing steel-making infrastructure. Despite being devised as a direct substitute for Portland Cement, the new technology-processes of CEC helps illustrate an innovative drive for sustainable action, which if successful, could be the foundation for new policy and regulations at a later time. However, until that moment, it is a company that has a push/pull relationship with existing policy and regulations while attempting this new pathway.

The very context of the cement sector is changing with the change in social, cultural, environmental and political values. "*The world of net zero policy and interest a decade ago was obviously completely different from today*" [*Excerpt from an interview*]. This shift has fostered a more robust commitment to addressing the climate crisis, compelling research groups to engage in innovative practices in the cement sector long before regulatory frameworks were formally established. A shift towards new innovation pathways that would match this perceptional transformation and create new pathways combined with newer forms of policy and regulation.

And yet, these new innovation pathways grow first in between existing policies and regulations before they could be used as basis for newer ones. In the cement industry, quality control regulated by standards is one of those immovable hurdles, each new alternative low-carbon cement must challenge and overcome before it can be used commercially. At the moment, Portland cement and accepted alternatives need to show they conform to either the BS 8500-1:2023 or the BSI Flex 350 V1.0:2023-10 standards.

One way of overcoming the current policy barriers is to develop a mature framework for *measuring carbon emissions*, *developing life cycle standards,* and *engaging the whole supply* chain in order to encourage transformations in the sector. However, to engage the

3 https://cambridgeelectriccement.com/

whole supply chain is easier said than done. On the one hand there is a perception barrier. Even if you have cement that has the right certification, would a project take on a new product in a risk averse industry? On the other, there is the issue of existing policies that make alternative cement innovations a challenge. Ultimately, this case study illustrates the significant interplay between policy, regulation, and innovative practices in advancing sustainable cement production. By fostering a conducive regulatory environment and encouraging collaborative efforts across the industry, stakeholders can work towards achieving ambitious carbon reduction targets and contribute to a more sustainable future.

4.2.2. Turning stink to gold: a way forward with Bennamann Ltd[4]

Data from Bennamann Ltd focuses on the development of new bio-methane storage, processing, and distribution technologies as a way to address the existing challenges posed by the disposal of agricultural slurry waste, such as that produced from the growth for the core ingredients used for distillation. Their focus is on the development of a technology that fully encloses slurry lagoons, capturing and upgrading emissions into high-quality bio-methane. This bio-methane can reduce energy costs, lower carbon footprints, and enhance profitability through decreased fuel and fertilizer costs, while also opening new revenue streams from bio-methane sales.

Despite its potential, the adoption of bio-methane technology in the UK is hindered by regulatory and operational barriers. One primary regulatory challenge identified by Bennamann Ltd is the requirement for gas odorization. Bennamann Ltd advocates for policy shifts to facilitate the use of unodorized bio-methane, because currently, there exists a significant gap in the market for affordable, small-scale odorization technologies necessary for effective bio-methane application. Current systems are predominantly designed for large-scale operations, which limits accessibility for smaller projects. Policymakers should prioritize the development and funding of innovative, cost-effective odorization solutions to enable broader industry participation and enhance the feasibility of bio-methane utilization. As one expert noted, "*generally, the only equipment that exists is used at the point of injection of gas into the grid. Therefore, it's really large scale, very expensive, and no one's done it small scale that we could find at the time, anyway*." This emphasizes the pressing need for targeted investments in smaller-scale technologies that can facilitate the use of bio-methane in various contexts, while also highlighting a clear call for regulatory reform to enable greater flexibility in how bio-methane is utilized, thereby promoting its integration into existing energy systems. Such reforms would not only alleviate some of the economic burdens associated with compliance, but also encourage innovation within the sector.

There are additional innovations to consider in relation to existing agricultural, economic, social, and political contexts. An integrated approach of government incentives paired with educational initiatives must be implemented to capture the benefits of adopting bio-methane technologies and pursuing net-zero initiatives. An emphasis is made on the importance of collective efforts for meaningful change such as collaborations between industry stakeholders and policymakers being the key to achieving net-zero emissions.

4.2.3. Pathway II: Revisited

These two case studies, within the development and adoption of new technological pathways serve to help us answer our (RQ 2): is innovation a driver for successful policy

4 https://bennamann.com/

development. Even though policy seems to drive innovation by creating a space where innovation is needed in order to meet policy demands, innovation does not seem to easily shift policy. Both presented cases show innovative technologies that can significantly alter their respective sectors, and yet policy stands as a barrier, a system not easily changed with constraints upon these innovative developments and practices. By description, these cases show innovation as the battering ram trying to break the policy gate and allow for the castle to transform from a carbon intensive place to a zero carbon space.

4.3. Policy and innovation: a comparative view of pathway I & II

These four case studies show that each of the two pathways to net zero has a different relationship connecting innovation with policy and regulation. For Pathway 1 (*improvement*), there is a passive and constraining relationship between innovation and existing policies. The passive nature of these policies for Pathway 1 is seen in their aim to either enable or constrain innovation, similar to a fence creating a property boundary. On the other hand, for Pathway 2 (*development of new technology-processes),* the pathway often has a more active, and potentially confrontational relationship with policy, similar to the banks of a river that may alter in response to water flow. For pathways using new technologies, there is a push/pull effect with policies when those new technologies challenge fundamental aspects of existing systems.

Separating the empirical materials in pathways helps with interrogating the data for academic research, but the reality for industry sectors is not so black and white. In distilleries and in cement there are drivers for both improvement and for the development of new technological processes. In both sectors, energy transitions face multiple barriers preventing main-streaming green innovative practices because of path dependencies and resistance to change.

We suggest that strategic policy efforts can help overcome these challenges. This relates to companies operating at a micro level, particularly in niche products. To this effect, Rogge et., al (2017: 1) in response to the multiple energy barriers that stifle greening the energy sector, suggest a multiplicity of instruments – or instrument mixes –needed to foster low-carbon transitions. However, Unruh (2000: 822) cautions that "*while technological lock-in at the firm level is important, the condition is further intensified by network externalities arising from systemic relations among technologies, infrastructures, interdependent industries and users*." [21] Largely, government institutions and incentives play a role in the diffusion of technology suggesting that policy instruments forwarded by government can greatly enable appropriate technology lock in. In another lens, this is a combination of Pathway 1 and 2.

A typology is suggested adopted from Rogge and Schleich, 2018, that predicates the success of policy towards technological innovation as dependent on the 4Cs alongside considerations of firm size internal factors that affect its technology pulls/pushes. Additionally; firm resources, capabilities and competencies matter for innovation just as financial performance and experience of the firm matter in relation to decarbonisation projects. Ideas for policy are borne from the need to have direction so there is traction to fundamentally change how we generate, produce, and use energy, advocating for a systemic transition [22] and innovation is critical for curbing the effects of climate change but cannot do so without a systemic transition [23]. Thus we argue, that our case studies show that supportive policy is a necessary, but not sufficient, condition for innovation, and neither is innovation to drive policy. There is a need to consider the overarching context, individual, firm, and industry behaviour as well as the entire value chain for the desired outcome of a systemic transition to decarbonisation in those industries.

5. Conclusion

In this paper, we presented evidence of the relationship between policy and innovation looking at two pathways to Net Zero. Two qualitative case studies showed a pathway of a passive relationship between policy and innovation where policy serves as a boundary constraining innovation. In this first Pathway, there are incremental improvements to the existing system and the impacts of innovation reach beyond the sector and affecting technologies, processes, codes and norms, as well as behaviour, perceptions, values and ideas. Two different qualitative case studies then showed Pathway 2 that is active, interventionist, and technology-process specific. This is where innovation is driven by intent for big shifts, but in reality it is rare for shake ups of the entire sector as the outcomes are narrower. And yet, it is in the push/pull between innovation and policy on this type of pathway that policy gaps can be identified. By highlighting the boundaries of the existing systems, but also having a holistic view of how the systems work, we believe we can search for the opportunities for systemic transformations.

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