Cambridge Journal of Science & Policy

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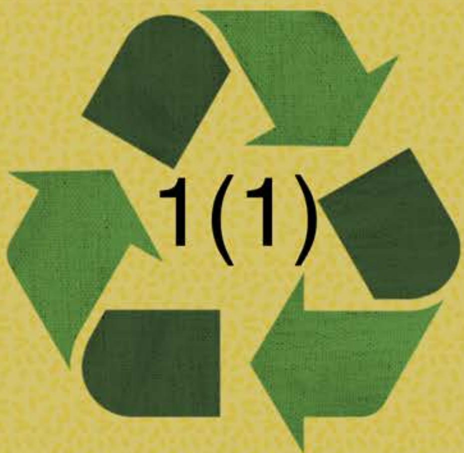

CUSPE | Cambridge University Science and Policy Exchange

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Foreword

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If ever there was a time when scientists and policy-makers needed to work together, it is now during the COVID-19 pandemic. Scientific evidence can be hard to interpret; the balancing act that politicians spend their lives performing depends on more than this evidence because they care (possibly too much) about voters' wishes. Appreciating the way these two, sometimes conflicting, trajectories interweave is crucial if a scientist is to be effective in the policy space. CUSPE and its work provide a wonderful way for students to examine these interactions first-hand and experience some of the challenges that they provide.

Sustainability is one arena where science and policy can collide painfully. Scientists may collectively believe whole-heartedly in anthropogenic climate change but deciding what to do about it in a way that will be acceptable to populations is another matter, particularly since global solutions must be sought. It is not sufficient for a scientist to say: stop burning fossil fuels or, alternatively or as well, introduce a carbon tax. In practice these things can't be done with a click of the finger of a leading politician. So, what can be done? How can scientists provide both evidence and insight that is actually useful to someone drawing up policy? That is a difficult question for anyone to answer, but imperative that scientists try to find a way that works for them and the specific problem in hand.

There are many other areas beyond sustainability – often the so-called wicked societal problems – where what a scientist thinks is the 'obvious' solution given the evidence may be totally unpalatable or impractical in our democracy. It is important to learn the tools of what may be persuasive, how to approach the policy-makers and when to back down, knowing that all the scientist can and should do has been attempted, whether or not successfully. Our education system is not great at teaching these skills alongside the purely scientific, yet we, as a nation, need people skilled at crossing the divide and helping decision-makers reach the best decisions. CUSPE provides a forum for early career researchers to learn, practice and perfect these skills.

Of course, mastering the ability to communicate is not just about spoken words, but about written arguments too. Being able to write succinctly, without drowning the reader in technical jargon, is a necessary skill to learn to be persuasive. Practicing the short, pithy briefing note is a good way to learn this skill. Getting to grips with clarity, excising excessive impenetrable detail is an art which takes time to perfect. Writing articles like those included here is an excellent introduction. I salute CUSPE for its work and wish it well.

March 2020

Cambridge Journal of Science & Policy

About the Author

Athene Donald is a physicist who is well known for her early work on synthetic polymers, concentrating on relating the structure of polymers to their function. Athene subsequently transferred her knowledge to soft matter and biological physics more broadly, developing specialised imaging techniques such as environmental scanning electron microscopy along the way.

In 1999 she was elected to the Royal Society and it was through her role chairing their Education Committee from 2010-14 that she really got stuck into the policy interface, beyond that simply concerned with research funding. She also served on their Council in two separate stints. In 2006, she was the Bakerian Lecturer for the Royal Society and in 2010 was awarded the Faraday Medal of the Institute of Physics and also received a DBE for services to physics. Beyond her research, Athene has an active interest in issues surrounding gender equality. She was the University's first gender equality champion and recently won THE's Lifetime Achievement Award for her work in this space. She is the current Master of Churchill College, Cambridge.

Cambridge Journal of Science & Policy

Evidence on the cusp between science, policy, and law

Communication | **Editorial** | Invited contribution | Perspective | Report | Review

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In his 2015 speech given in front of the Royal Society, the then President of the UK Supreme Court Lord Neuberger outlined a valuable parallel between Science and the Law. Both are systems produced by the human intellect, both are trying to identify laws *that work*—the former regarding natural phenomena, the latter human social behaviour—and ultimately to bring order into chaos [1]. One could generalise even further this parallelism to public policy and organisational decision-making. In these cases, procedures (and sometimes legislation) stand in for empirical rules, amending the aim to design a course of action *that works* towards a goal [2] or to deal with a problem or matter of concern [3]. If we accept that purpose is at the basis of policy-making, then we can see how the orderly pursuit of the expected policy outcomes clashes with the chaos of conflicting (political) interests and evidence. However, it is not trivial to assume that policy *has to* achieve a goal, as one can commonly observe the lack of linkage between 'goals, programs, decisions, and effects' [4] in the workings of government and the civil service.

In this Editorial, I will discuss evidence in three fundamental and increasingly interdependent domains of modern society—science, policy, and law—and some of the challenges arising when evidence needs to be included in real-world decision making. This is crucial, because a focus on evidence is beneficial for policy (and beyond), as it shifts the public discourse towards pragmatism [5] as opposed to polarisation. Increasing attention for (scientific) evidence in the policy making discourse is indeed one of two main goals of the *Cambridge Journal of Science & Policy*—the second being to build a platform that shares 'fresh' points of view at the science-policy interface from early-career researchers, students, and other contributors to a larger audience of academics, policy makers, and the general public.

In 1843 British philosopher John Stuart Mill argued on how fundamental evidence is for decision making across all aspects of society:

> [t]he business of the magistrate, of the military commander, of the navigator, of the physician, of the agriculturalist is merely to judge of evidence and act accordingly. [6]

However, practitioners within different fields apply specific sets of rules in order to evaluate evidence (and even the 'same' evidence) in their decision process. These 'rules of the game' can be as varied as the scientific method for a scientist or the codes of legal procedure for a practitioner of law. So—even though evidence is at the foundations for Science and the Law, and increasingly so for policy and business–it informs each of these

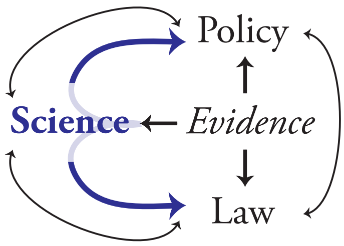

Figure 1: Evidence lies at the foundations of science, policy, and law—however definitions and procedures of partaking with it are only partially shared among the three. The three mutually influence each other: science informs and fosters change in both policy and the law through channelling its body of knowledge, law sets the legal boundaries for science and policy, policy can instruct the law via legislation and affects science via regulating its environment (funding, organisational requirements, and so on).

systems according to their peculiar features (Figure 1). However, one can find three general issues, that are shared any time evidence-informed decision making occurs: 1) *how much* evidence is available, 2) its quality level, and 3) how it interacts with the values of society, policy-makers, and so on.

The first aspect is not only about obtaining large volumes of high-quality evidence (either via data collection or pilot projects) in order to instruct decision-making [7]. One also needs to consider the concept of *bounded rationality*, which is borrowed from behavioural economics and much used in business and policy management [8]. Bounded rationality encompasses three crucial aspects of evidence-informed decision making: the limitations of time before taking a policy (or legal) decision; the fact that the available information might be partial and not conducive to an optimal decision—this, even if possible, can be evaluated only *post-hoc*; the difficulty of decision-makers to process or weight multiple streams of sometimes contradicting evidence, or even sets of coherent evidence, but in large quantities.

When one is collecting evidence to inform a decision, a second crucial challenge is to reflect on the quality of the data or information that have been collected. This is not a simple task. Firstly, there is no universally established definition of data quality, although a commonly used operative definition is the fitness of data for the intended use [9]. This definition feeds back into the previously discussed issue of bounded rationality, when it is not clear at deployment whether some data is fit for the intended use. Secondly, there is the question of how 'objective' the data is, with the further issue that the positivist assumption that 'out-of-the-box' objective evidence exists is challenged on multiple fronts [10]. Nonetheless, if we consider a dictionary definition of objectivity as lack of bias, obtaining evidence with limited bias is still fundamental to avoid what can be called 'policy-informed evidence' [11], that is the selection of the data supporting a policy already decided for and the exclusion of competing evidence. Thirdly, there's the explanatory power of evidence—*is the available evidence strong enough to inform a decision?* Here the differences between scientific, legal, and policy methodologies are the most difficult to reconcile, and this point goes hand in hand with the interaction between (scientific) evidence and values.

Harmonising empirical evidence and the values of policy-makers and the general society is the last crucial challenge. Decision making becomes 'political' [11], in the sense that it relates to the interactions between the stakeholders of the polity. This may entail, for example, the way different lines of evidence are weighted according to one's moral or ideological values before reaching a decision. Another issue is prioritisation: while in the sciences it is acceptable (if not desirable) not to reach a conclusion unless there is enough convincing data, this is often not the case in law and policy making. A policy maker needs to respond to the requests of the general public and a court needs to find the 'legal truth', e.g. whether for the Law some damage occurred after exposure to given chemicals, even when the science is not set on the issue. A paradigmatic example is the 2017 ruling *W vs Sanofi Pasteur* where the Court of Justice of the European Union accepted that, in trials where science has not proven nor ruled out a causal connection between a claimed damage and vaccination, some types of evidence—such as those that a scientist would consider purely circumstantial—can be admitted in order to establish a (legal) causal link [12]. This decision, that the scientific community received with shock, has been described by legal scholars as 'measured' [12]: it makes it easier for plaintiffs to win their cases (that would be extremely difficult if the scientific method ought to be applied strictly) while keeping established scientific evidence at the centre of the process. The different expectations that society puts on science, law, and policy set the ground for much needed mediation, particularly when dealing with evidence. As Prof Dame Athene Donald writes in the Foreword to this volume, scientists interested in affecting policy ought to appreciate the different requirements of policy making, and find a method to communicate evidence in a way that works for them and for the issues at hand.

After talking about evidence in abstract terms, I have to engage here with the great challenge that the COVID-19 virus pandemic is presenting to societies worldwide in terms of the organisation of public healthcare, the necessity of keeping a steady supply and distribution of necessities—such as food, detergents, and protective personal equipment—and the need for government interventions in order to contain the infection rate. These unprecedented times highlight how scientific evidence and scientific advisors have a crucial role in guiding policy-makers in making the right decisions and at the right time; this is true not only in case of emergencies and epidemics, or for global menaces such as climate change, but in everyday policy decisions, too.

This first issue of the *Journal* is dedicated to the themes of sustainability and green policy. Climate change is the most critical challenge of the current generation, amidst the current pandemic and even more so in a post COVID-19 world. Pandemic-related restrictions on travel and economic activities is causing the global CO_2 emission levels to fall for the first time in decades [13], however the sharp rebound to 'normal' levels of emissions of CO_2 and pollutants after the lifting of lock-downs shows how thorough structural changes are necessary in order to limit global warming to 1.5°C above pre-industrial levels [14]. The contributions presented here describe a range of solutions to transition towards a sustainable way of doing business, managing resources, devising policies and regulations, and fostering growth and development via investments. I believe that these works will provide some thought-provoking contributions to the current discussion among scientists, policy-makers, and the general public about how our society can be sustainable in the near and long-term future.

Acknowledgements

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About the Author

Michele is a member of Gonville & Caius College and a PhD student at the Centre for Misfolding Diseases (Department of Chemistry). His research involves the systems biology and biophysics underlying neurodegenerative processes and ageing, with a focus on protein aggregation in Alzheimer's disease. Before coming to Cambridge, Michele received a Postgraduate Diploma in Biology from Scuola Normale Superiore and an MSc in Biology Applied to Biomedical Sciences from the University of Pisa. Michele is interested in the relationship between science and the law and how policy making might address the challenges arising from their interaction. He is among the founders of the *Cambridge Journal of Science and Policy* and he is editor-in-chief of its first volume.

Cambridge Journal of Science & Policy

Expanding the policy menu: how demand-side interventions can help the UK reach net zero

Communication | Editorial | Invited contribution | **Perspective** | Report | Review

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Abstract

Public concern about anthropogenic climate change has grown over the last decade, and world governments have ramped up efforts to meet the challenge. The United Kingdom recently pledged to reach net zero carbon emissions by 2050. While ambitious mitigation goals indicate the right intentions, the target's success depends on the efficacy of the government's climate policies. National and international climate strategies are dominated by research into low-carbon energy sources, and programmes to charge large emitters. These strategies have solid foundations in economic theory but are hamstrung by slow rates of diffusion of new technologies and industry opposition to carbon taxes. Drawing on the increasing public support for drastic climate action, policymakers should implement interventions that focus on reducing consumers' demand for energy and other carbon-intensive products. These consumer-facing policies would enable meaningful individual action, complement existing climate interventions and widen the government's avenues to net zero.

Introduction

A recent study, co-signed by 11,000 scientists, warns that our planet is facing a climate emergency [1]. To avoid disaster, they recommend an immediate and significant reduction in global emissions. Last year the United Kingdom legislated a target of net zero emissions by 2050. However, current policies neglect the abatement potential of demand-side changes. Like most countries across the world, the UK's core climate policy focus is threefold. First, research funding stimulates innovation in breakthrough low- or no-carbon technologies. Second, deployment of low-carbon technologies, such as off-shore wind energy and electric vehicles, is encouraged with subsidies and tax breaks. Finally, a carbon pricing scheme aims to charge emitters for the environmental harm they create. All three branches of current climate policy address how upstream producers of goods, services or electricity – the 'supply-side' - can reduce their emissions. Alternative policies aim to change consumption patterns – the 'demand-side'. Figure 1 compares supply-side and demand-side policies. In order to create enough mitigation to meet climate scientists' call to action [2], UK climate policy should

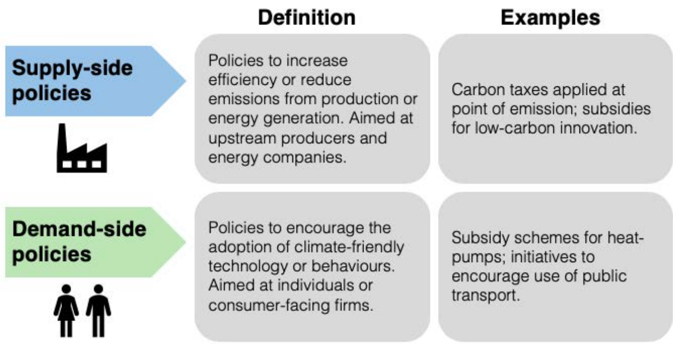

Figure 1: Definitions of supply-side and demand-side policy interventions. Note that some authors take a different definition of supply-side policies (eg, Hoel [3] defines supply-side as pertaining only to the supply of fossil fuels, rather than the use of fossil-fuels by manufacturers and producers).

utilise demand-side policies to reduce the emissions burden.

So far, so supply-side

To date, the UK's carbon policy primarily addresses how the supply-side can reduce its climate impact. In particular, low-carbon innovation dominates headlines and soundbites. However, the potential for new technologies to stop climate change is hampered by the time delay between invention and widespread use. Most innovations - particularly energy technologies - take decades to go from prototype to market-ready [4]. Instead, ambitious deployment of existing low-carbon technologies could reduce our reliance on polluting fossil fuels relatively quickly [5]. Green energy sources such as wind and solar are a key component of this strategy. While they are usually more expensive than their dirty equivalents, prices have fallen faster than expected in the last decade [6]. Nonetheless, widespread uptake of renewable energy requires extensive changes to the electricity grid to accommodate intermittent generation [7], which we can expect to be slow and pricey. Smil [8] has shown that previous large-scale transformations of the energy market have taken three to five decades. In order to meet climate targets, a grid-scale energy transition would need to happen faster than ever before [9]. Energy needs might be reduced by improving current technology and processes in industry and manufacturing. It has been proposed that better allocation of energy and materials in manufacturing could save both money and emissions [10]. However, a large body of literature casts doubt on the existence of these win-win industrial efficiencies. Allcott [11] suggests that business-side barriers, such insufficient information about potential energy savings, prevent these seemingly free gains.

Charging emitters for their environmental impacts boosts incentives to decarbonise [12]. A carbon price can be imposed using direct taxes on emissions, or permit trading schemes where a regulator sets a cap on total emissions by allocating allowances to emit. Firms can trade permits: the resulting permit price is the carbon charge [13]. The world's largest carbon pricing scheme is the European Union's Emissions Trading Scheme (EU ETS) [14]. The UK has taken a reasonably proactive stance on carbon pricing by implementing a price floor that boosts the level of the EU ETS [15]. However, the current price floor of £30 per tonne of CO_2-equivalent gases is still far off the true environmental cost of emissions, which most experts agree is between £60 to £80 per tonne of CO_2 [16]. Some estimates put damages even higher - at more than £300 per tonne of CO_2 [17] (see Figure 2). Implementing higher carbon prices is difficult. Voters are justifiably concerned that carbon prices disproportionately affect low-income people [18]. Moreover, industrial stakeholders lobby against taxes that cut into their profits [19]. Already, subsidies in carbon-heavy industries like steel have been shown to reduce the effective carbon tax rate by up to 95% [20]. The result is a carbon price that has negligible impact on industrial profit margins and generates insufficient motivation to achieve meaningful emissions cuts.

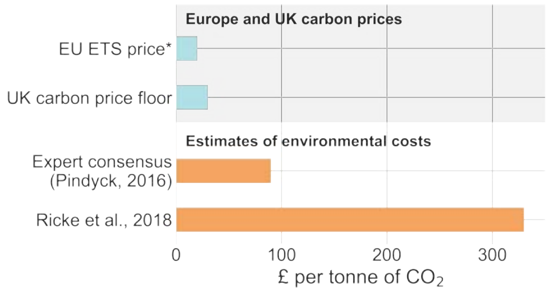

Figure 2: The price of carbon in Europe and the UK compared to estimates of the cost of carbon emissions. * EU ETS price as of 6 January 2020. Sources: [21]; [15]; [16]; [17].

The UK government should leverage the economic power of demand. Demand-side policies would complement carbon taxes and change commercial incentives of heavy emitters. The last 30 years of climate policy have shown that the traditional supply-side mechanisms are not enough to achieve required emissions cuts. Moreover, the worldwide dominance of these policies has eclipsed other policy options [22]. A coalition of civil societies go further, arguing that the focus on carbon pricing narrows the vision of domestic and international policy negotiations [23]. Subsidies for low-carbon innovation and carbon taxes remain necessary. However, they should be implemented alongside policies that enable individuals to influence carbon-producing activities. To achieve its net zero ambitions, the UK needs to utilise both supply-side and demand-side interventions.

Turning to demand

Climate policies have mostly addressed emissions reductions that don't affect final consumers [2]. Allowing for policies that require meaningful public engagement would hugely expand the policy menu. Demand-side policies encourage changes in how people use energy or purchase goods (see Figure 1). They can encourage environmentally-informed decisions such as lowering the thermostat or buying smaller cars. Policies designed to influence individual choices can be controversial, but governments can achieve meaningful change by capitalising on societal pressure for climate action. Opportunities already exist. Flight-shaming, or flygskam, the social movement that discourages flying, has already prompted Swiss bank UBS to halve their estimate of next year's global aviation growth based on passenger surveys [24]. Social movements like flygskam offer governments a chance to entrench change by incentivising carbon-friendly choices, such as stay-cations or train travel. Demand-side climate policies can have far-reaching impacts on society. The impacts are positive when emissions-saving choices have non-environmental benefits, or 'co-benefits'. Financial co-benefits of environmental policies exist when efficiency gains yield cost savings. Demand-side policies can also yield improvements in health and lifestyle. For example, urban planning laws that allow for higher-density housing in central boroughs slow urban sprawl, resulting in fewer driving hours and healthier transport options [25]. A wide-scale shift to low-meat diets would have health co-benefits [26]. However, climate policies can also have undesirable impacts. Careful thought must be given to the impact of demand-side policies on disadvantaged groups, especially if policies make carbon-intensive necessities more expensive. Lessons can be taken from previous unsuccessful interventions. The French government's plans to increase carbon taxes on diesel fuel sparked the 'gilet jaunes' movement in 2018. The tax hike would have disproportionately affected poorer rural residents, who tend to drive further distances and drive diesel cars [27]. After three weeks of violent protests, the French government abandoned the tax increase.

The gilet jaunes movement highlighted the risk of imposing climate solutions with uneven social impacts. This lesson is particularly pertinent for price-based policies: low-income households cannot absorb price increases, so would have no choice but to cut back consumption. Whitmarsh [28] suggests that demand-side policies should retain individuals' sense of agency and help them translate their values to behaviour changes where possible. Using non-price levers for low income households might be a way to nudge them towards climate-friendly decisions without adding excessive financial burden. By their nature, demand-side interventions will affect people's lives in more ways than just their climate footprint, whether that is improving their health or increasing their cost of living. These social side effects - both positive and negative - should be emphasised and quantified in climate policymaking in order to maximise the benefits and minimise the risks of demand-side policies.

Alongside changes in individual decision-making, another avenue for change is through climate-friendly businesses. Social change is usually seen as top-down or bottom-up. However, research suggests putting more emphasis on the middle-out role of professionals and practitioners [29]. The middle-out perspective rests on individual action from within organisations to create and facilitate social change. For example, industry group Investment Property Forum considers how to drive investment in energy efficiency improvements in rental homes [30]. They recommend that property managers encourage the use of 'green leases', which share cost savings between tenants and owners. Some firms facilitate change by encouraging employees to participate in climate demonstrations. Several companies, including Patagonia, Lush and Burton, shut stores to allow workers to join the Global Climate Strike in September 2019 [31]. Other proposals include initiatives to enable engineers to design buildings with less carbon-intensive materials [29], or encouraging climate-friendly car fleet managers to adopt electric vehicles [32]. Middle-out change from firms and practitioners complements demand-side initiatives, and could help cement a rethink in the approach to climate mitigation.

Demand-side climate policy would reduce future mitigation requirements from as-yet-undeveloped technology, and could be deployed relatively quickly. The diffusion rate of demand-side mitigation policies is under-researched. Qualitative studies suggest that societal transitions can be non-linear – social tipping points can drive sudden transformations in beliefs and behaviours [33]. For climate change, these non-linearities mean that demand-side mitigation may propagate much faster than supply-side interventions [34]. The UK government can look to other countries for demand-side success stories. Norway's electric vehicle policy, most of which was rolled out in the last 20 years, makes it cheaper to own an electric vehicle using tax breaks and lower registration fees. The policy has proven successful; 40% of cars sold in 2017 were fully electric [35]. Transport accounts for a third of the UK's total emissions [36]; encouraging electric vehicle purchases is a key avenue to tackle this sector. The UK government could achieve meaningful and timely demand-side mitigation by applying lessons from international case studies.

The time to act is now

The 2050 net zero target requires broadening the policy remit, and there is no better time than now. Current policies generally focus on the companies that emit, but emissions reductions would be swifter if policy also covered the individual decision-makers who drive demand. Climate protesters are walking out in the millions [37]; environmental vegetarianism is on the rise [38]; more people are avoiding carbon-intensive flying [24]. Policymakers need to capitalise on the increasing social frustration at stalled climate action to push through policies that would have been unthinkable a decade ago. In particular, the strategies they pursue should enable individuals to use their own influence, as consumers, voters and workers, to lessen their country's impact on the environment.

The UK's current mitigation strategies of innovation support and carbon pricing have achieved some emissions reductions, but the government needs society's help to meet the mitigation needs of the 21st century. Figure 3 shows UK emissions have fallen 37% since 2000 [36], driven mostly by supply-side savings. However, the impact of current policies is curtailed by long innovation timelags and industrial barriers to tax. Traditional mechanisms cannot be relied on to achieve the emissions savings necessary to avoid serious climate damages. Policymakers must consider unconventional alternatives. Policy can play a role in prioritising the changes in behaviour that can have the most impact. The Committee on Climate Change's report that prompted the 2050 net zero target briefly discussed how citizens could effectively contribute to mitigation by making climate-conscious choices, such as moving to mostly plant-based diets [39]. Discussions on the most effective methods to create demand-side change must be more highly prioritised in climate policymaking.

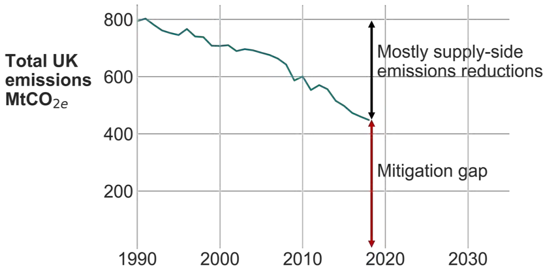

Figure 3: UK emissions since 1990. Source: [36]

Up until now, the UK has pursued climate policies that do not affect the majority of their voters. Policymakers underestimate people's desire for meaningful climate action. Societies have been spurred into change before, albeit at a smaller scale. Nuclear testing in the South Pacific was banned after galvanising protests [40]. Ozone depletion ceased after outcry from scientists [41]. Climate movements – from school walkouts to Extinction Rebellion – indicate a growing policy gap between society's desired climate action and what has been implemented so far. Policymakers must fill that gap with new policies that enable individuals and businesses to make climate-conscious choices. Interventions that reduce energy demand will complement existing price mechanisms and cut emissions. Policymakers must look to the people if the UK is to achieve net zero carbon in 2050.

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Towards a shareholder-driven transition to a green economy

Communication | Editorial | Invited contribution | **Perspective** | Report | Review

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Abstract

Recent announcements by large asset management firms have indicated an increased emphasis on sustainability within the investment mainstream. This article argues that shareholders have a central role in driving the transition to a green economy and it explores the key reasons why their impact on listed enterprises is crucial. It is concluded that in order to support this development from a policy perspective, information standards must be adopted to promote transparency for the right audience. Furthermore, policy makers should direct measures towards passive investments as well. Ultimately, well-coordinated, environmental, social, and governance (ESG) investments can be leveraged as a central tool to mitigate the effects of climate change.

With his CEO letter in early 2020, Larry Fink, CEO and Chairman of BlackRock, has captured the investment world's attention. Emphasising the financial risk of climate change, he announced that the world's largest fund manager will focus on a more sustainable portfolio and an increased transparency in the investment process [1]. In doing so, BlackRock seemingly shows a strong commitment to putting sustainability at the core of its operations. Clearly, the announced strategy alone will not disrupt the entrepreneurial environment on a larger scale. In fact, due to their predominantly passive portfolio structure, a potential divestment would directly affect less than 0.01 per cent of BlackRock's total assets [2]. Nevertheless, the letter raises hopes that both investors and asset managers will follow their lead in establishing an environmentally responsible mindset at the heart of the financial sector.

The case for a shareholder-driven transition to a green economy

Despite the urgency to act upon the threat of climate change, the results of existing approaches to the overwhelming challenge have been incremental, at most. There are two key reasons for that inertia. Firstly, markets have consistently failed to put a price tag on environmental externalities of economic behaviour. As a result, growth has been fuelled by the overprovision of greenhouse gas-emitting and polluting products at prices below their actual social cost [3]. It is the risk of this unsustainable system that, according to Fink [1], 'markets have not reflected'. The second reason lies in the short-term orientation of both the economic and the political environment: corporate decision makers are still incentivised to quickly meet shareholders' expectations and politicians are under pressure to achieve results before the next election occurs. In this myopic system, considerations of sustainability, which require a larger time horizon, have been upstaged or neglected completely.

With large asset management corporations like BlackRock, a new group of players has entered the stage. They could finally bring powerful levers to the table and enable the change that policy makers have aspired to for years. As a result, Fink's letter might mark a crucial turning point in the young history of human answers to the climate crisis: it paves the way for a shareholder-driven transition to a green economy.

Environmental activists have often referred to the financial sector as a main contributor to climate change [2]. Therefore, the idea of relying on them to shape the green transition might sound ironic. Indeed, the financial sector has not been designed to promote sustainability and many corporate leaders still share the impression that investors see environmental goals as compromises to their returns [4, 5]. However, the idea to harness finance for good is by no means new. Building on Rudolf Steiner's vision to create non-conventional financial institutions for an anthroposophical cause, the first social banks were founded in Europe in the mid-seventies and a decade later the concept of socially responsible investing picked up momentum in the US and Japan as well [4]. Furthermore, organisations across the world have promoted the opportunities of green finance. Among others, the United Nations Environment Programme (UNEP) [6] published a roadmap on sustainable financial systems, the OECD [7] informed on investment channels to enable institutional investments in green energy, and the UK Government recently released its pioneering strategy on green finance [8]. Although these ideas had a positive impact, they were, as Jones [4] points out, 'not yet transformational'.

The power of the investment mainstream

This time, the situation has a different momentum. Previous forms of shareholder activism relied on alternative investments by progressive individuals [4]. Over the years, however, sustainable investment assets have risen globally as illustrated in Figure 1. Today, environmental, social, and governance (ESG) issues seem to have become assimilated by the investment mainstream [5]. Moreover, instead of policy proposals and regulation pushing for sustainable investments, it seems to be the shareholders' intrinsic motivation to proactively advocate a green financial sector. As a result, they might become the motor of a green transition. There are three reasons to support this view.

Firstly, demand for ESG investment products is rapidly increasing. As investors start to care about the impact of their money, asset managers are encouraged to design more sustainable portfolios in the first place [5]. In particular, the willingness of major institutional investors to stand in for ESG values has put pressure on the financial sector and plays a role in Fink's ongoing advocacy of sustainable investment. A few months before his announcement, the Government Pension Investment Fund of Japan – one of the world's largest pension funds – had shifted a considerable share of their assets away from BlackRock to emphasise their ESG-based mission [2]. As millennial investors have shown to be even more concerned about having a positive impact, this development is expected to continue further [12].

Secondly, shareholder activism has become more fashionable and since investors' intentions have started to align across industries, it might be more influential than ever [5]. Studies imply that its impact on the environmental and social behaviour of listed firms is effective. Neubaum and Zahra [13] found evidence that activism by long-term institutional owners has a positive effect on corporate social performance. Building on previous ideas of stakeholder salience, they argue that large owners exert power by 'monitoring and [...] challenging executives', and that corporate decisions regarding sustainability would therefore be aligned with the shareholders' pref-

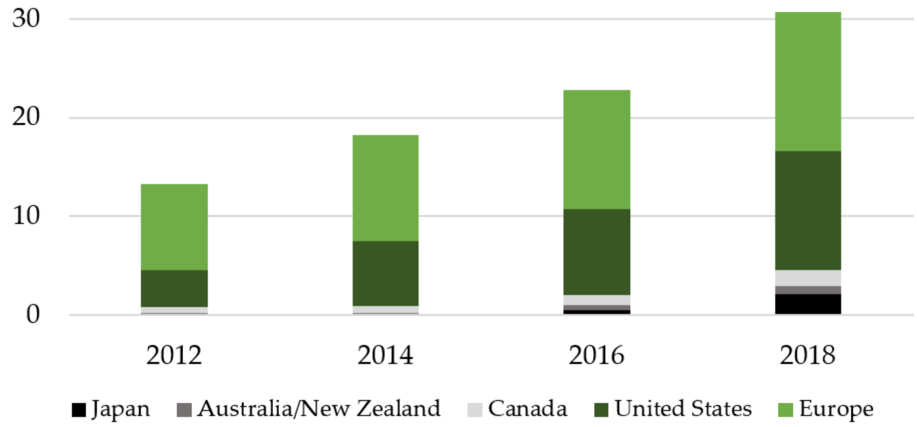

Figure 1: Sustainable investment assets by region in trillion US-$ (Data: [9–11].)

erences (pp. 112-114) [13]. By this mechanism, investors can exert influence on firms to provide more environmentally conscious products and services. This view is supported by findings showing an improved governance on green innovation in predominantly institutionally-owned firms when external shocks such as changes in the regulatory environment occur [14].

Thirdly, a high concentration in the investment market accelerates the green transition even further. There are two aspects to this argument. On the one hand, as Eccles and Klimenko [5] point out, the top ten asset managers hold more than a third of the global externally managed assets. As there is no way for them to hedge against climate change, they are forced to think more long-term and mitigate effects on the global economy. On the other hand, a few major investors can coordinate better to design their portfolio in a more sustainable way. Such a harmonisation of long-term interests tends to affect corporate social performance of firms positively [13]. Taking into account that concentrated ownership has been found to be beneficial for innovation in general [15], leveraging these effects will be crucial to drive the green transition at the required pace.

Policy implications

With these opportunities in mind, the question remains as to how the regulatory environment should be designed for the financial sector to facilitate the rise of the green economy. Here, transparency by both shareholders and stock companies has been identified as a key factor [16]. From the early days of responsible investing, information provision has been a constant and relevant pattern in its development [4]. Once implemented, a transparent financial system does not only enable efficient monitoring, but also fosters collaboration between investors, for example through project exchange networks as suggested by the OECD [7]. Therefore, initiatives like the Task Force on Climate-Related Financial Disclosures should be endorsed across the world, as done by the UK Government in 2017 [8].

However, information is purposeless to investors as long as it is primarily released for non-financial stakeholders like NGOs [5]. Current ESG assessments are predominantly qualitative and come in a variety of forms. In order to make investments comparable, the message needs to be conveyed in a language that financial decision makers are able to comprehend quickly and intuitively [17]. Thus, environmental and social impact ought to be measured in a way that is comparable to other metrics of business analysis [17]. To tackle this problem, joint standards need to be developed and put into use. They can build on existing approaches like the ESG metrics advocated by leading scholars in the U.S. [18], or the work of the European Union, which recently agreed on a taxonomy for sustainable investments [19].

Whichever measures will be taken, they must cover the vast portion of passive investments as well. Therefore, indexing companies have to be taken into consideration by the regulator as they are the ones who automatically choose assets for mainstream managers [20]. If these entities have to live up to transparent ESG standards as well, there is hope that a competition for sustainable passive portfolios will arise. As a result, they are encouraged to adjust their algorithms towards more sustainable assets.

Conclusions

To conclude, although announcements alone are not going to have any transformative effect, they promote the shareholder-driven transition to a green economy. If investors and asset managers can leverage the learnings from almost five decades of non-mainstream sustainable investing, they have the potential to induce a major shift in corporate decision-making. The main factors in their future impact are a growing demand for ESG products, the power of shareholder activism, as well as a highly concentrated investment market. Policymakers should embed this momentum in an environment of transparency and common standards. In that, there is hope to induce far-reaching changes across industries and to have found an effective tool to strive for climate change mitigation.

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Conflict of interest The Author declares no conflict of interest.

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Cambridge Journal of Science & Policy

A capital theory approach should guide national sustainability policies

Communication | Editorial | Invited contribution | **Perspective** | Report | Review

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Abstract

The question of how to sustain human development in the current ecological and institutional landscape is arguably one of the utmost scientific and administratively challenging contemporary dilemmas. In response to this issue, the concept of Sustainable Development was proposed by the United Nations to inform policies for societal and human development. However, for national governments, the prevalent sustainability schemes summon more confusion than coherence. This is due to the frequent and inconsistent ways the concept of sustainability is put into practice, and consequently, difficulties in measuring and managing sustainability. The ability to evaluate how sustainable public projects are, will remain deficient if sustainability remains a notion open for interpretation. This perspective article maintains that the capital theory approach to sustainability stands out as the most rigorous framework on the topic. The capital theory is a state-centric system of ideas where national governments oversee a portfolio of capital stocks of four families: natural capital, economic capital, human capital, and social capital. It is the duty of the government to act on the capital flow between different stocks to allow sustainable long-term development. This perspective paper underscores several envisaged gains from the application of the capital theory approach in public policy. Considering these expected gains, policy makers should be encouraged to experiment with the approach.

Global environmental change

Anthropogenic climate change brings disturbances to states and societies. With a persistent rise in the concentration of greenhouse gases in the atmosphere, the average global temperature has been increasing for over a century [1]. Consequently, oceans have acidified [2], ice sheets have melted [3], biodiversity has been jeopardized, and marine and terrestrial ecosystems have disintegrated [4, 5]. At some geographies, the frequency of droughts and dry spells has increased [6]. At others, the intensity of cyclonic storms is expected

*Opinions stressed in this article are solely of the author and do not represent those of the centre.

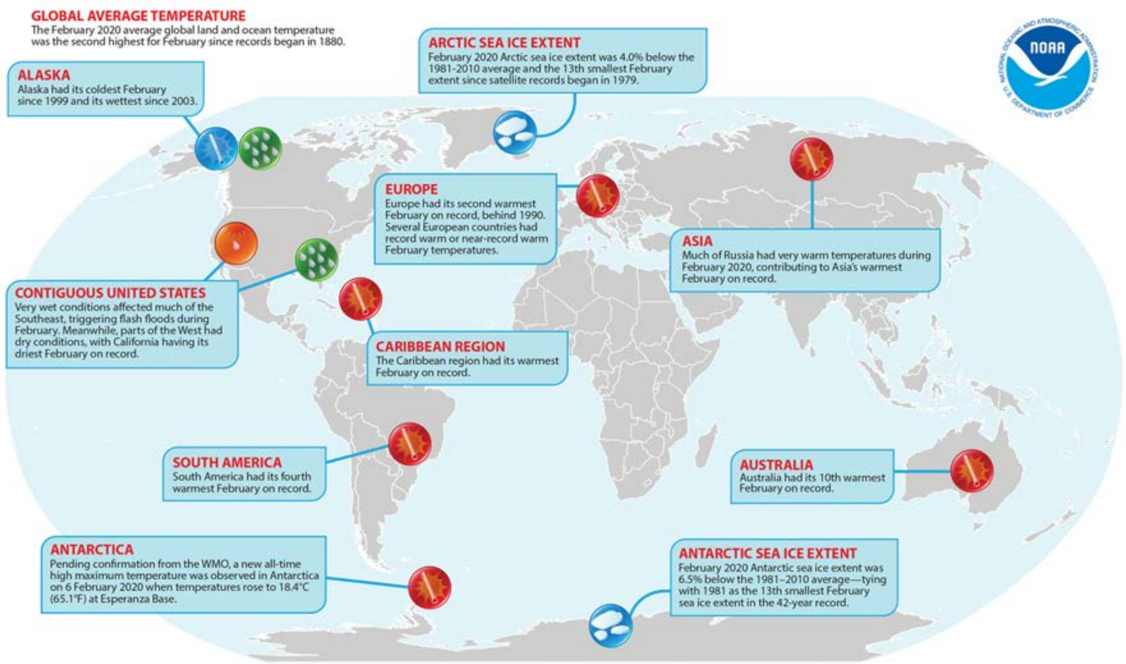

Figure 1: World map noting several significant weather climate events that occurred during February 2020. Figure adapted with permission from NOAA and the National Centers for Environmental Information [14].

to rise [7]. Globally, climate anomalies (see Figure 1) and climatic warming has inspired, and continues to inspire food insecurity, forced migration and conflict [8–13].

Alongside the transformation of the biosphere, the overexploitation of seas and top soils, fisheries and forests, of mineral deposits, and not least chemical contamination [15] have resulted in an array of human discomforts: diseases [16–18], displacements and disenfranchisements [19, 20].

For governments, global environmental change and the accelerated rate of alterations of ecosystems has created an ecological and institutional landscape that is much more challenging to maneuver through than ever before. The question of how to sustain human development in this landscape is arguably one of the utmost scientific, technological and administratively challenging contemporary dilemmas. The need to avoid social decline is a pressing concern facing twenty-first century governments in capital-constrained, competition-driven and fragmented and fragile environments.

Against this backdrop, scholarly and scientific schemes have evolved in recent decades to support better interventions in social affairs – at the global ranging down to local policy theaters – for societal and human development. One seminal proposal, the idea of Sustainability, or Sustainable Development, was introduced in 1987 by the Brundtland Commission to suggest that development ought to *'meet the needs of the present without compromising the ability of future generations to meet their own needs'* [21].

The 1987 sustainability project went on to inspire the United Nations Conference on Environment and Development, known as the Earth Summit, in 1992. The new interpretation of the notion by the Brundtland Commission also motivated 1) the institution of the Commission on Sustainable Development in 1992, 2) the Rio Declaration on Environment and Development– which listed 27 guiding principles for governments—in the same year, and 3) underpinned Agenda 21, an action plan for governments and regional organizations. Nonetheless, these schemes may have summoned more confusion than coherence and consistency for governments.

A fuzzy notion

Three years before the Brundtland Commission brought the concept of sustainability to the fore of international policy thinking, it was argued that sustainability had become an article of faith, frequently used, but little explained [22]. Too little has changed since. In 1991, it was claimed that sustainable development

> appears to have gained the broad-based support that earlier development concepts lacked [. . .] yet, the absence of a clear theoretical and analytical framework [. . .] makes it difficult to determine whether new policies will indeed foster an environmentally sound and socially meaningful form of development [. . .]. The absence of semantic and conceptual clarity is hampering a fruitful debate over what this form should actually be. [23]

Similarly, other critics maintained that the concept does not enjoy an accepted theoretical foundation [24], and that the idea of sustainability invited a theoretical 'maze of complexity' [25].

Cynics have highlighted the advantages attached to ambiguity:

> politicians have undoubtedly welcomed the opportunity to fasten onto a phrase that suggests radical reform without actually specifying what needs to change or requiring specific action [. . .] sustainable development has no coherent theoretical core. [25]

These criticisms have not subsided. More recently, it was proposed that sustainable development is not a scientific project, but a normative one (i.e. based on a belief of how things should be) [26], and that the concept remains open for interpretation [27]. In effect, researchers chose tautology over precision and measurability to define these concepts. For example, sustainability transitions theory, a branch of science and technology studies that has gained a foothold in various policy halls, defines a *sustainable* transition as a process through which '*a system shifts to more* sustainable *mode of production and consumption*' [28].

This theoretical weakness has not gone unnoticed in public policy institutions. In 2008, the United Nations Economic Commission for Europe (UNECE), the OECD and the European Union Eurostat asserted that sustainability alone, has no intrinsic value [29]. In 2014, the UNECE contended that a cloud of ambiguity hangs over the notion [30].

The policy consequences of scientific indistinctness

Six years in the wake of the Brundtland Commission, scholars began deliberating on the policy implications of an indistinct concept. One reproach was that sustainability covers development policies which vary from

> light-green to dark-green [. . .], from romantic and nostalgic conservatism to utopian socialism, from absolute-zero growth in the economy to maintaining the present world economic growth rate [31].

Indeed, from a public policy perspective, lack of clarity is obstructive [32–34]. The efficacy of allocating scarce resources to achieve a policy objective will be compromised if that policy objective is ill-defined. Furthermore, the ability of governments to evaluate the degree of sustainability of spending and investments, public projects, financial reforms, green deals or sectoral transformations will remain deficient if sustainability is not clearly measurable and cannot be deduced from empirical observations.

One more progeny of the international sustainability project—the Sustainable Development Goals, a framework of 17 goals, 169 targets and 232 indicators—was criticized for lacking a clear vision of what sustainable development really means [35–37]. In a similar fashion, it was proposed that sustainable development per se is unfit as a priority goal [38]. The International Council for Science pointed out the fact that the framework is under-informed by science [39]. The Council's experts survey showed that of the 169 targets, 54% (91 targets) could have been better specified, and 17% (29 targets) required significant elaboration. Furthermore, criticisms were related to the matter that goals and targets are often too theoretical and cannot be operationalized (i.e. put into practice), that indicators are of uneven quality, and that according to several nation states 17 goals, 169 targets and 232 indicators are cumbersome to implement and communicate to the public [40]. In view of these, and other caveats, it was argued the goals should merely be viewed as persuasive rhetoric [41]. The *Economist* labelled the goals '*worse than useless*' [42] and *Foreign Policy* considered them '*unactionable, unquantifiable, and unattainable*' for public policy [43].

Hinged on the indistinct concept of sustainability, the Sustainable Development Goals inevitably suffer the same shortcomings as previous proposals. To properly guide public policy, sustainability sciences should provide it with an alternative scheme, preferably pitched at the national level, where alternatives for the allocation of scarce resources are weighed and determined, and where accountability for development outcomes reside.

An alternative sustainability scheme for states

In the sustainability corpus, one interpretation of the idea stands out as the most rigorous, the most measurable, and the most applicable framework on the topic: the capital theory approach to sustainability [44]. Despite not receiving proper attention and being an often-neglected area of research, the capital theory has important implications for the contemporary sustainable development agenda. The theory is informed by both orthodox and heterodox approaches to economics including classical economics, natural resource economics and environmental economics [45–50], as well as by sociology [51–53] and environmental and sustainability sciences [54, 55].

The central premise of the capital theory system of ideas is that national governments steward a portfolio of capital stocks[2]. Each asset in the portfolio can be part of the state's natural, economic, human, or social capital. This approach makes capital theory state-centric. By the capital theory, maintaining human development over time entails the careful governance, use, measurement, conservation (if needed), and substitution (when necessary) of the critical assets which constitute the aforementioned four capital categories [29]. In order to understand capital theory, the following concepts should be defined.

Assets (or asset stocks) are the items which constitute each capital category. Natural capital, for instance, comprises mineral deposits, forests and fisheries.

Utilities are benefits that an asset yields to the state; as such they can be direct—that is, deriving immediately from the asset—or indirect, tangible (e.g. ore from a deposit) or intangible (e.g. trust).

Critical capital assets are assets that provide a stream of essential utilities for which no known substitute exists, for instance non-renewable phosphate reserves, public health apparatuses and trust, and so on.

Capital flow is a distinct process that causes the change of the value for a specific asset stock in time [29].

The good governance of asset stocks ensures the sustainability of nationwide progress: if stocks deplete or degrade, human development will eventually stop or reverse. The separation of capital stocks from capital flows, first suggested by Fisher [59], implies that governments administer capital assets through the regulation of flows (see Figure 2).

The capital theory underscores the important yet under-acknowledged duty of governments in managing the broad assets portfolio at their disposal (see Figure 3). Historically, this govern-

[2]The theory takes a broad and pluralistic interpretation of the concept of capital stock. Here, capital stock is defined as a set of physical or non-physical items–this could be a depository, a reservoir, a reserve, an accumulation, and so on–materials or information, that have built up over time. This interpretation is found in other strands of scholarship, for example system dynamics—a technique used to study the behavior of multipart systems using stocks, flows, feedback loops and time delays, which is frequently employed for policy analysis [56–58].

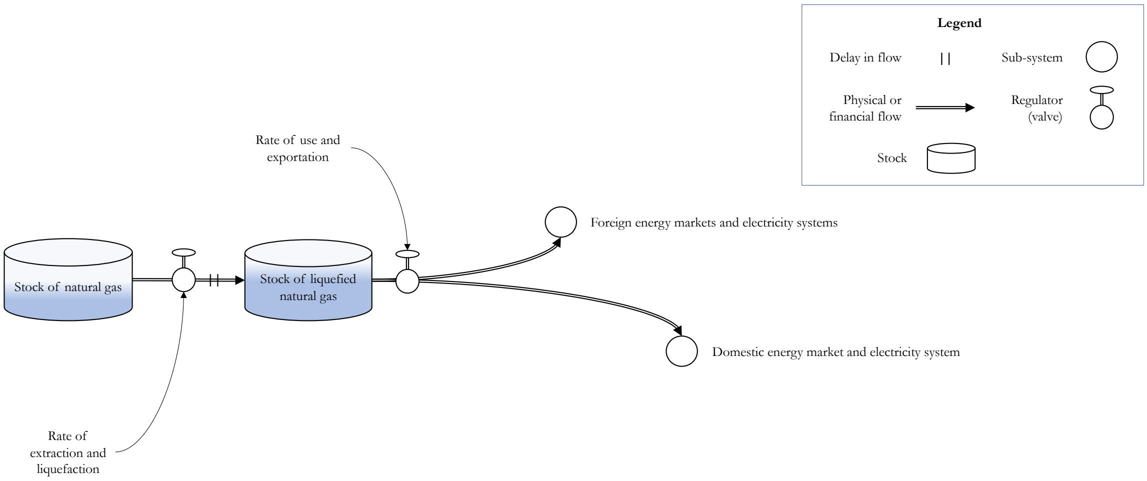

Figure 2: **A stock-and-flow model.** In the model, government institutions extract natural gas from a stock – a reservoir, or a natural storage place – liquify it to accumulate it in a stock of liquified natural gas, and set a rate of exportation and domestic use.

ment responsibility has been overshadowed by their emphasis on managing and measuring gross domestic product—which is just a flow variable. Prosperity, progress or human development, at any given time or over long periods of time, have never really been an explicit public policy priority. In former times, a focus on economic growth and other flow variables may have been justified. Human development could be assumed to increase more-or-less in step with gross domestic product. Considering the current extent of debts, inequalities, environmental pollution, deforestation, loss of biodiversity and climate change, this is no longer true [60].

Consistent with the capital theory, the United Nations, the European Commission, the International Monetary Fund, the Organization for Economic Co-operation and Development and the World Bank, interpreted sustainable development as

> development that ensures non-declining per capita national wealth by replacing or conserving the sources of that wealth; that is, stocks of produced, human, social and natural capital. [61] (paragraph 1.21)

More recently, the UNECE accepted the theory and maintained that sustainable development stresses the significance of protecting the national resource base and the capital stocks it encompasses [30]. Evidently, this operationalization of the sustainability notion is not foreign to public policy institutions.

Public policy gains

Policy gains from the application of the capital theory approach in public policy are an insufficiently discussed aspect of the approach and it is underutilized by governments. Delineating expected gains is therefore a modest contribution this paper aims to make to the philosophy and practice of sustainability. Deliberating on them may encourage policy makers to officially and explicitly experiment with the approach.

Firstly, the capital theory approach removes terminological ambiguity shrouding the concept of sustainability, which has been obstructive to sustainable development efforts. With a tangible, measurable and working conceptualization of sustainability, government interventions—public projects, financial reforms and green deals—can become easier to weigh and compare in terms of their multifaceted impacts on the societal broad base of resources.

Similarly, a system of national capital assets indicators should offer a space in which the sustainability of states and sectors, firms, factories, and farms can be assessed by measuring changes in val-

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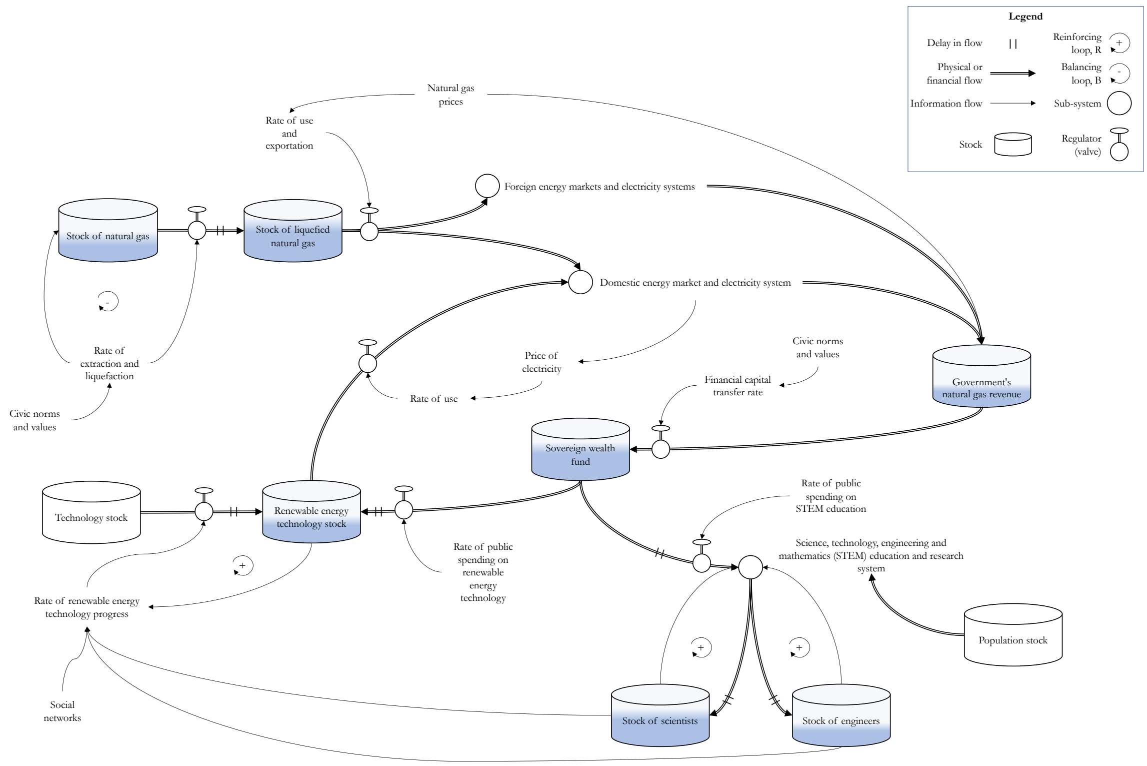

Figure 3: **Hypothetical schematization of the capital theory using a stock-and-flow casual loop model**. In the model, government institutions measure and manage (i.e. allocate and substitute) certain capital assets. In the model, natural gas (a depletable, tangible natural capital asset) is extracted from a reservoir, liquified, used domestically and exported. Civic norms and values (intangible social capital assets) inspire the government to create a state-owned sovereign wealth fund, where the government accumulates natural gas revenues (economic capital assets). In the long-term, returns to the fund's investments support science, technology, engineering and mathematics education (human capital assets). It also incentivizes renewable energy technology infrastructures (economic capital assets). The stocks of scientists and engineers increase over time, which accelerates the renewable energy technology progress. It is important to note that a final inventory of critical capital assets is context-dependent. Assets should be identified for each country separately. This schematization is a dynamic hypothesis for illustration purposes only.

ues and sizes at the capital stocks level overtime (see Figure 3). Such a system will assist governments to evaluate whether policies that aim to cater for the needs of the present generation draw too deeply on the resource base that will provide the needs of future generations. Moreover, analyzing first and second order effects of specific changes occurring in this space can guide more forward-looking institutional interventions.

As opposed to the system of 17 sustainable development goals, 169 targets and 232 indicators, a catalogue too comprehensive for the capacity of many government to measure and manage, a four-capital-stocks-and-critical-assets set of indicators promises a succinct yet rich enough tool for reflexive governance, easy to comprehend and disseminate—this is crucial to proceed to practical decisions [62].

Applying a capital theory approach within policy analysis and policy-making should help institutions focus on the factors –i.e. the stocks of capital – that allow economic production, social progress and human development to continue into the indefinite future, rather than merely on growth in the gross domestic product [63]. Alternatively put, and from the perspective of national statistics, a system of capital stocks indicators should enable governments to move beyond conventional socio-economic measures towards measures of the factors that produce socio-economic progress.

This statistical and policy focus would challenge traditional near-term, present-biased thinking and policy-making. In addition, the integrated model will illustrate how institutional interventions in the administration of some socio-economic or environmental sub-systems have spilled over to interrelated sub-systems. It should indicate unsustainable development paths and will be capable of signaling ways in which regimes develop dependencies in depletable resources (see Figure 3). Moreover, the evidence-based framework should provide policy analysists and policy makers with an analytical device which connects sectoral-confined reforms and social-wide national consequences, assessing how each dominant sector (e.g. mining of rare metals) affects the sustainability of society at large.

By putting the framework to the task, turning the theoretical approach into a policy analysis and assessment framework, policy makers can benefit from a well-anchored theoretical perspective [64], which also operationalizes the concept of sustainable development, something which many projects and propositions in the sustainable development corpus do not do. In other words, a public policy approach based on the capital theory would allow policymakers to think more broadly about institutions, policy delivery systems, investment and consumption policies, national resources, and the state of capital stocks all at once.

Such framework will assist in focusing the attention onto the remaining capital assets and their interconnectedness [65]. It can help to investigate new capital stocks creation mechanisms and possibilities, and it underscores institutional intervention sweet spots. In the local context, it can give insight into how to rebuild capital of various sorts in different countries, where previous policies resulted in their depletion, for instance arable lands, soils, aquifers, and mineral resources.

Previous policy experiments with the capital theory, albeit implicit (i.e. before the approach reached theoretical maturity, and formalized as such), demonstrate that the conversion of capital assets from one form to another is a reoccurring exercise [66]. More important, particularly for governments, previous informal applications of the theory indicate that when capital assets are exploited and substituted is a proper manner, for instance by avoiding environmental contamination in extraction or by accumulating resource rents in sovereign wealth funds, human development outcomes can be maintained and enhanced over long periods of time [67, 68]. To this end, the case of Norway (i.e. the Government Pension Fund of Norway), and to a lesser extent that of Saudi Arabia (i.e. the Public Investment Fund), stand as such informal yet successful experiments with the theory [68–70] .

For risk management–such as planning, preparedness, prevention, reduction, response and recovery policies associated with risks–capital stocks should be considered as both buffers and strategic reserves [71]. In view of the COVID-19 pandemic, and the interdependency between systems' sustainability and systems' resilience [72–74], the emphasis the capital theory puts on stocks measurement and management, yields further benefits for public policy.

Finally, the capital theory allows a degree of flexibility and contextuality, which is helpful for the works of governments. It is through public agencies, state-owned and state-operated, that the sustainable administration of national resources can be achieved. Governments should start experimenting with it.

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On the Politics of a U.S. Federal Carbon Price

Evidence from Three North American Case Studies

Communication | Editorial | Invited contribution | Perspective | Report | Review

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Abstract

To limit catastrophic damages associated with global warming in excess of 1.5^{o}C above pre-industrial levels, the Intergovernmental Panel on Climate Change has been unambiguous in its calls for "rapid and far-reaching transitions" in land-use, energy and industrial systems. However, perceived asymmetry between the significant up-front costs and relatively abstruse, delayed benefits of climate change mitigation creates particular challenges for the political favorability of policies to reduce greenhouse gas (GHG) emissions. As a result, carbon pricing mechanisms overwhelmingly endorsed by economists across the ideological spectrum have been, with a few notable exceptions, resoundingly rejected by legislators and political constituencies. Assessment of partisan, policy design, public opinion, and interest group pressures counteracting momentum for carbon pricing is critical in the deployment of a politically durable climate change agenda. This policy-focused communication assesses these dimensions through the examination of three case studies initially discussed by Barry G. Rabe in "Can We Price Carbon?" (MIT Press, 2018)—British Columbia's carbon tax, the Regional Greenhouse Gas Initiative in the northeast United States, and California's cap-and-trade system for GHGs. Drawing on lessons from case studies and applying political theories to develop Rabe's analysis, this work synthesizes guiding principles to comment on the feasibility of a U.S. federal carbon tax within the next five years.

Lost in Translation: Roadblocks to Carbon Pricing When Political Economy Decouples

Throughout the later 20th century, market mechanisms were championed to great effect in solving pressing environmental challenges. The Montreal Protocol enjoyed success in curbing chlorofluorocarbons responsible for ozone depletion at the international level [1]; sulfur dioxide emissions trading drastically curtailed effects of acid rain from industrial pollution in the United States [2]; and durable carbon taxes in fossil fuel-dominated Nordic economies were upheld as globally applicable [3]. Such achievements of market-based policy were especially notable in light of parallel shortcomings of the Kyoto Protocol's command-and-control framework to achieve buy-in for legally binding emissions reduction requirements at the international level [4]. Touting the virtues of economic efficiency and potential to decouple emissions and economic growth through the market, American policymakers had warmed to the idea of carbon pricing by the early 2000s, leading to bi-partisan sentiment that a carbon price could form a pillar of U.S. national climate policy [5].

The failure of subsequent legislation delivered a shock to the American political system. Indeed, recent congressional efforts to promote a national carbon tax have stalled, with the last major effort culminating in the failed Waxman-Markey bill of the early Obama presidency, which was subject to "pork barrel" politics in the House of Representatives and was never brought to the Senate floor for debate [6]. No serious effort to rekindle momentum toward carbon pricing is expected until after the conclusion of the Trump presidency, and even then, prospects remain highly uncertain.

Perhaps these failures are attributable to consumers' acute awareness to increased prices of high-carbon goods, or the distributional implications of environmental taxes, as seen in France's gilets jaunes protests. Perhaps a lack of trust in scientific institutions, heightened partisan polarization, formidable opposition from the fossil fuel lobby, and a poisoned public discourse on environmental issues are to blame. Perhaps carbon pricing is simply a low-priority item on an already-packed national agenda, and decision-makers have instead embraced largely tokenistic alternatives such as relatively unambitious renewable portfolio standards and emissions reduction goals, hoping to appease environmentally-inclined constituents. The examination of carbon taxation in British Columbia, Canada, and American emissions trading systems in New England and California reveals the simultaneous operation of these political barriers, and the need for context-specific and creative policy techniques to overcome them. Ultimately, a U.S. federal carbon tax is found unlikely to emerge amid a diverse coalition of oppositional forces in the near term, though the potential to adopt principles from successful policy formulation and implementation provide reason for cautious optimism over longer time horizons.

The Case of British Columbia's Carbon Tax

Kingdon (1984) proposes that the "window of opportunity" for major legislation opens conditionally upon the presence of political alignment, coherence of policy ideas, a clearly defined problem, and committed entrepreneurs to see policy through to fruition [7, 8]. Kingdon's multiple streams model of policy adoption is particularly applicable to the circumstances in which British Columbia introduced a tax on business and household carbon emissions in 2008. While British Columbia's extraction-oriented economy appeared an insurmountable obstacle for the province's early climate initiatives—with even left-wing parties opposed to carbon taxes due to an anticipated backlash—developments in two critical streams repositioned the balance of feasibility.

Firstly, dynamics of the "problem stream" shifted as climate change impacts suddenly became exceptionally palpable, with warmer winters enabling the proliferation of the mountain pine beetle (*Dendroctonus ponderosae*) across millions of acres of forested wilderness [5]. Over a period of several seasons, infection of more than 300 million trees inflicted damages estimated at $6 billion [9]. In addition to the beetles' economic impact on regional ecosystem services, incalculable damage was done to B.C.'s intrinsic and historical place value and reputation [10]. As an acute, localized crisis, the beetle infestation captured public imagination in ways that abstract academic literature on forecasted climate impacts never could. Resulting social pressures served as authorization for British Columbia's politicians to take bold action on climate change [5, 10].

In concurrent events affecting the "politics stream," Premier Gordon Campbell became uniquely positioned to push an ambitious carbon tax through B.C.'s center-right controlled legislature. Facing a reelection fight in the wake of personal political scandal, Campbell understood that pushing an audacious carbon tax could offer him both a signature policy item and critical political cover [5]. Drawing on the prodigious experience of his inner circle led by Finance Minister Carole Taylor, Campbell expertly navigated the fraught landscape of carbon tax policy design—efficiency advancing simple, robust legislation before intra- or inter-party opposition could mobilize. Campbell's ingenuity allowed the tax to pass over left-wing opposition, which had expressed concern about the policy's potential to burden low income populations during a time of high gas prices [11]. Growing public and business popularity of tax rebates known as "carbon dividends"—which combat regressivity by distributing all revenues in uniform annual payments back to households—has since sustained the legislation despite repeated left-wing "Axe the Tax" campaigns [11, 12].

The British Columbia case therefore points to a two-prong approach for broader applicability. It is first necessary to consider how to catalyze social momentum to act on climate change (either through direct impacts or enhanced messaging); public pressures must then be seized upon by talented policy entrepreneurs.

The Regional Greenhouse Gas Initiative as an Act of Political Mimicry

Political scientist Herbert Simon's theory of bounded rationality suggests that decision-making by political actors on complex issues is often inhibited by temporal and cognitive limitations [13]. In this way, legislative outputs are often irreconcilable with the conclusions of rational decision theory, a favored tool of economic analysis [13]. Policymakers are well aware of such personal limitations and rarely lose sight of how an unpopular decision might impact a future reelection bid. As such, legislators often seek to establish a "consensus in the field of forces"—relying on a range of exogenous inputs to guide their personal beliefs on a particular course of action [14]. Perhaps no input is more influential than the voting behavior of trusted colleagues; when like-minded decision-makers act as a bloc on collective interests, they position themselves to reap communal benefits while avoiding political damage associated with fringe votes [15].

It is exactly the same politics of mutual interest and safety in numbers that underlie the Regional Greenhouse Gas Initiative (RGGI), a cap-and-trade system shared across the interwoven economies of ten New England states, representing 7% of aggregate U.S. CO2 emissions [16]. What began as a single-state emissions trading system in New Hampshire was transferable across jurisdictions of similar political ideology and demographic composition. In this way, RGGI states successfully captured the benefits of learning-by-doing, capitalizing on collective experience to overcome informational and administrative barriers and build strong public support for the carbon market prior to its entry into effect in 2009 [5].

RGGI capitalizes on a well-established framework of regional cooperation through joint quarterly emissions allowance auctions, while respecting participating states' independent regulatory techniques and revenue structures [5]. Several aspects of RGGI's policy design have been crucial in the program's durability. First, RGGI is narrowly focused to target carbon emissions from the electricity sector; the restricted scope of the initiative (i.e. compared to British Columbia's multi-sectoral tax structure) has produced effective mitigation results while simplifying necessary oversight and limiting broad political resistance [17]. Indeed, despite RGGI's narrow regulation of power plants with capacities of at least 25 megawatts—fewer than 200 facilities in total—emissions from in-state electricity generation decreased by 20% between 2012 and 2018, while electricity sales remained virtually constant [16]. Additionally, by encouraging the reinvestment of revenues in energy efficiency programs and renewable energy technology development, RGGI states have demonstrated a transparent linkage between emissions trading costs and concrete benefits [18].

The resulting program is thus politically self-sustaining due to its carefully cultivated jurisdictional alliances, simple and intuitive market approach within a limited power sector context, and transparent flow of money and information into tangible climate solutions. The RGGI case may therefore serve as proof of concept for the scale-up of simple, effective market-based policies that minimize administrative costs and leverage collaborative governance to aggressively target "low-hanging fruit" emissions reductions in decarbonizing the grid. Indeed, by eschewing a grandiose, complex policy vision, New England has quietly positioned itself at the forefront of U.S. national climate policy.

The Case of California's Cap-and-trade Program

California has, for decades, cultivated its image as a national standard-bearer on environmental issues; the state's longstanding bi-partisan ideological embrace of cap-and-trade is no exception, representing a clear indication of desire to lead on climate [19]. However, examination of the fallout from California's cap-and-trade legislation since its implementation in 2012 yields mixed conclusions, suggesting political consensus to be inconsequential in the absence of prudent policy forethought and planning [5].

Notably, the California case does not call into question the effectiveness of cap-and-trade as an emissions reduction strategy. The centerpiece of California's ambitious climate goals to reduce GHG emissions by 40% from a 1990 base year by 2030, the state's cap-and-trade system, despite periods of volatility, has achieved GHG abatement as intended [20]. The California Air Resources Board, which administers and enforces the program, notes that emissions from regulated entities are on track to decline by over 16% between 2013 and 2020.

Building on RGGI's electricity sector focus, California's program has generated a substantial revenue pool—in excess of $1 billion per year—from the auction of emissions permits spanning power, industrial, and transportation sectors [5]. However, revenue generation is not sufficient to ensure a successful market mechanism: to be self-perpetuating, revenues must be disbursed in an open, unambiguous, and socially admissible manner. It is in this phase that California has hit a political stumbling block; failure to prearrange an acceptable revenue scheme has precipitated competing political factions and wide-ranging influence campaigns to secure funding for innumerable (worthy) causes [21]. Rather than unite stakeholders around a cooperative vision of mitigation in the likeness of RGGI, California's cap-and-trade has provoked contention and the erosion of trust among statewide environmental alliances. Specifically, dueling proposals calling for investments in clean transportation, residential energy efficiency programs, and waste management have divided and confused community and NGO partners, undermining the policy's public appeal [21].

In this capacity, California's eagerness to enact legislation without specifying future implications has, in retrospect, proven rash and potentially counterproductive. As an alternative, Governor Jerry Brown has instead scored easy political victories penning relatively vague, symbolic environmental commitments—including recent legislation to convert California entirely to renewable energy by 2045 [5]. This case underscores the need for a defined vision of policy performance to complement initial adoptability if substantive change is to endure.

Will We See a U.S. Federal Carbon Price in Five Years?

Monumental challenges ingrained in the modern American political system will confront any meaningful near-term federal carbon pricing effort. As postulated by Kraft, congress has the necessary institutional capacity to study modern environmental problems but grossly lacks the cooperative mindset to prioritize of long-term public well-being over short term partisan political gains [15]. Such polarization reflects deep divisions in public opinion on climate change; fewer than 70% of Americans agree there is solid evidence of warming temperatures [22]. These conditions make the probability of durable federal carbon pricing legislation in the next five years extremely unlikely, however, successful carbon prices have often emerged from seemingly disadvantageous circumstances. Lessons from British Columbia, RGGI, and California dictate a series of prerequisites for any federal carbon price to overcome present barriers:

1. Climate change mitigation must be framed in the national discourse as a salient policy priority with impending consequences for individual and social welfare; a public sense of urgency must motivate and lend credence to policy entrepreneurs. Iterative communication of

scientific evidence between authorities, including the IPCC, and local decision-makers must lend legitimacy and political license to bold policy responses [23]. Meanwhile, civil society interventions must remain effective in amplifying public demand for ambitious action.

2. While no particular model of partisanship appears particularly inclined to succeed on carbon pricing, mutual trust among coalition members must enforce a joint commitment to a given pricing vision. Broad stakeholder engagement capable of incorporating local knowledge into policy planning processes is critical to facilitating long-term durability [5]. By contrast, undercutting of allies leads to the fragmentation of support and increases vulnerability to unstable policy "pendulum swings" from changing administrations [24].

3. Effective pricing mechanisms, whether carbon taxation, cap-and-trade, or otherwise must transparently showcase the application of revenues to achieve concrete social benefits (i.e., carbon dividends, energy efficiency programs, climate change adaptation, infrastructure). The federal government must advance a clear and decisive vision for distribution of revenues, thereby undermining the politically unpalatable idea of taxation [5].

Serious pursuit of a national carbon price undoubtedly poses an existential threat to a small subset of political careers, however, failure to engage this issue will relinquish the foremost policy mechanism to combat an existential threat that confronts society collectively. While five years may prove too short a timeline to dissolve ingrained oppositional interests, successful models inform the notion that carbon pricing is a worthwhile policy priority within the realm of long-term feasibility in the United States.

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A Proposal for a Mile-tax on Commercial Aviation in Spain

Communication | Editorial | Invited contribution | Perspective | Report | Review

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Abstract

The following communication uses Spain as a case study to survey how a mile-tax on short-distance flights could reduce CO_2 emissions in the commercial aviation sector by encouraging individuals to use alternative methods of transportation. The first part of the paper makes a case for action based on the foreseeable impact of climate change on Spain and evaluates the policies that have already been implemented. In doing so, the paper argues that there is room to increase taxation in the aviation sector because international agreements such as CORSIA and European Union Emission Trading Scheme (EU ETS) struggle to drive down the growing demand. The article then outlines the main aspects of the proposal and considers its potential impact along three dimensions: the environment, the economy and society. The paper therefore does not rigorously estimate the costs and benefits of the tax at an aggregate level but aims at showing how the tax could be applied and why could it be beneficial. Whilst Spain is used as a case study throughout the communication, the conclusions are not only relevant to this country but are valuable elsewhere.

Case for Action

Spain is a country that will suffer from climate change due to its geographic location and socio-economic characteristics [1]. An increase of just 1.5^{O}C in the mean global temperature would increase the likelihood of heat waves and reshape Spain's coastlines [2], reducing tourism in the Mediterranean littoral by 8% [3]. Under the 2030 European Energy and Climate Policy Framework, Spain has committed to reduce by 2030 its carbon emissions by 20% compared to 1990 [4].

However, the global targets will be missed unless measures are taken to address emissions in the transportation sector, and particularly in the aviation industry. While aviation currently accounts for 3.6% of total emissions and 13.4% of transport related emissions in Europe [5], emissions are growing at much higher than expected rates despite fuel efficiency improvements [6]. Indeed, international emissions in aviation could grow between 300 and 700% by 2050 [7]. International agreements such as the CORSIA scheme, which limits action to adopting fuel efficient technologies and implementing carbon offsetting projects, are not enough to reverse the trend [8]. A study from the European Commission showed that 87% of offsetting projects are not delivering the reductions they had been certified for [9].

At a national level, Spain should also play an important role in reducing aviation emissions: it is the tenth largest polluter [10] and its emissions have experienced a 5.3% annual increase over the past three years [11]. However, so far, the government's actions to reduce emissions in the aviation industry have been limited to complying with the European Union Emission Trading Scheme (EU ETS), which has allocated tradeable allowances to airlines operating flights in and between EU airports since 2012. Nevertheless, the inclusion of aviation emissions into the EU ETS has not yielded the expected results due to overallocation of allowances. Almost half of the allowances are given for free to airlines and the average cost of a permit is €20; implying just a €4 cost increase per flight [12]. As a result, the aviation industry has increased its emissions by 26.3% while other industries under the EU ETS have reduced theirs by 11.6% [12]. Moreover, the EU ETS will struggle to meet the 2^{O}C target by itself [13] because it is vulnerable to both lobbying [14] and fluctuations in the price of the allowances due to changes in the macroeconomic conditions. [15].

Therefore, the scope of the CORSIA and EU ETS schemes is limited because both schemes fail to address the main factor driving aviation emissions: the increasing demand. Indeed, aviation traffic is forecasted to double in the next 15 years; partly driven by the sector's low prices [16]. In Spain, ticket prices have fallen by 13% since 2013 [17] and a study by Nilsson shows that up to 60% of the demand for low cost flights has no intrinsic motivation besides their low price [18]. The CORSIA and EU ETS schemes could therefore be complemented by increasing taxation on the aviation sector. Doing so would not only help drive down demand, but also account for the environmental costs of carbon emissions — costs which are not currently reflected on the final ticket price but paid for by society as a whole. Given that the establishment of an EU wide aviation tax would face many challenges [19], national governments should take the lead and immediately drive down aviation emissions through taxation. The remaining part of this communication will study how raising ticket prices through a mile-tax on aviation might change consumer behaviour and reduce the demand.

A Mile-tax on Aviation: Goals, Scope and Alternative Models

1) Goal: reducing emissions by reducing demand.

As a first step, the proposed policy should set as its goal to stabilise aviation demand by achieving zero net growth. Over the past three years, the demand for domestic aviation in Spain has increased on average by 9.6% [20]. If growth is expected to continue over the following years under the business-as-usual scenario, the present demand would have to be reduced by 10% in order to supress demand growth. Reducing the demand by 10% would also reduce CO_2 aviation emissions by 10% under the European Commission's taxation model [21].

2) Scope

In order to suppress demand growth, this communication proposes setting a ticket tax on short distance flights to equate flight prices to a level playing field with other transportation methods [13]. For instance, taking a morning train from Madrid to Barcelona on the 19th of February costs €76,25 on economy class while the cheapest flight available for the same trip costs €43 (data retrieved from SkyScanner and RENFE websites). Flights are cheaper even if compared to cars since the trip fuel would amount to around €47.[1]

Using the European Commission model for aviation taxes, the proposed tax would have to increase the price of flight tickets by 10% in order to achieve a 10% reduction in demand, assuming the demand is linear [21]. In fact, prices could be increased less than this since the European Commission's model proposes the tax is applied to all flights equally, while this policy only applies to short distance flights which have a higher elasticity of demand due to the readily available

[1] Assuming an average gasoline consumption 5.6l/km [22] and gasoline price equal to 1.29€/l [23].

alternative transportation options [21]. While it is true that a 10% tax does not equate the price of flights to other available transportation methods, its levelling effect could still be reinforced by setting the tax as a hypothecated tax. This means that the revenues obtained from the tax are reinvested in improving the transportation network by, for example, increasing the frequency of trains and subsidising ticket prices.

The mile-tax would only apply to flights covering a straight-line distance between airports less than 850km and for which the quickest alternative transport option lasts less than 5.5 times the duration of the flight (distance limit adopted from [24], see also Table 1). The tax would therefore apply to Spain's three most popular peninsular air routes (which together amount for almost 4.5 million passengers) and would also include international destinations such as Barcelona-Paris (2.5 million passengers). Nevertheless, routes such as Madrid-Lisbon would not be taxed due to the poor rail infrastructure: while a flight to Lisbon takes roughly an hour, the train takes more than 10 hours. The tax would also exclude flights between the peninsula and the Canary and Balearic Islands (as well as Ceuta and Melilla) in order not to hinder the economic development of these regions.

3) Alternative Models

Alternatively, there are other taxation models the Spanish government could implement in order to drive down carbon emissions. Since EU member states need to enter into bilateral agreements in order to tax aviation fuel on intra-EU flights [26], countries like the United Kingdom have instead introduced ticket taxes which target long-distance flights [27]. However, the UK Aviation Tax has failed to stop the increase in demand [28] because it acts as a revenue-raising charge with no behavioural impact due to the absence of realistic alternative transport options [29]. Another proposal that has recently gained traction in the British media is to place a tax on frequent fliers [30, 31]. Proponents of this policy argue that 70% of flights are taken by just 15% of the British population [32] and should therefore be taxed more. However, the above argument is distributional rather than environmental in nature. Indeed, a frequent flier tax is unlikely to reduce demand because frequent fliers are less likely to change their behaviour because they are wealthier and less price sensitive [30]. Therefore, higher taxation for frequent fliers could complement, but not substitute, a mile-tax on aviation.

Cost and Benefits: Impact Assessment on Different Sectors

1) Environmental Impact

The environmental impact of short-distance flights should not be underestimated: one passenger travelling between Madrid and Barcelona emits more than the average citizen of eight different countries in a given year [33]. For instance, CO_2 emissions could be reduced by 25,000 tons per year if only 10% of the users of the Madrid/Barcelona route used the train instead of the plane.[2] Moreover, short-distance flights are less carbon efficient than long-distance flights since their emissions per passenger and kilometre travelled can be up to 30% higher [35].

2) Economic Impact

The proposed tax increase would have a negative economic impact on the aviation industry. A 10% ticket tax could reduce employment and the value of the sector by 12% [21]. Moreover, since the tax would not be applied equally to all flights, it would hinder the competitive position of certain Spanish airlines such as Air Europa, Iberia Express, Air Nostrum or Binter Canarias which mostly operate domestic flights [36]. The tax could also threaten the economic viability of smaller airports. In particular, the airports of San Sebastián, Valladolid, Pamplona, Vitoria, Leon, Algeciras, Salamanca and Burgos could be affected since they rely heavily on national flights and have less than 300,000 passengers per month [37]. However, the above worries need to

[2] Assuming that the emissions difference from a passenger taking a train instead of a plane in the Madrid/Barcelona route is 98.1 Kg [34] and that 2,572,410 passengers took a flight between Madrid and Barcelona in 2019 [25].

Table 1: Flights affected by the proposed carbon tax according to the 5.5 time ratio discussed in text. Bold: flights that would not be taxed; italic: flights between islands. Data elaborated from [25].

	Plane (min)	Train/Ship (min)	Ratio	Number of Passengers	Distance (km)
Madrid – Barcelona	75	330	4.4	2,573,822	506.1
Barcelona – Paris	110	396	3.6	2,521,633	831.85
Madrid – Lisbon	**70**	**637**	**9.1**	**1,557,731**	**504**
Barcelona – Malaga	95	300	3.15	846,105	771.45
Barcelona – Sevilla	100	330	3.3	1,041,850	830
Barcelona – Granada	90	380	4.22	492,247	683.01
Barcelona – Bilbao	75	394	5.25	619,794	469
Madrid - Santiago de Compostela	74	311	4.20	715,461	487
Madrid – Asturias	70	306	4.37	548,114	372.94
Madrid – A Coruña	75	355	4.73	681,626	509.54
Madrid – Vigo	70	366	5.23	684,274	465.9
Madrid – Bilbao	60	304	5.06	836,144	323.19
Ibiza – Palma de Mallorca	*45*	*120*	*2.66*	*534,540*	*117.76*
Palma de Mallorca – Menorca	*40*	*120*	*3*	*387,267*	*131.93*
Tenerife – Las Palmas	*30*	*120*	*4*	*146,930*	*88.45*

be put in perspective: the average passenger in Spain only pays €2.57 in aviation taxes while the average passenger in the United Kingdom pays €40.04 [21]. There is therefore enough room to increase taxes on aviation.

A tax on aviation could as well reduce connectivity and negatively impact domestic tourism [38]. However, its potential impact is limited. While almost 87% of national journeys are carried out for leisure or to visit friends and family, only 5.2% of those journeys were flights [39]. Moreover, the Spanish rail network, being the second largest High Speed Network in the world [24] and having an occupancy rate of 87.23% [40], is in a very good position to absorb most of the passengers lost by the aviation industry. Several studies have shown that trains, and particularly high-speed trains, work well as substitutes for aviation over the distances covered by the proposed tax (between 400 and 800km) [24]. The effect could be further reinforced by subsidising train tickets using aviation fiscal revenues which would quadruple after the introduction of the tax [21]. In 2013, a decrease of the price of train tickets by 11% [24] led to an increase of the number of passengers by 9.6% [40] despite GDP falling by 0.8%.

3) Societal Impact

The psychological effect of taxation and its potential to change consumer behaviour should not be underestimated. Increased taxation on particular products can trigger behavioural spillovers; inducing changes in separate but related behaviours [41]. For instance, a simple 5p levy on plastic bags did not only drive down plastic bag usage by 90% in the England [42], but also increased the support for additional charges on plastic bottles and excessive packaging [41]. A mile-tax on short distance flights is therefore a simple, initial step which could have a foot-in-the-door effect [43] by increasing awareness about sustainable transport and increasing support for more drastic policies concerning traffic restrictions and international aviation.

Challenges and Feasibility of the proposal

The political context is now suitable to introduce new taxes on aviation. Aviation taxes also enjoy increasing public support [44] and the French [45] and German [46] governments have recently introduced new taxes at a national level. In Spain, a tax on aviation is likely to receive the approval of the parliamentary majority which supported the establishment of the new, progressist government in Spain [47]. However, further consideration should be given to the legal feasibility of the proposal. In 2009, the European Commission forced the Irish government to withdraw a tax which charged higher rates to flights departing from Dublin covering distances larger than 300km on the basis that it provided unlawful state aid to domestic airlines [48]. However, the tax outlined in this proposal does not commit the same mistakes as the Irish tax since it does not measure distance from a particular airport and does not benefit national airlines over European airlines. Moreover, the above concerns could be easily resolved if the scope of the proposed tax was limited to domestic flights, as in the case of Italy, which applies different rates to domestic and EU flights [21].

Summary of the Opportunity

Given that international schemes such as the EU ETS and CORSIA are not enough to tackle aviation emissions, there is an increasing need for national governments to take action. This article has studied how introducing a 10% ticket tax increase on all flights shorter than 850km could help reverse this trend. Doing so would not only drive down demand and consequently carbon emissions but could also drive behavioural change towards more sustainable transport options as well as opening the door to further environmental restrictions. While it is still necessary to undertake a detailed cost-benefit analysis to estimate the full impact of the proposed policy on macroeconomic growth, the communication has argued that the impact on tourism would be minimal and that the Spanish rail network is in a good position to absorb the costs imposed by the policy on the aviation sector.

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A Long Overdue End to Flicker: The 2020 EU Lighting Efficiency Regulations

Communication | Editorial | Invited contribution | Perspective | Report | Review

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Abstract

Flicker, the temporal modulation of light, is an unwanted effect found in energy efficient light bulbs. It is caused by cheap ballasts, the power supplies that are required for their operation. As energy efficient light bulbs were pushed into consumer's homes by EU and US energy efficiency regulations, it has become a health concern: Flicker has been linked to eyestrain, headaches and migraines. Literature and studies on these effects were widely known by the time the first energy efficiency legislation was passed. Complex and thus more expensive ballasts have always been able to provide high quality, flicker free light, but were adopted only slowly. When fluorescent lights made their way into consumer's homes in the early 2000s, regulation was enacted that all but eliminated the flicker caused by their ballasts. When it became clear that LEDs would soon replace their fluorescent counterparts, no legislative action was taken to ensure the same performance standards. Instead, priority was given to lower lamp cost.This resulted in the widespread use of cheap power supplies in LED products released during the past decade. To consumers, the flicker behavior of lamps seemed arbitrary and a general property of LED light bulbs, rather than the result of an inadequate, yet low-cost power supply. This led to reservations about the new technology amongst consumers. The latest EU lighting energy efficiency regulation (EU) 2019/2020 finally made LED based light bulbs flicker free by enacting strict performance limits on ballast performance. The United Kingdom must adopt similar standards or risk seeing all those low-quality light bulbs that cannot be sold on the EU market on store shelves. This policy brief aims to inform about the fundamental cause of flicker in artificial lighting, its negative effects on wellbeing and considers the drivers of EU legislative response in support of advances in lighting technology.

1 Introduction

We are surrounded by artificial light wherever we go. It has become integrated into our environment, be that it in the office, in factories, hospitals or at home. Yet, its importance for economics and human well-being cannot be understated. Historically, human productivity has been directly correlated with the available amount of artificial light [1]. Such was our hunger for fuelling the lamps that provided us with the urgently needed illumination, that humans hunted entire species of whales to the brink of extinction for their fat-rich blubber. Even today, more than 10% of total produced electricity is used to light our homes, streets and factories [2].

Following the commercialization of the incandescent light bulb by Thomas Edison in 1879, efficiency improvements were few and far between. Better glowing filaments and inert gas fillings eventually led to halogen light bulbs still on store shelves today. Their low average efficiency of 15 lm/W mean that more than 90% of energy was radiated as heat instead of visible light. Edison also experimented with fluorescent lights but initially did not pursue their development further. Operating at a higher efficiency of 100 lm/W, their large scale deployment in factories and offices started in the 1920s. Research into light emitting diodes (LEDs) started in the 1950s and led to the first use of red LEDs in computers and calculators in the 1960s. High cost and low light output limited their use to indicator lights. Only when Shuji Nakamura and colleagues achieved a performance breakthrough in blue LEDs in 1993 did scientists start to see the possibility of general illumination applications for LEDs [3]. Since the first prototypes of red LED lights in 1968, light output increased 30-fold per decade with prices falling 10-fold. Today, efficiencies in excess of 200 lm/W have been achieved.

In the wake of technological improvements, the first regulations on lighting energy efficiency were proposed shortly before the turn of the 21st century. In 2009, the incandescent light bulb was being phased out in Europe and the United States [4, 5]. The projected savings resulting from the enforcement of increasing minimum efficiency requirements (Figure 1) are impressive. Regulations put in place in 2009 and 2012 are currently saving EU consumers 20 Bn.€ annually, compared to a scenario without any legislative action on the behalf of energy efficient lighting. Electricity consumption was decreased by 93 TWh annually, the equivalent of the total consumption of Croatia [6].

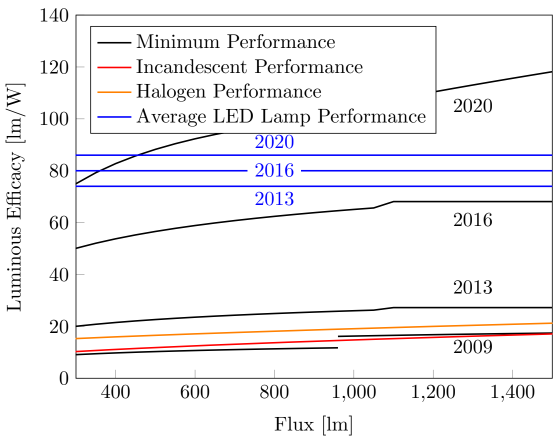

Figure 1: Minimum required efficacy for lamps set out in EU regulations 244/2009, 1194/2012 and 2017/2020. The performance curve for the year 2009 still shows a discontinuity at 900 lumens, an exception originally made for household bulbs. Efficacy takes into account the wavelength-dependent sensitivity of the human eye and describes how efficiently electrical power is converted to the radiant power of a light source. Sources: [4, 7, 8].

Yet these energy efficiency regulations were implemented at a time when the most affordable technology able to meet requirements were fluorescent lights. These contained considerable quantities of mercury and produced a spectrum that is known to interfere with the human circadian rhythm [9], increase the likelihood of eye disease [10] and alter cognitive performance [11]. More importantly, a completely new problem came with the use of fluorescent and LED lighting: flicker, the visual unsteadiness of light output. The discomfort and health issues that came with it were addressed by legislation in fluorescent lights as they entered consumer's homes but were disregarded for LEDs until recently. For once, public concern about EU legislation was supported by scientific evidence from the very beginning.

More than a decade into the post-incandescence era, the European Union has finally fixed legislation to include strict performance requirements

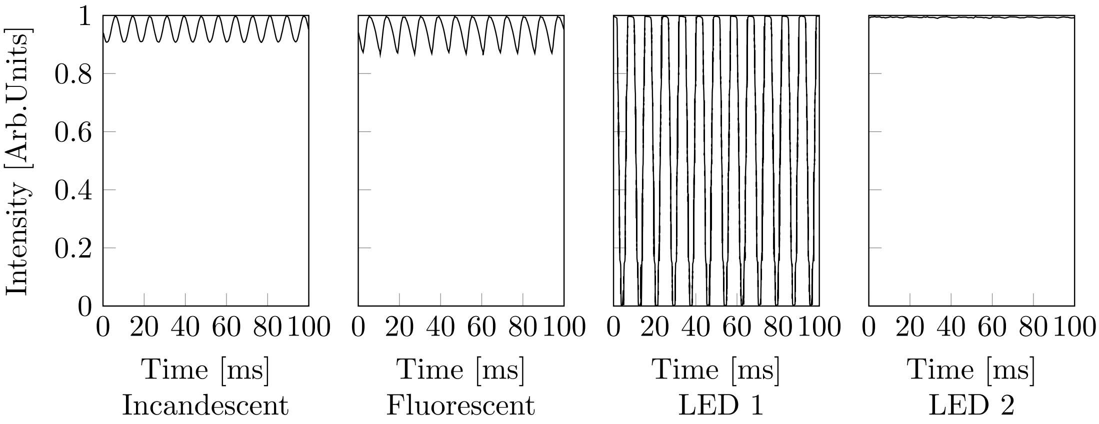

Figure 2: Time-dependent light intensity of incandescent, fluorescent and two different LED light bulbs. The incandescent bulb shows little modulation in its light intensity and thus good flicker performance. Significant increases in modulation can be seen for the fluorescent bulb. LED 1, equipped with a cheap ballast, displays levels of modulation that cause flicker at a level that is classified as 'dangerous' according to the safety guidelines from Figure 3. LED 2, equipped with a more complex and more expensive ballast, shows no visible flicker. Source: [12].

on all aspects of light quality and energy efficiency. Earlier concerns about the problem were relegated with references to the higher cost of the needed technology. Considering the history of flickering lights can provide useful insights into how negligence has fuelled public concern and contributed to consumer uncertainty.

Theory of Flicker

Flicker, the temporal modulation of light intensity, is a ubiquitous phenomenon. We are confronted with it in the form of rays of sunlight shining through roadside trees or flashing neon signs. At certain combinations of frequency and intensity, flicker can have unwanted effects on health.

Temporal modulation of intensity in artificial light sources can have different causes, but fundamentally stems from the use of alternating current (AC) of roughly 50Hz in our electrical mains. Following the 'War of the Currents' between Thomas Edison and George Westinghouse in the late 1880s, AC power distribution systems became widespread [13]. Current in our appliances reverses direction 50 times per second, effectively switching all electrical lamps on and off at twice that rate.

Following the commercialization of tungsten-filament incandescent light bulbs at the turn of the twentieth century, this had little effect on the quality of light. The afterglow of the tungsten filament in incandescent bulbs is long enough to smear the effect of the AC current. The first prominent examples of flickering appliances only came to market in the 1930s in the form of fluorescent light tubes. No afterglow is present in this technology, owing to their fundamentally different mode of operation. Connected directly to the grid, these lamps produced flickering at a rate of between 100-120Hz. LED lamps too have no afterglow momentum and cannot be connected directly to power mains[1]. Dedicated electronic power supplies, called ballasts by lighting professionals, are thus used for both technologies. In theory, they should mitigate flicker and protect the light bulbs from surges in the electricity grid. However, the increased cost associated with high performance ballasts makes them the bottleneck of light quality and ultimately responsible for flicker. The comparison of time-dependent intensity of the different types of light bulbs discussed is shown in Figure 2.

[1]Confusion is sometimes caused by 'Driverless LEDs', which in fact *do* have drivers (ballasts), which are integrated into the circuit board on which the LEDs are mounted.

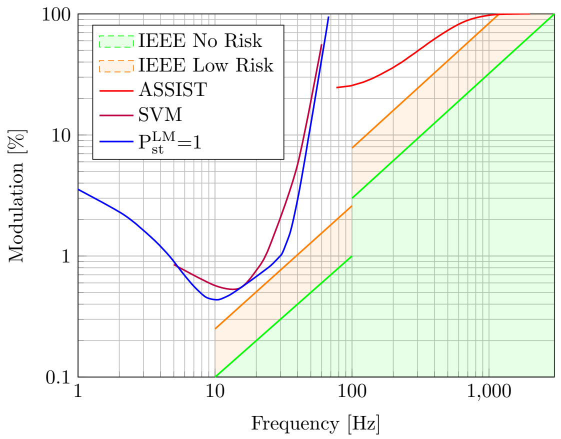

Figure 3: Limits for human perception of flicker, according to different models : ASSIST by Rensselaer Polytechnic Institute, the IEEE and SVM/P_{st} by the IEC. Below the curves, flicker is invisible to the human eye. The shaded areas give an approximate risk assessment for health issues caused by exposure to flicker. The human nervous system is most sensitive to flicker in the range of 10<f<50Hz, as can be seen from the curves. The $P_{st}^{LM} = 1$ curve has been adopted as a minimum performance limit in EU Regulation 2019/2020. It is equivalent to the levels of flicker present in incandescent light bulbs. Sources: [14, 15, 16].

Reliably measuring flicker is a challenge in and of itself. A meaningful metric must include both the waveform of the light intensity, the base frequency of flicker and the frequency dependence of human flicker perception, shown in Figure 3. Still, the most commonly reported metrics today describe only basic waveform properties like minimum and maximum values [12]. Out of many recent attempts made to combine frequency, modulation and human visual response into a compound metric [17], the European Union has settled on P_{st}^{LM}, the short-term flicker indicator. Defined by the International Electrotechnical Commission, it takes into account the frequency-dependent sensitivity as well as base frequency and waveform. The output is a real number, indicating the likelihood of flicker detection by an average observer. Lower numbers indicate lower levels of flicker and thus lower likelihood of detection. A value of $P_{st}^{LM} = 1$ corresponds to the amount of flicker produced by a 60W incandescent lamp with average mains voltage modulation. This value is chosen such that a 50% of human test subjects can identify flicker [18]. Values of $P_{st}^{LM} = 1$ are achieved by fluorescent lamps with electronic ballasts, while values of $P_{st}^{LM} > 1$ are easily achieved by inadequately driven LEDs.

As can be seen from the bibliometric analysis in Figure 4, the health effects of lighting flicker had been an active area of research before the advent of LED lighting for general illumination in 2010. Such was the concern about flicker that even the effects on captive birds were studied, showing that the amount of flicker affected mate choices made by females [19]. Exposure to light flickering at 100Hz has been linked to eyestrain, headaches and migraines, even though this rate of flicker is above the human perceptual flicker-fusion frequency of around 60 Hz [20]. Effects of flicker on humans were summarized most recently in a 2010 review by the IEEE, the largest professional organization of electrical engineers [20].

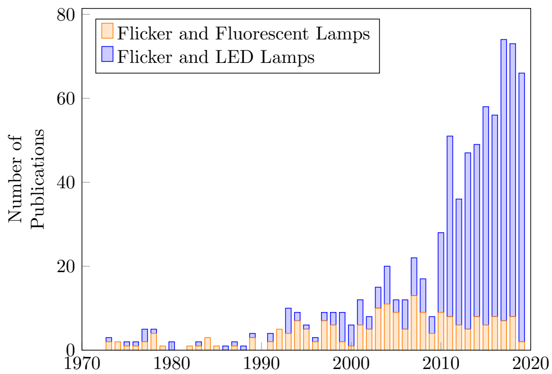

Figure 4: Stacked plots of the number of publications dealing with flicker related to lighting technologies. Data from Elsevier Scopus.

The Ballasts

Fluorescent lamps and LEDs alike have no afterglow and translate the rapidly changing mains current directly to light. For both the mitigation of flicker and their electrical properties, they require ballasts. These components regulate the amount of current flowing though the lamp and protect it from surges in the grid.

Magnetic ballasts for fluorescent lamps used a simple copper coil to achieve this. Capacitors were later added to improve efficiency. This gave rise to the characteristic plinking noise upon switch-on and the buzzing sound during operation. Essentially, the lamp still operated at the electrical mains frequency of 50Hz, resulting in flickering at a rate of 100Hz [21].

Electronic ballasts that used additional electrical components to increase the current frequency were introduced in the 1970s. By the end of the decade, not only their superior flicker performance, but also their positive effect on fluorescent lamp efficiency had been recognized [22]. Because of their increased complexity and the use of active electrical components, their overall cost was higher than their magnetic counterparts.

For LEDs, much like for fluorescent lights, lower flickering and higher efficiency are attained by complex multi-stage electronic drivers that include more expensive components and are more costly in manufacturing than their magnetic counterparts.

The Regulation of Lighting Efficiency

Since 2009, three different pieces of legislation have set minimum performance requirements for lamps in the EU. Regulations *(EC) No 244/2009*, *(EU) No 1194/2012*, and *(EU) 2019/2020* each set minimum performance requirements in increasing stages. 2009 exceptions for lamps with a luminous flux below 900 lm, shown in Figure 1, were soon repealed and resulted in a phase out that was more commonly referred to as the 'light bulb ban'. The latest regulation is not only increasing the minimum required efficiency even further, it also limits flicker dramatically. The requirement is now for LED lamps to perform at a level of $\mathrm{P}_{\mathrm{st}}^{\mathrm{LM}} \leq 1$, never exceeding the level of flicker found in a 60W incandescent light bulb.

The Regulation of Flicker

Energy efficient lighting was first used in office buildings and factories. For these industrial applications, basic flicker standards were quickly set, as flicker was known to cause nasty accidents caused by the stroboscopic effect in rotating machinery. Only around 2000 did fluorescent lights find their way into consumer's homes as a result of energy efficiency regulations. At that time, electronic ballasts had gradually replaced magnetic ballasts where cost was less of a concern and high efficiency was of paramount importance. In low cost applications, lamps continued to 'flicker on'. As prolonged exposure to flickering lights thus became more prevalent, measures were taken to quickly phase out old magnetic ballasts. In the US, the *Energy Policy Act* of 2005 extended efficiency standards to magnetic ballasts, effectively phasing them out in 2010 [5]. In the EU, *Regulation (EU) No 347/2010* finally prohibited the use of magnetic ballasts in lamps following the introduction of minimum efficiency requirements in 2010 and 2012 [23]. This effectively ended visible flicker in fluorescent lights.

By 2010, it had was clear that LEDs would soon replace their fluorescent counterparts [24]. But while a 2013 study following up Commission Regulation (EC) No 244/2009 concluded that *'modern CFLs are basically flicker-free due to their electronic high frequency ballasts'*, it dismissed all further concerns on this effect by arguing that there was lack of scientific evidence pointing to it causing more serious conditions such as epilepsy. It also acknowledged the discomfort caused by flicker [25]. The absence of any regulations on this important quantity was explained in the study as conflicting with goals set for compactness and cost of LED lamps. This was corroborated by other authors [26] and ran contrary to a prior warning in the 2009 impact assessment prepared for the 2012 EU legislation which concluded, that *'These technologies have important energy saving potentials, but may have (still) some functional drawbacks [...]. If these new energy saving technologies are "pushed" prematurely, it may well have a detrimental effect on their long-term success'* [27]. Thus, while the detrimental health effects of flickering lights were well recognized and successfully addressed for fluorescent lights, economic and environmental considerations led to an omission of similar requirements in the legislation at the time. No cost-benefit analysis prepared for the legislation impact assessment considered the health effects or the potential public backlash against lower quality lighting.

Resulting Public Concern

LED light bulbs are saving consumers hundreds of dollars per year in electricity costs [28], have a significantly longer lifetime and contain no toxic metals. But existing legislation in the EU and the US left LED ballasts unregulated, which has led to a market situation where flicker in light bulbs is completely arbitrary [29]. Some products show no flicker, while some have dangerous levels, as defined by the IEEE and shown in Figure 3 [16]. The uncertainty that came with this market situation has since been used to justify legal action against lighting energy efficiency regulations. Four bills opposing a phase-out were drafted in the US. While one bill sought to limit federal involvement in energy efficiency programs more broadly [30], all sponsors cited health concerns as the primary reason for the bill. In the United Kingdom, an interest group called the Spectrum Alliance similarly lobbied to amend the existing regulations [31].

Looking beyond the EU and Conclusion

Nearly ten years after the first commercial LED bulbs made it to store shelves, the technology has matured, now providing higher efficiency, longer lifetimes and lower lifecycle costs compared to incandescent or fluorescent alternatives. EU energy efficiency policy played a key part in helping the technology gain market penetration and generate the impressive energy savings it did [6]. With the latest regulations, quality of light too will finally surpass that of incandescent light bulbs.

Yet for consumers in the United Kingdom, the situation is not as clear. For one, lamps are traded globally. Foreign markets thus benefit from increasing efficiency requirements in the European Union. However, if the United Kingdom does not adopt similar requirements on flicker, producers have an opportunity to dump those lamps that do not meet EU regulations on the UK market. To reduce flicker and all the discomfort and health issues that come with it, it is therefore imperative that the UK follows suit and adopts EU legislation on lighting efficiency and quality of light.

On a larger scale, legislation that has well documented potential to impact consumer health must look beyond its original motivation of increasing efficiency and ensure that regulatory frameworks exist to ensure all effects of new technologies are considered holistically and their externalities are mitigated. Efficiency regulations for combustion engines serve as an excellent example, having been introduced not only to reduce carbon emissions, but also to improve air quality and by extension increase consumer health and well-being.

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Afforestation's potential to help Cambridgeshire reach net-zero by 2050

Communication | Editorial | Invited contribution | Perspective | Report | Review

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Abstract

I present a preliminary assessment of afforestation's ability to help Cambridgeshire reach net zero emissions by 2050. Considering 7 different planting scenarios with different tree species over 3,000 hectares (about 1% of the county), I calculate a maximum cumulative net sequestration of 1.44 Mt CO_2 over the period 2020-2050, about 2.3% of the county's projected total emissions over that period under an ambitious decarbonisation strategy (or about double the county's projected emissions in the single year 2050). In addition, a methodology for calculating carbon sequestration and the associated abatement cost is presented, with sensitivity to land price and timber revenue explored. I calculate abatement costs of £20-50 per tonne CO_2, considerably less than those from bio-energy carbon capture and storage (BECCS) and direct air carbon capture and storage (DACCS), although it depends strongly on timber price. This suggests afforestation has the potential to be a cost-efficient method for contributing to Cambridgeshire's ambitious climate change strategy, but significantly larger areas would need to be planted if it were chosen to be a major driver in reducing net emissions.

Introduction

Reforestation and afforestation, the acts of replanting trees in deforested regions and in regions without previous tree cover respectively, have been identified as a key method for reducing net carbon dioxide emissions globally, a vital for mitigating climate change. A recent paper in *Science* stated that '*the restoration of trees remains among the most effective strategies for climate change mitigation*' [1] and the UK's Committee on Climate Change Net Zero report identified an afforestation target of 20,000 hectares per year increasing to 27,000 by 2025 [2]. In contrast to Direct Air Capture (DACCS) and Carbon Capture and Storage (CCS), afforestation does not require infrastructure to transport and store captured CO_2. In addition to sequestering CO_2, afforestation, when properly planned, can enhance biodiversity and inhibit soil erosion while also benefiting the public by providing places for exploration and recreation [3]. Programmes in Scotland increasing the public's interaction with woodland have been shown to help contribute to positive mental health in a cost-efficient manner [4]. Afforestation efforts have significant political support, appearing in the 2019 General Election manifestos of the Conservative, Labour and Liberal Democrats [5]. However, quantitative analysis of the amount of carbon sequestered by afforestation is less common but is crucial if countries are to continue to calculate accurate greenhouse gas emissions inventories and if afforestation is to be carried out efficiently as a mean of mitigating climate change.

A preliminary assessment of afforestation's potential to help Cambridgeshire reach net zero formed part of the report 'Net Zero Cambridgeshire' written in partnership with Cambridgeshire County Council (CCC) [6]. The report was presented to the CCC's General Purposes Committee and accepted as part of the evidence base for CCC's Climate Change and Environment Strategy. Here I describe the methodology for calculating the carbon sequestered by afforestation in brief and the respective results focusing on the extent of necessary afforestation, estimated abatement cost, and timescale of sequestration.

Cambridgeshire's Emissions

Cambridgeshire's total greenhouse emissions in 2016 were 6.1 Mt CO_2e (mega-tonne of carbon dioxide equivalent) [6]. Two scenarios, 'business as usual' (BAU) and 'ambitious' were considered for future emission projections. The BAU scenario considered only current or planned emission reduction policies, following the Steady Progression National Grid Electricity System Operator (ESO) Future Energy Scenario (FES) [7] for electricity and gas demand and decreases in the National Grid's carbon intensity following projections from the Department for Business Energy and Industrial Strategy [8]. In this scenario net annual emissions fall to 3.5 Mt CO_2e by 2050 (43% reduction). A major driver of this decrease is the decarbonisation of the national grid. In the 'ambitious' scenario, net annual emissions decrease by 90% to 0.6 Mt CO_2e with significant additional emission reductions predicted in the transport, domestic housing and commercial buildings sectors. This is driven in part by a significant decrease in gas demand due to adoption of low carbon heating, and transport emissions decline by 95% due to total electrification of cars and buses. However full decarbonisation is highly unlikely, as electricity generation in 2050 won't be zero-carbon intensive [8] and because decarbonising certain industries, such as agriculture, is challenging. In order to reach net-zero, there is a need to explore negative emission options such as afforestation.

Carbon Sequestration

To calculate cumulative net sequestration of carbon dioxide over time for different combinations of tree species, data was used from the Woodland Carbon Code (WCC) [9], the UK standard for afforestation projects for climate change mitigation. An area of 3,000 hectares (ha, 11.7 sq. miles or 30 km^2, equivalent to about 1% of Cambridgeshire) was considered for these calculations, and seven different planting scenarios (Table 1) spanning coniferous and broadleaf species covered by the WCC data were investigated. Some of the species considered like Sitka Spruce are commonly used in afforestation while others like the native woodland mix would promote slower growing, more diverse woodland. Spacings on a range between 1.5 and 3 metres were considered, with 3m spacings resulting in about 1,100 trees per hectare. Thus 3,000 ha would result in 3-7 million trees being planted in Cambridgeshire, an order of magnitude greater than the total number planted since 2000.

Methodology and Assumptions

The cumulative net sequestration after a given period of time after planting is defined as the carbon dioxide sequestered by the trees and soil less the carbon emitted from soil disturbance and other establishment processes, calculated following WCC guidance [9]. Sequestration from the trees was calculated using inputs of tree species, tree spacing, yield class, and management regime. The yield class for the different species were determined using tools from the Forestry Commission (in line with WCC guidance) [10]. Yield class defined as the average volume (m^3) of wood produced by a tree species per hectare (ha) per year and it is a proxy for the suitability of a particular

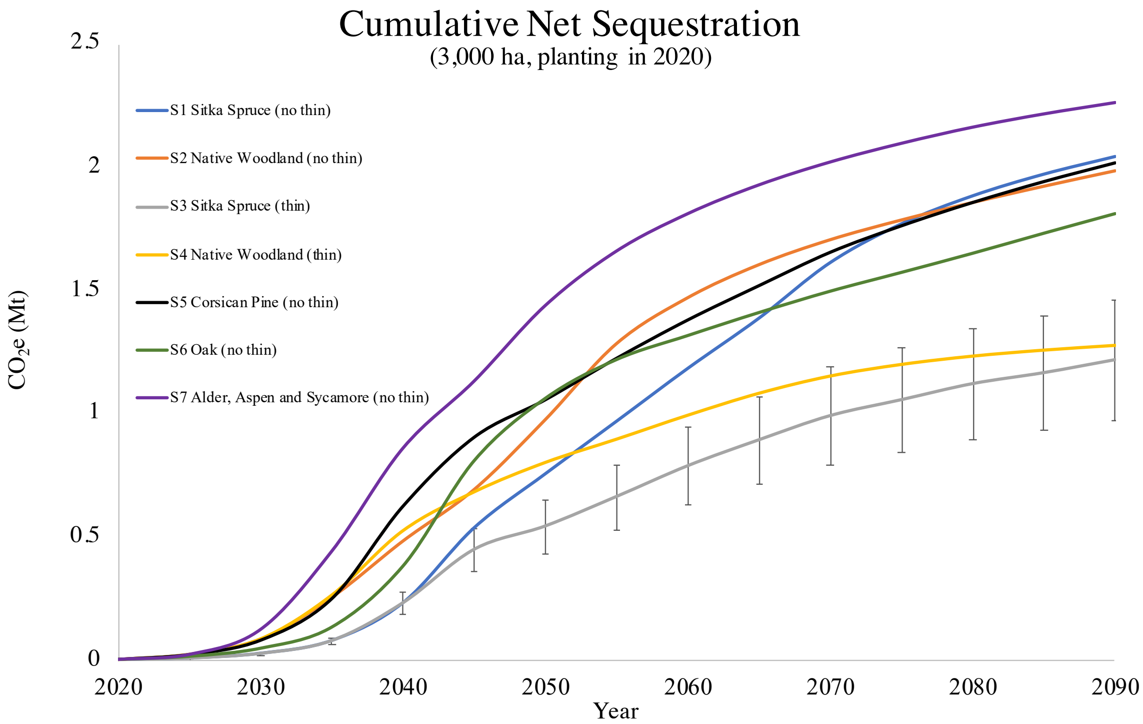

Figure 1: **Cumulative net sequestration with time.** The mixture of Alder, Aspen and Sycamore results in the greatest sequestration, while both simulated scenarios in which thinning occurs every 5 years ('thin') show substantially lower sequestration. Errors bars have been included for one scenario to provide an idea of the uncertainty in the model.

tree species for a certain location: a species of yield class 10 produces 10 m^3/ha/year of wood.

The yield class for a particular tree species is strongly dependent on the soil quality and species. Slow growing species such as Oak have yield classes between 4 and 10 while fast growing species such as Sitka Spruce and some pines have yield classes which can exceed 20 in the right conditions. Soil quality is parameterised using two metrics: Soil Moisture Regimes (SMR) and Soil Nutrient Regimes (SNR). These describe the level of moisture and nutrients in the soil respectively. SMR ranges from very moist (deep peat) to very dry (shingle), while SNR varies between very poor (deep peat) to very rich while also having the option of carbonate which restricts the species suitable for planting. In this study, values for SMR and SNR of 3 (very moist) and 5 (very rich) respectively were used as these conditions are found throughout Cambridgeshire and are suitable for a range of species. The management regimes considered were thinning once every 5 years or with no thinning at all; both were explored (Table 1). Finally, for each scenario, the carbon sequestered by trees was reduced by 20% in line with WCC guidance to account for uncertainty in the underlying data before calculating the cumulative net sequestration.

Soil carbon sequestration, which averages about 0.55 tCO_2 per ha per year, was also included for all scenarios which had no thinning following the WCC protocol. Disturbing the soil when planting can release carbon dioxide, and these emissions were included in the calculations. The quantity of CO_2 emitted depends on the soil type, previous land use, and level of soil disturbance. The soil type was assumed to be mineral, a fair assumption in Cambridgeshire; the chosen previous land use was arable given the dominance of crop agriculture for land in Cambridgeshire; and soil disturbance as low following the WCC's definitions. The validity of such assumptions will vary between planting locations, but they are not anticipated to have a significant effect on the cumulative sequestration after 20 years of growth. Additional establishment emissions from fuel used during ground preparation (0.06 tCO_2 per ha) and seedlings (0.38 tCO_2 per ha) were included in accordance with WCC guidance. Emissions from tree felling and processing of the timber was not included.

The plots of cumulative net sequestration with time (Figure 1) show that over the 30 years to 2050, the cumulative net sequestration varies considerably between scenarios with the mixture of Aspen, Alder and Sycamore (1.44 Mt CO_2e) sequestering well over twice as much as the thinned Sitka Spruce (0.54 Mt CO_2e). This highlights the importance of assessing potential carbon sequestration and planting the optimal mixture of trees when deciding on planting strategies. The increase of sequestration with time is also highly non-linear with a slow initial increase followed by a faster increase commencing at around 15 years of age. This illustrates an important feature of sequestration by afforestation: that of a time lag at the start where cumulative sequestration is small for several years. Thus, the sooner trees are planted, the better, particularly given the urgent requirement to reduce net carbon emissions. In the context of Cambridgeshire's emissions, planting 3,000 ha is predicted to sequester 0.9-2.3% of the county's total emissions between 2020-2050 (Table 1) or around 100-200% of the emissions predicted to occur in the year 2050.

Cost of the intervention

In addition to the net sequestration of carbon, the associated costs were estimated to allow for calculation of the abatement cost (AC) which is defined as the cost per tonne of CO_2 sequestered. The major costs were taken to be cost of trees, planting, purchase or rental of land, and the cost of managing the land. Financial support from the Government and revenue from timber sales were considered as means to reduce the abatement cost. The cumulative net CO_2 sequestration over a 30-year period (2020-2050) was considered assuming planting in 2020. The abatement cost is described by the following Equation:

$$AC = \frac{(\mathrm{T} + \mathrm{P} + \mathrm{L} + \mathrm{M}) - (\mathrm{G} + \mathrm{S})}{\mathrm{CO}_2^{\mathrm{seq}}} \tag{1}$$

where T is the purchase cost for the trees, P is the planting cost, L is the land cost, M is the management cost, G is the government support, S is the sales from timber, and CO_2^{seq} is the cumulative net CO_2 sequestration.

Methodology and Assumptions

The cost of land was the most dominant factor, and four scenarios were considered: renting land from either the 12,000 ha Rural Estate (RE) owned by CCC at £327 per ha per year (strictly an opportunity cost in the case of the CCC using their own land for afforestation), renting land at the East of England (EoE) average rate of £240 per ha per year on Full Agricultural Tenancy [11], or purchasing Grade 3 farmland (£7,500 per acre [12]) or grazing land (£4,500 per acre [12]).

Wholesale purchase of trees of £0.40 per tree[1], planting costs of £1,250 per ha [13], management costs £150 per ha per year without thinning (thinning scenarios had an additional £1000 per ha every 5 years) and staffing costs (£75,000 per year) were included. Financial support from the UK Government for purchasing trees, in the form of the TE4 Capital Grants scheme (£1.28 per tree) [14], was also included.

Revenue from timber sales was estimated. Multiplying the duration of tree growth by the yield class gives the volume of wood per hectare. While timber prices are a source of considerable uncertainty, they have shown long-term growth [15], increasing by 130% over the last 20 years (coniferous wood, sold standing) and a drive to use more sustainable materials in construction such as wood over concrete is expected to increase demand in the future. Data for softwood prices (pine, spruce etc.) were used for all species due to a lack of reliable data for other species. This means that the calculated abatement costs calculated are likely to be lower bounds. To account for this uncertainty as well as for other unforeseen costs, the total wood yield was halved to produce a more conservative estimate. In addition, the AC shown in Table 1 also includes the scenario where there is no revenue from wood sales. It is also assumed that the wood sold is not combusted (but is instead used in construction, paper, or other applications that do not release the stored CO_2).

[1] Price determined from a wholesale tree supplier (April 2020).

Table 1: **Scenario Details, Net Cumulative Sequestration (2020-2050) and Abatement Cost.** YC: yield class [m^3/ha/year], CO_2^{seq}: cumulative net CO_2 sequestration, AC: abatement cost, *Assuming 5% year-on-year drop in emissions (~80% reduction by 2050), ** Assuming planting on Rural Estate, *** Native Woodland: 20% Oak , YC 8; 20% Sycamore, YC 10; 20% Birch, YC 4; 8% Aspen, YC 10; 10% Alder, YC 6; 10% Rowan, YC 4; 12% Willow, YC 4; all spacings 2.5m, except for Oak at 2m (WCC Standard Example 2).

Scenario	**Scenario Description**	**CO_2^{seq}(% of total 2020-2050 emissions*) [Mt CO_2]**	***AC*** **with and (without) timber sales [£ per tCO_2]**
S1	Sitka Spruce, 2 m, YC 12	0.76 (1.2%)	34 (57)
S2	Native Woodland***	0.98 (1.6%)	35 (44)
S3	Sitka Spruce, 2 m, YC 12, thinned	0.54 (0.9%)	80 (112)
S4	Native Woodland,*** thinned	0.75 (1.2%)	65 (76)
S5	Corsican Pine, 1.5 m, YC 14	1.06 (1.7%)	22 (41)
S6	Oak, 3 m, YC 6	1.06 (1.7%)	32 (40)
S7	Alder YC 6, Aspen YC 10, Sycamore YC 10, spacing 3m (equal fractions)	1.44 (2.3%)	20 (30)

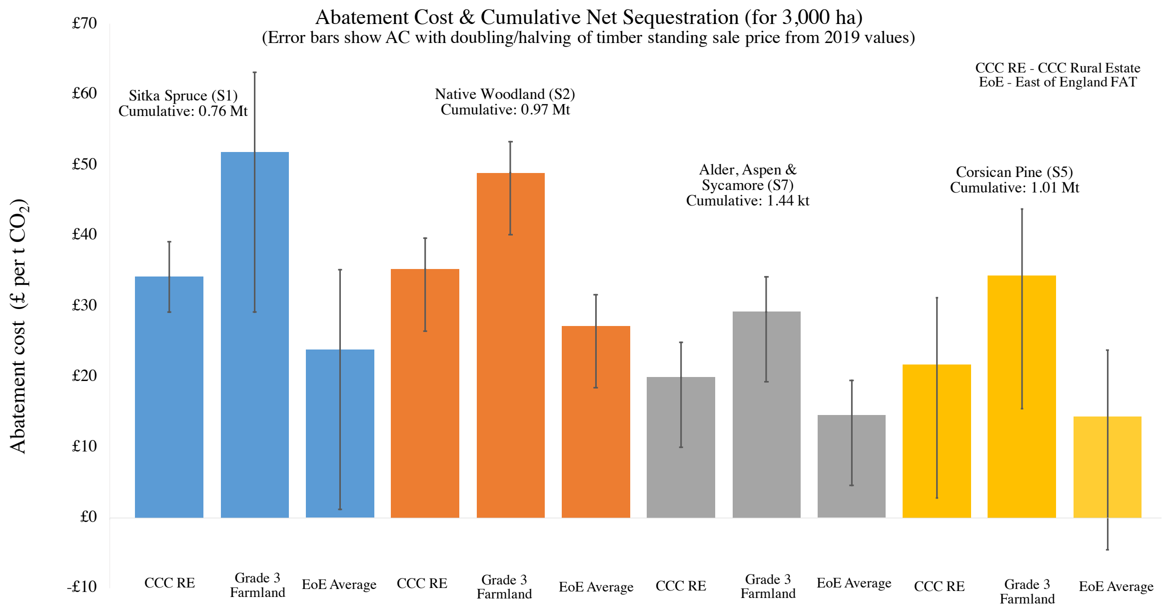

Figure 2: Abatement cost and Cumulative Net Sequestration for 4 planting scenarios in 3 different land scenarios: CCC Rural Estate (RE), Grade 3 Farmland [12], and East of England Full Agricultural Tenancy [11]. Sensitivity to the timber price [15] indicated by the doubling/halving the value (indicated by error bars) is shown to be a major driver of the calculated AC, particularly for the plantings that rely on high timber yield. Therefore, consideration of future timber price is important for more comprehensive afforestation studies.

To understand the influence of the timber price on the predicted AC, the AC was calculated with no timber revenue (Table 1) and under situations where the timber price was doubled and halved (relative to 2019 value) on RE, EoE and Grade 3 farmland. These changes resulting in average AC changes of -£15 and +£8 per tCO_2 respectively across the scenarios (Figure 2). The EoE and GZ option had ACs as low as £16 per tCO_2 for Scenarios 5 and 7. The magnitude of this uncertainty means that any plans for afforestation should consider timber price projections carefully and account for potential fluctuations.

Conclusion

This preliminary investigation suggests afforestation in Cambridgeshire could have an abatement cost of £20-50 per tonne CO_2 evaluated over a 30-year period and play an important role in helping the county reach the target of net-zero emissions by 2050. However, if afforestation is to be employed as major driver for reducing net carbon emissions in Cambridgeshire, an area fraction considerably larger than 1% of the county would be needed; even afforesting 10% of the county would not be sufficient on its own to reduce the county's emissions to net zero. Decarbonisation of energy generation, a reduction in private car usage and electrification of transport, a transition away from gas for heating, and a reduction in meat and dairy consumption are all necessary actions. Nevertheless, several important conclusions about afforestation can be drawn.

Sequestration varies significant between different planting scenarios, with the most efficient scenario examined here sequestering 2.6 times more CO_2 than the least efficient. This highlights the critical importance of quantifying the carbon sequestration of planting strategies if afforestation is to be performed efficiently. Of the scenarios considered, an Alder/Aspen/Sycamore mix is predicted to result in the highest sequestration with 3,000 ha (about 1% of county's area) sequestering, over a 30-year period, around 1.4 Mt CO_2e. If the county follows an ambitious decarbonisation strategy [6], such a level of sequestration is likely to amount to more than 2% of the county's cumulative emissions over that time and, after 2050, a considerably greater fraction as forest sequestration rises and anthropogenic emissions continue to fall. Sitka Spruce and other coniferous species delivered lower cumulative sequestration but are likely to be important to ensure a supply of softwood, a commodity in higher demand, and thus increase the financial return and lower abatement costs. Native woodland would also lead to significant sequestration and, if properly managed, help promote biodiversity by ensuring a mixture of species.

The abatement costs calculated in this work are higher than the nation-wide average value of £12 per tCO_2 suggested by the Committee on Climate Change [2]. One reason for this difference is likely to be to higher land costs in England with the Committee on Climate Change considering afforestation on a national scale including regions of Scotland where agriculture is not as efficient and thus land prices are lower. Furthermore, the abatement costs are significantly lower than the marginal abatement costs predicted for Bioenergy with CCS (£158 per tCO_2) or DACCS (£300 per tCO_2) [2], suggesting afforestation is still a cost-efficient method for removing CO_2.

The abatement costs calculated here also showed significant dependence on timber prices, highlighting the importance of future timber demand in the viability of any project. Therefore, afforestation on a commercial scale is likely to be much more feasible if more policies are introduced which incentivise the use of timber in construction and other industries. Such policies would have a dual environmental benefit of promoting the safe, reliable removal of carbon dioxide from the atmosphere as well as reducing the usage of energy and carbon intensive materials of concrete and steel. In addition, well-regulated markets for timber, tied into sequestration verifying bodies like the WCC, would also help promote sustainable practices by both foresters and purchasers, aiding the industry.

The modelling presented in this work is a first step but provides a strong basis for further planning of afforestation projects. Such projects should include a thorough consultation with an ecologist to consider the effects on biodiversity; maximising carbon sequestration should not come at the expense of all other environmental concerns. The effect on the water table (an important issue in Cambridgeshire [16]) should also be considered along with the development of an efficient business plan to maximise revenue from wood sales. Furthermore, other stakeholders, such as farmers, should be consulted to ensure afforestation brings them benefits to them as well; for example, selecting trees that will return more nutrients to the soil or reduce soil erosion. It should also be noted that afforestation will need to compete with other land uses [17]. Future climate change is likely to make land less productive, and increasing population will place a higher demand on land for agricultural output.

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James Weber read Natural Sciences (Chemistry) at the University of Cambridge before starting a PhD in the Department of Chemistry in atmospheric modelling and climate change. His research focuses on the interactions between the biosphere and climate, mediated via the chemical oxidation of biogenic volatile organic compounds, and how these processes will influence future climate. He has also been involved in the 6th Coupled Model Intercomparison Project (CMIP6) looking at biogeochemcial feedbacks which will contribute to the evidence base used by the Intergovernmental Panel on Climate Change (IPCC).

Conflict of interest The Author declares no conflict of interest.

Data availability All data is available upon request from James Weber.

Cambridge Journal of Science & Policy

Leadership at the science policy interface: *A case study of the Policy Challenges collaboration between Cambridgeshire County Council and Cambridge University Science & Policy Exchange*

Communication | Editorial | Invited contribution | Perspective | **Report** | Review

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Cambridgeshire County Council

Abstract

The Cambridgeshire County Council Policy Challenges Programme provides a unique model by which evidence-informed policy is developed as a collaboration between policy makers and early career researchers. Volunteer researchers from the University of Cambridge gain experience working with councillors and council officers on six month research projects on issues challenging the council and make policy recommendations. Past challenges have included questions around educational inequalities, government structure, and climate change. This paper is written in the hopes that insights can be shared with other councils looking for successful models of exchange with their local research communities. Here we outline the context, give two case studies of past programmes and highlight the key ingredients and lessons learnt from three successful years of this partnership, thought to be unique within the UK.

Introduction

The Cambridgeshire County Council Policy Challenges were launched in 2016 by Councillor Ian Manning, member of the Cambridgeshire County Council, and James Dolan, then president of Cambridge University Science and Policy Exchange (CUSPE), the science policy society of the University of Cambridge. This paper details the first three years' experience of a unique flagship collaboration between the two organisations.

The CUSPE committee provides the continuity, support, and university links to advertise the opportunity and maintain the relationship, despite naturally high turnover of individual students.

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These efforts are led by the Policy Challenges Coordinator who is elected to this committee every year- drawing preferentially from the pool of individuals who undertook the project the year before. The Cambridgeshire County Council provides the policy challenge questions, and these are addressed by policy challenge teams, made up of two to six university early-career researchers. During their work, the teams are supported by the council's 'Transformation Team', the team working to drive reform within the council to maximise impact across communities, and have contact with senior council officers throughout the project. Each team investigates a research challenge over six months, writes a report, and presents findings and/or recommendations at a county council committee meeting. As councils run under the committee system, committees set policy in their area, with accepted recommendations becoming council policy.

The programme runs between March, when teams are selected, and September, when reports and policy recommendations are presented. Since its inception, the programme has grown in size every year – from nine participants in the first year working on three projects, growing to twenty five participants involved in five projects in 2019. For the 2020 round, 42 participants were initially allocated to nine projects, however due to the COVID-19 crisis only 4 were carried on, redistributing the participants. Table 1 gives an overview of all the challenges accepted so far.

Project stages

Over the three years that the programme has been running, the model for how Policy Challenges progress has been refined. While this will continue to evolve, this section captures the current ideal case for the different stages of the programme.

In the first stage, questions are developed internally within the council. Councillors and council officers are invited to propose questions, which then are workshopped internally to produce a shortlist to be presented to researchers. It is important at this stage that ownership of the questions is established and champions for projects are identified. However, it is equally key that expectations are managed, as not all the projects will be taken forward by researchers.

In the second stage, the questions are presented to researchers at an open event where the councillors pitch their project, and network with interested researchers. This is promoted to researchers by CUSPE, utilising its networks within the university. These researchers then submit preferences for projects and are allocated to teams. Projects which do not receive a quorum of interested researchers are not taken forward.

In the third stage, projects are initiated, and teams meet with their counterparts within the County Council. Early work often involves refining the project question and identifying the preferred strategy for answering it, with researchers conducting desk-based research and council teams giving background and co-ordinating data access where appropriate. Each team investigates their research challenge over six months. This culminates in writing a report, with the inputs being novel data analysis, translation of research into the local context, or the insights gained from primary research conducted by teams such as surveys or focus groups.

In the fourth stage, the reports are presented to the council. Most are planned at the outset to be presented to the relevant county council committee meeting (e.g. Health, Economy and Environment, Children and Young People, etc). Teams present findings and/or recommendations, giving councillors the opportunity to ask questions. Recommendations accepted by council committees form the basis for shaping council policy. Following the committee presentations, the reports are circulated to relevant parties and made available online. There are also opportunities to influence working outside of the designated committee and this is usually guided by councillors and officers.

Project results

Over the course of the programme, 11 reports have been completed involving 32 researchers. Out of these reports, the following outcomes were achieved: eight were presented to Cambridgeshire County Council committees, one successfully influenced a team's working outside the committee, and another resulted in changes to a specific fund

Table 1: Policy challenge questions taken forward by researchers from the University of Cambridge for Cambridgeshire County Council since its inception in 2017.

Year	No. of projects	Project titles
2017	3	1: Investigating the educational achievement gap [1] 2: How can we improve outcomes in areas of high deprivation? A focus on early years interventions [2] 3: What are the next generation of models to transform organisations, and how could they benefit Cambridgeshire County Council? [3]
2018	4	1: What factors influence parental preference of schools, and what are the outcomes of those preferences (and for whom)? [4] 2: What impact does rurality have on the life chances of young people? [5] 3: What measures of outcomes are possible beyond simple financial calculations that will make different investments comparable, particularly where budgets are shared with other organisations? [6] 4: How effective has the implementation of the First Response Service been for those who experience mental health crises? [7]
2019	5	1: What actions must Cambridgeshire County Council take to reach net zero carbon emissions by 2050? [8] 2: Reducing air pollution, congestion and CO2 emissions from transport across Cambridgeshire [9] 3: What is the most appropriate evaluation method for the healthy fenland fund? [10] 4: How can we design the future of local government today? [11] 5: How does pupil mobility impact academic outcomes, and how can we improve the outcomes of pupils who move between schools? [could not be completed]
2020	4	1: What does the evidence tell us about the type of support that would have most impact on ensuring our care leavers can make a successful transition from being a supported young person into an independent adult, including the transition from education to work? 2: What are the impacts and opportunities of growth on the ability of local community groups to develop community-led solutions and interventions? 3: How can we use community-based networks and resources to jointly tackle the climate emergency with our communities? 4: How can Cambridgeshire businesses that have set, or are interested in setting, carbon neutral and carbon negative targets invest to reduce carbon emissions and also reduce fuel poverty both for oil dependent communities and the wider public? *Note on disruption due to Covid-19: This year the number of projects going ahead has been reduced to ensure every project can be fully supported by the council during the COVID-19 pandemic. The initial stages of the programme will take place virtually and the programme may be extended longer than six months if needed.*

analysis without going via committee. Only one report was not able to address the question that was asked, and therefore was not presented to the committee. One team failed to complete a report, due to a lack of data available. All others have been followed up by the council post-committee stage.

The impact of the most recent reports has not yet had time to manifest, but considering the remaining seven, three have had definable real-world impacts, and the other four have changed council policy and had indirect real-world impacts. The three with definable real-world impacts are:

- **The measures of outcome policy challenge** [6]. Members of the team assisted in the strategic restructuring of the council's Innovate & Cultivate Fund. The fund helps voluntary, community and social enterprise sector organisations deliver projects that assist the needs of local residents. The fund aims to redirect council funding from high cost front-line services, towards support and services that are delivered within, and by, local communities.
- **The deprivation policy challenge** [2]. The council's Best Start in Life programme used policy recommendations set out in this report to inform the development of an overarching early years' strategy. The strategy proposes how public and community health, early year's education and early help services can work together to support outcomes for children pre-birth to five.
- **The educational achievement gap policy challenge** [1]. The council's Schools Intervention Service Team implemented a range of strategies across schools following the recommendations from this policy challenge, in order to give a clear focus on 'narrowing the achievement gap'. There has since been a 5% improvement in outcomes for pupils in receipt of pupil premium grant across Cambridgeshire, a faster rate than in any of the other 101 Local Authorities.

Below are two examples from the most recent program in 2019 shown in greater detail to demonstrate the variety of projects available.

A team of seven researchers undertook a project titled 'Net Zero Cambridgeshire: What actions must Cambridgeshire County Council take to reach net zero carbon emissions by 2050?' [8]. This challenge gave rise to two reports, one focusing on sources of carbon emissions in Cambridgeshire, and the other on transport options to reduce carbon emissions. The former went to the central committee of the council, General Purposes Committee, and the other to the Greater Cambridge Partnership (a partnership between three councils and central Government).

The Leader of the Cambridgeshire County Council wrote to the councillors, chief executives, leaders of district councils, and the Cambridgeshire and Peterborough Combined Authority to highlight the report:

> The report provides an emissions baseline against which we can measure our performance in meeting our carbon requirements across Cambridgeshire and Peterborough. The report also sets out the shape of the challenge faced by Cambridgeshire and Peterborough in reducing emissions from the current 6.1 million tonnes (Mt) of carbon dioxide equivalent (CO2E) per year to net zero emissions by 2050. At General Purposes Committee it was resolved unanimously to accept the CUSPE research report and use it as part of the evidence base to inform the development of the Council's Climate Change and Environment Strategy and Action Plan (CCES).

The Cambridgeshire County Council Draft Climate Change and Environment Strategy is in the consultation phase at the time of writing.

The second example comes from the Evaluating the Healthy Fenland Fund study [10]. The aim of this research was to understand which evaluation methods would be most appropriate for the stakeholders involved in the Healthy Fenland Fund. Researchers in this group conducted primary research in the form of surveys and focus groups, underpinned by literature review on current theories for evaluating asset-based community development projects. Thirty individuals took part in four focus groups in two regions of Fenland, March and Wisbech. The individuals involved were both group leaders and participants from groups supported by the Healthy Fenland Fund. The final report was presented to the Health Committee at Cambridgeshire County Council who recognised the need to evaluate the Healthy Fenland Fund urgently and discussed allocating funds towards outsourcing this evaluation as recommended by the researchers.

Findings

Many of the successful programmes have shared features that allowed them to work effectively as a collaboration between researchers and policy makers and optimise the chances for success in achieving real world impacts. To this end, we have identified some of the key ingredients for a successful Policy Challenge Programme and lessons learnt on both sides in the following three sections.

Key ingredients required to establish the Policy Challenges relationship

1. A champion within the council. For these Policy Challenges, this has been Cllr Ian Manning, who established the relationship with CUSPE in 2016 and the pilot scheme in 2017. He has provided oversight for the entire initiative and acts as a link between officers, councillors and participants. While Cllr Manning's role in championing this scheme within the council has proved invaluable, the importance of generating shared and distributed ownership within council has also become increasingly important as the relationship has matured.

2. Officer leadership/support at a senior level within Council. For these Policy Challenges, the Council Chief Executive, Gillian Beasley, immediately championed the idea with the then transformation manager, Amanda Ascham, pushing it forward. Senior leadership gives visibility to the programme and empowers managers and teams within the council to contribute.

3. Cross party buy-in. Within a committee-based council system, this cannot be something driven and accepted only by one political group, but requires bipartisan acceptance.

4. A local university-linked group. Within these Policy Challenges, this has been CUSPE, a science-policy society comprised of early-to-mid-career researchers, graduate students, and postgraduate researchers. Despite naturally high turnover of students, the continuity is provided by the committee structure, with a Policy Challenges Coordinator sitting on this committee and leading the universities' efforts. The co-location of the university and county council has facilitated the collaboration.

Lessons learnt from the council perspective

The lessons learnt by the council around how to effectively utilise the skills of researchers include creating equal partnerships, investing in question design, limiting scope and giving early feedback.

1. This is a partnership of equals

- The challenges must be of interest to the council. The process of question design for the research projects is led by the county council, with strong input from CUPSE coordinators. Council collects proposals for questions that have been identified by elected Cllrs and senior council officers.
- However, both sides must be interested. To ensure researchers have the opportunity to work on a question of interest, more challenges are offered than the number expected to go ahead. For the Policy Challenges, CUSPE leads an annual launch event where councillors and officers present the different projects available and prospective participants have opportunities to ask questions. This also

facilitates early networking, increasing visibility, and breaking down barriers. Researchers then submit preferences for projects, which ensures that they complete projects of interest and of value to their personal growth.

2. Question design is key.

- Make it attractive to the researchers. Questions have to be specific enough to be identifiable to a particular part of the council, but broad enough to allow researchers to own how to answer them. It's a challenge – not a question.
- Make sure you can access the data. Some projects have run into difficulties in answering questions due to lack of access to the data that was held by third parties. Good accessibility is necessary for the project to proceed.

3. Scope it. A limited project scope is necessary to ensure a clear direction from the researchers and a valuable end product for the council. In some instances, it is preferable to leave methods or report specifics open to the researchers. A first meeting between researchers and a council lead early in the project should clarify which methods the researchers intend to use and what they intend to focus the report on, based on preliminary desk research by the Policy Challenge team and material provided by the council lead.

4. Invest in early feedback. Even when initial question scope is narrow, early input from council and question disambiguation is key. Time made available for this and discussion with teams early in the project saves time and improves the usefulness of the final product tenfold.

Lessons learnt from researcher's perspective

The lessons learnt by the researchers centre around how to work together effectively to clearly answer the challenge by starting early, utilising good communication between the team and the council, and having good time management.

1. Start early, start on the same page. Establishing the scope and approach clearly at the very start of the project is invaluable. This often involves a clarification meeting within the first month with the senior council officer, and a team kick-off meeting to ensure that the approach is consistent with the question they are looking to explore. It is also useful to receive material from the officers during this initial stage of scoping work, to ensure everyone has access to the same information.

2. Keep talking to each other. It is important to set up face-to-face meetings among researchers on a regular basis (fortnightly if possible). This avoids duplication of work and miscommunication. For example, the team on the Net Zero project found that they had to re-work their climate models when they individually used different assumptions or underlying projections.

3. Schedule time for revisions. Create a timeline to allow enough time for corrections and changes to the report, and accommodate unpredicted obstacles. Be flexible, but respect the schedule as much as possible.

Feedback from previous participants

Previous participants were contacted to understand their thoughts on the projects, how useful the projects were to their studies or careers, and what they thought were strengths and weaknesses. Of the 28 contacted, 11 responded via survey[2].

Reasons for applying to the programme fell into five categories:

Scoping out career choices – Understanding if they were interested in going into a policy-related career after their studies.

CV-building – Broadening experiences in policy-making to enhance their skillset. Personal interest in the field or question.

Local government – Interest in learning about and being involved in local decision making.

[2] The low nature of this response rate was likely due to defunct contact details.

Improving evidence-informed policy – Making a real difference in and for the community.

Participants reported that the aspects of the Policy Challenges Programme they most valued were the opportunity to work with the council, and having recommendations heard, valued and, in some cases, implemented by the council.

At this stage, it is too early to evaluate the potential impact of the Policy Challenges Programme on future career, as 82% of respondents were still completing their studies, though this would be worth exploring in future evaluations. However, having completed the programme, 64% of respondents were interested in policy-related roles, with the majority of others interested in research and consulting. 78% reported that they had included their involvement with Policy Challenges on their CV, with three of those that have applied for jobs stating that the programme enabled them to gain their current or upcoming roles.

Possible Programme Improvements

The council and CUSPE are continually seeking potential improvements to the scheme on a trial-and-error basis. Some improvements being considered for future projects include accommodation of master's student timeframes, publication of outputs, and expansion of the model to other local authorities across the UK.

Master's student timeframes. Currently, the project timeframes stretch over the summer holidays, which often do not suit Master's students who may complete their studies halfway through the project timelines. This reduces the number of potential candidates for research projects. The possibility of running 3-month projects, or to shift project timeframes is being explored.

Publication of outputs. All reports are published on data.gov.uk [12] and Cambridgeshire Insight [13], and they are often anywhere between 40-80 pages. Few clear mechanisms exist for publishing this sort of cross-disciplinary research. To address this, in 2020 CUSPE is launching the Cambridge Journal of Science & Policy (CJSP) [14] – a diamond open access journal (free to submit, free to publish, free to access) targeted at early career researchers. The ability to publish in this journal supports the development and CVs of these early career researchers, and the peer-review process promotes rigour. The challenge in synthesising key findings of a report for an intelligent non-expert–from 40 pages down to 2,000 words–exercises a key skill for those wishing to further their career in policy. Not only is this a previously unavailable platform for the dissemination of translatable findings of this programme (which other councils may then apply), it is also an open opportunity for dissemination of any evidence-based policy activities happening at any level across the UK.

Broaden the collaboration. In part, the purpose of writing this article is to promote the Policy Challenges model to other councils and university groups across the UK. Other efforts include branching out to other councils via the New Local Government Network, and explicitly inviting our district councils to be involved in the challenges. The authors would also be happy to be contacted by those interested in exploring this model in their local area.

Conclusions

The Cambridgeshire County Council Policy Challenges Programme provides useful evidence to local councils and excellent experience to early career researchers at the University of Cambridge through the collaboration with the Cambridge University Science Policy Exchange.

This partnership of equals is seen as a unique model within the UK, where the collaboration between policy-makers and researchers promotes evidence-informed policy. The key ingredients to establishing a successful programme include a champion within council, a local university-linked group, and a few years to really get going. When designing projects being mindful of equal partnership question design, limited scope and early feedback are key for councillors and council officers to ensure targeted projects, while project teams benefit from clear scopes set-out at the beginning and good, constant communication and time-management throughout.

The impact of the Policy Challenges on council policy and decision-making is difficult to assess at such an early-stage. Some examples, such as the use of a policy-challenge report as an evidence base to inform the development of the Council's Climate Change and Environment Strategy and Action Plan (CCES), demonstrate how the challenges are assisting council policy-making.

Previous participants identified their main reasons for applying were to scope out career choices, build their CV, make a difference in the community and for personal interest. They most valued working with the council, and having recommendations heard and accepted. Though it is too early to evaluate the potential impact of the policy challenge programme on future career, most participants had used the program to enhance their CV and most were considering policy-related roles.

Any scheme such as this is constantly improving, and some such aspects under consideration include how the programs may be made more inclusive to master's students on one year programmes, and publication of outputs. The success of the first three years has encouraged the collaboration to promote the model, with the broadening of this collaboration to other councils and universities. The goal is that this mutually beneficial partnership can provide a model to support the development of early-career researchers and the quality of research underpinning council policy across the UK.

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About the Authors

Conflict of interest The Authors declare no conflict of interest.

Before starting her PhD, Liz worked for the UK Government Office for Science. She has also worked for the Australian Government as a nuclear medicine chemist after graduating first in her class in her undergraduate in chemical engineering. She has completed an MSc in Science Communication at Imperial College London and is now undertaking a policy-focussed PhD in Education at the University of Cambridge. She maintains her connections between policy and science by continuing to work with UK Government Office for Science during her studies. She was the President of CUSPE in 2019-2020.

Orla is a second year PhD student at the Institute of Metabolic Science researching the gut-brain axis in the control of appetite and feeding behaviour. Orla previously completed an undergraduate degree in Biological Sciences at Durham University and an MRes in the Biology of Ageing at UCL. An interest in science policy drove Orla to get involved with CUSPE in 2018 to help coordinate the annual Science and Policy Forum. In 2019, Orla took on the role of Policy Challenges Coordinator to help build relationships between Cambridge academics and Cambridgeshire County Council, and enable early-career researchers to gain experience working on real-world policy issues.

Ian Manning graduated from York with an MPHYS in Physics, and although he then pursued a career in IT, he took with him the sense of needing to solve challenging problems and the desire to critically analyse evidence. When he moved to a new-build estate in Cambridge he became involved in politics, eventually getting elected (for the Liberal Democrats) to Cambridgeshire County Council 2010. He was re-elected in 2013 and again in 2017 to the new Chesterton Division. Ian became frustrated at the number of decisions that Councillors made without robust evidence, and the lack of interaction with the City's Universities. After taking part in a CSaP policy fellowship, and negotiated and set up a successful pilot 'Policy Challenges' programme - seeing researchers from CUSPE working directly on problems raised by elected Councillors and senior offices. This programme, now in its fourth year, led to him being appointed the Council champion for evidence-informed policy. With this new role, Ian now has an apolitical remit to build further links with the academic community and welcomes input from Cambridge's academic community to achieve that goal.

After her degree and PhD in Chemistry, Cecilia joined the Department of Biochemistry as research associate. There she applies metabolomics to a range of topics, including bio-production of chemicals, drugs and viral-host interaction. She participated in the 2019 Cambridgeshire County Council Policy Challenge, interested in helping her community through her research skills, and in 2020 she coordinated the initiative with Orla.

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