Celebrating 10 years of UCL Institute for Sustainable Resources

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THE BARTLETT
INSTITUTE FOR
SUSTAINABLE RESOURCES

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UCL Institute for Sustainable Resources (UCL ISR) turns 10 years old in 2021. In celebration researchers from across our six themes and three methods have written reflective pieces on their areas of expertise. These reflections will highlight UCL ISR's remarkable contributions towards sustainable resources policies, debates, and decision-making processes – whether by governments, private sector, civil society, or other actors – through our research, engagement and teaching activities.

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Reflecting on 10 years of UCL Institute for Sustainable Resources

From start-up to world-class institute

PAUL EKINS - FOUNDING DIRECTOR, PROFESSOR IN RESOURCES & ENVIRONMENT POLICY

The UCL Energy Institute came first, founded in 2009 out of the Bartlett School of Graduate Studies. A substantial donation from BHP Billiton (BHPB) in 2011 then provided the opportunity (and challenge) of creating a sister institute that had a wider focus on natural resources and the environment. The UCL Institute for Sustainable Resources (ISR) was born.

A major portion of the BHPB donation was earmarked for the funding of 20 PhDs related to sustainable resource use. Students were appointed over the next couple of years and somehow arrangements were made for their adequate supervision – no small task for a new institute with few staff. They started graduating from 2015, and the final student is submitting their thesis this year.

Two successful Masters courses have been developed: the Economics and Policy of Energy and the Environment (EPEE), which opened in 2014 and is now one of the largest Masters courses in UCL; and Sustainable Resources: Economics, Policy and Transitions a couple of years later, which is also recruiting strongly. These courses have provided the financial underpinning for the subsequent growth of ISR.

ISR's teaching was always intended to be led by world-class research, and so it has proved, with a research programme centred on achieving the Sustainable Development Goals (SDGs) and Paris Agreement, and individual themes on sustainable, circular and resource-efficient economies, energy transitions and energy access, the water-food-land nexus, and innovation and finance for decarbonisation.

These are some of the biggest challenges facing

Reflections from a former BHPB Chair

RAIMUND BLEISCHWITZ - BSEER DIRECTOR, CHAIR IN SUSTAINABLE GLOBAL RESOURCES

Joining UCL in August 2013 as 'BHPB Billiton Chair in Sustainable Global Resources' and Deputy Director of ISR, I was determined to shape the ISR founding partnership towards sustainability transformations. In a joint strategic decision about a 'sweet spot' of mutual interests, the donation was spent on setting up the institute and running a PhD programme, complemented through annual symposia addressing UCL's Grand Challenges on sustainable cities, earth stewardship, sustainable food, and water security. Such critical mass has enabled ISR to think outside the box. ISR's research areas were designed to be funded by other sources. Almost naturally, a new MSc programme on Sustainable Resources could evolve, which now serves as a wellspring for new talent.

The collaboration has been stretched by the 'fossil free university' movement arising in the UK around 2015 and by international commodity markets turning downwards, which together made an extension after the five years infeasible. It has been a pwroductive partnership with a number of lessons learned:

1. Founding partnerships for novel topics work well, if a 'sweet spot' of common interests can be identified (such as building up academic capacity rather than commissioning of research deliverables);

2. Legacy thinking needs to be built in, as circumstances and preferences change over time; and,

3. Navigating the partnership needs active communication, trust, and milestones as much as a 'hands-off' approach.

ISR is now established as an independent think tank with deep academic grounding – it is a unique place and a promise for future endeavours.

Celebrating 10 years of the UCL Institute for Sustainable Resources

JULIA TOMEI - FORMER INTERIM DIRECTOR, ASSOCIATE PROFESSOR OF ENERGY, RESOURCES AND DEVELOPMENT

Over 10 weeks we have been celebrating 10 years of the UCL Institute for Sustainable Resources (ISR). Launched under the leadership of Professor Paul Ekins in 2011, the ISR is now firmly established as a leading research institute on the sustainable use of global natural resources.

Over the past six months, I have had the pleasure of leading the institute while we seek a successor to Prof. Ekins, who reminas active in ISR in both teaching and research. I am pleased to announce that I will hand over to the new Director of the ISR, Professor Jim Watson. Prof. Watson's extensive experience of leading large, interdisciplinary research centres, engaging with diverse audiences, and strong policy impact, means we will continue to go from strength to strength.

This has been a challenging period for all of us as we seek to adapt to new ways of working following the COVID-19 pandemic. It has also been an exciting one as momentum grows behind a just transition to net zero. Improving resource governance is a vital component of this, helping us to avert climate catastrophe while restoring our natural environments and enhancing human rights. Not only will this transition require transformations in every aspect of our societies and economies, but the urgency means action is needed today. The ISR, with its inherently interdisciplinary approach and deep expertise on diverse aspects of resource use, is uniquely positioned to inform and influence how this transition occurs. The ISR has much to look forward to as we set out on making our second decade even more memorable and impactful than the first!

UCL Institute for Sustainable Resources: The Future

JIM WATSON - DIRECTOR. PROFESSOR OF ENERGY POLICY

Global resource challenges have become even more urgent since ISR was founded 10 years ago. The continuing dominance of fossil fuels in energy systems and the impacts on the climate stands out. The extreme heat and flooding that has been experienced in many regions in 2021 reinforce the urgent messages from the IPCC's sixth assessment report. At the same time as tackling climate change, the Sustainable Development Goals highlight a host of other areas where access to resources is neither equitable nor sustainable.

ISR's expertise is likely to remain in high demand from governments, companies, communities and citizens. But the nature of global resource challenges will continue to change. So ISR will need to adapt, and anticipate where new research, expertise and skills will be required. Three recent successes illustrate some of the agendas that will be important in future.

First, we have expanded our research on energy, resources and development in collaboration with partners in low- and middle-income countries. Despite unwelcome cuts to UK budgets, we are working with UCL colleagues and our partners to develop strategies and plans that integrate climate action, sustainable resource use and economic development.

Second, we are helping to develop the international evidence base on greenhouse gas removal methods to inform decision-making. These methods, whether nature-based or technological, are widely agreed to be essential if the UK and other countries are to reach net-zero greenhouse gas emissions. But they are fraught with technical, environmental, economic and other risks. So it is important that implementation is evidence-based and subject to rigorous evaluation.

Third, ISR researchers are involved in two national research centres on the circular economy. New economic models that use materials and other resources more efficiently and wisely are urgently needed. Our research in this area fits with ISR's tradition of interdisciplinarity that combines economic rigour with the imperative for environmental sustainability.

Driving the low carbon transition through "induced innovation"

As part of our 'Directing innovation for sustainable development' research theme Senior Research Associate Paul Drummond reflects on why the low carbon transition may be much cheaper than models predict.

To achieve net-zero emissions by mid-century, global energy systems must undergo a wholesale switch to low-carbon and energy-efficient technologies. Government decarbonisation strategies often draw heavily on the outputs of integrated assessment models (IAMs) that attempt to represent the energy system and economy. These models select combinations of energy-supply and energy-using technologies to achieve decarbonisation with the lowest total cost over time.

However, the representation of innovation in such models often doesn't reflect the reality. Understanding and driving innovation is key for achieving decarbonisation and sustainable development more broadly. This is an important area of research for the UCL Institute for Sustainable Resources (UCL ISR).

Models vs. reality

Typically, the costs of low-carbon technologies in these models are assumed to gradually decline as they become more mature, primarily as a function of time and policies such as R&D support. This means that low-carbon technologies are assumed in these models to remain more expensive than mature, incumbent technologies long into the future, and that investing in them is best delayed until R&D has made them more competitive.

However, such models overlook findings from a vast literature showing that the costs of these technologies decline as a result of their use. Our paper in Environmental Research Letters, published earlier this year, draws on evidence from more than 200 journal articles and concludes that policies promoting such "induced innovation" have been a clear factor behind the remarkable success of low-carbon technologies. This suggests that not only is urgent action essential to drive the clean energy transition, but the transition itself may also end up much cheaper than often predicted.

"Demand-pull" drivers

Although the role of 'technology-push' policies in driving innovation, such as public R&D funding, is well known, the role of 'demand-pull' drivers has been less well recognised. Such drivers can take various forms, from "market-wide" phenomena such as rising energy and carbon prices, or "targeted" policies such as technology subsidies or regulations.

Different drivers appear to induce innovation in different ways. Rising energy and carbon prices do incentivise the development of lower-cost or lower-carbon technologies, but such innovation has so far been quite incremental, and encourage developments like more efficient fossil-fuelled vehicles, rather than electric or hydrogen technologies.

We find that more radical innovation – necessary to deliver newer, initially expensive renewable energy technologies – is much more responsive to targeted policy approaches, such as long-term subsidies provided by Feed-in Tariffs (FiTs).

We also found that firms are much more likely to innovate in a way and direction they have done before, producing accumulation effects, and that the wider policy environment is highly important,

with factors such as overall policy coherence and consistency, future policy expectations and institutional context can have a strong influence on the propensity to innovate.

Measures of innovation

Patent applications are by far the most common measure of innovation, largely because data is widely available, quantifiable and detailed. However, they provide only a partial picture. Patents are a good measure of innovative "activity", but not of "outcomes" such as reductions in technology cost.

Examining the full link between demand-pull drivers and outcomes is highly complex. However, we attempt to partially bridge this gap by including studies deriving "experience curves" and associated "learning rates" – the percentage reduction in cost for each doubling of cumulative deployment – for low-carbon technologies deployed as a result of demand-pull policies.

Solar photovoltaics (PV) and wind energy were by far the most studied technologies we considered, with solar PV experiencing a learning rate averaging around 20% for much of the last 40 years. This has led solar PV from a position of being a highly expensive way of generating electricity, to the International Energy Agency (IEA) now believing it to offer the "cheapest electricity in history". Much of this cost reduction can be attributed to learning-by-doing and economies of scale that come when a new technology is deployed and the supply chains and markets around it develop.

To drive the low-carbon transition, and potentially achieve an energy system that in the long run is cheaper than the fossil-fuel based system we have today, it is crucial that policymakers and those advising them are aware of these complexities and recognise the opportunities that early, large-scale investment may offer.

Tracing climate investments and shifting investment behaviour

Principle Research Fellow Nadia Ameli from our 'Financing the low carbon transition' research theme writes on seeking to support system changes to the financial industry on climate change issues through data-driven analysis.

The sustainability transition requires a system-wide structural change towards low-carbon technologies and infrastructures backed by an unprecedented mobilisation of financial resources. Indeed, huge investments are needed to cut greenhouse gas emissions and adapt to the impacts of climate change that can't be avoided. This investment can be provided by the global financial system. Finance is the driver that will pivot economies away from highly polluting activities and towards clean and sustainable development.

Economists talk about 'shifting the trillions' to close the climate investment gap. But, to make it happen, we need to understand investors' interactions and the dynamics of their investment behaviours. This is important because investors' collective dynamics shape the actual flows into low-carbon technologies and drive the direction of technical change. These dynamics also determine how the system could pool long-term financial assets to boost the low carbon transition, and can also trigger non-linearity and tipping points in investment trends.

The ISR research theme on sustainable finance seeks to support systemic changes to the financial industry on climate change issues through data-driven analysis. Employing network analysis of long-term investment data allows us to determine the structure and growth of the investment system based on the dynamism of its investors' behaviour, their influence in the system and investment trends. Network models are used to explain how a dynamic and evolving financial system emerges from the interactions between individual economic agents. Such models can detect the groups of influential investors and their investment patterns that are most effective at transferring capital to where it is needed, and such findings can act as a guide for policymakers. This type of thinking will be critical to the equitable distribution of climate finance across the world. In order that the pledged US$100 billion per year (which at COP26 African countries will request increases tenfold) from the developed to the developing world reaches the most vulnerable and is distributed fairly, it is vital to monitor the financial channels through which it flows and its impact on the economies of recipient countries.

By focusing on the financing dimensions of low-carbon investment and the architecture of the financial system, we hope to identify points where climate-centred policy can intervene and spur green finance. To that end, our research focuses on three priority areas:

1. The design and implementation of technological transitions based on effective investment channels. We identify the leading investors and followers, the most influential investors as well as those on the periphery, and provide impactful insights to determine investors' profiles and preferences for different low-carbon technologies. There is very limited empirical evidence on which financial actors are more relevant to channel investment at different stages of technology development, for example for a relatively immature technology or established ones. Such insights are crucial to derive technology-specific financial outlook and investment policies to support decarbonisation pathways.

2. The support of virtuous cycle of investments and non-linear growth trajectories through optimal allocation of public resources, both domestic and international. Non-linear effects, which can occur via strong cascading channels, allow relatively small injections of public resources to a set of actors to irreversibly propagate through the climate finance system, leading to rapid and large increases in low-carbon investment. The research quantifies the multiplicative potential of public investment across the structure of the financial system to understand supportive financial structures and policy incentives that increase private involvement.

3. The mobilisation of financial flows in developing countries for a just and inclusive energy transition. Understanding the international financial system and the actors involved becomes crucial to reach the most vulnerable countries, where a narrative for climate finance is still missing except from the need for more public support. New evidence informs what financing channels enable better risk management to attract diverse private money, ensure equitable access to capital, and create sustainable financial structures in developing countries. Our research also highlights domestic country contexts that best support the involvement of international finance and quantifies the impact that domestic policies can have on improving financial mobilisation.

Through this exciting and innovative research programme, we hope to not only understand the system, but to create the evidence that will support a fairer distribution of global financial flows.

Measuring the environmental sustainability of countries

Arkaitz Usubiaga-Liaño, Alison Fairbrass and Paul Ekins tell the story of the Environmental Sustainability Gap framework as part of our 'Sustainable resource-efficient economies and societies'

In the late 1990s, Prof. Paul Ekins developed the Sustainability Gap (SGAP), a theoretical framework to address the lack of adequate metrics to monitor the environmental sustainability of nations. SGAP brought together key concepts such as strong sustainability, critical natural capital, environmental functions and science-based environmental standards. It also proposed novel indices that facilitated, amongst others, measurement of the environmental sustainability performance of countries, as well as progress towards or away from environmental sustainability. These novel metrics were intended to better communicate different aspects of environmental sustainability to high-level decision makers and to the general public.

During the early 2000s, Prof. Ekins published several papers on SGAP. These papers further developed key concepts of the framework and described the links to the environmental-economic accounting practices available back then. However, while the framework was conceptually sound, limited progress was made in the quantification side due to the lack of sufficient data. Over time, these papers have been cited widely in theoretical discussions of sustainability measurement and by those proposing sustainability indicators, but the actual uptake of the framework was limited beyond academia.

In 2013, SGAP got a second push through the allocation of eight BHP Billiton funded PhDs to its implementation. Each PhD addressed a different environmental topic. In their first year, these eight PhDs focused specifically on the SGAP framework, and then moved on to broader sustainability considerations of their chosen topic. In 2015, a new PhD was devoted to the consolidation of earlier work and to the quantification for the first time of the environmental sustainability of countries across a range of environmental and resources issues. As part of this PhD, SGAP has been updated, further developed conceptually and renamed as the Environmental Sustainability Gap (ESGAP) framework, to stress its focus on the environmental dimension of sustainable development. More importantly, new metrics of environmental sustainability have been proposed and computed for European countries, thereby representing the first full implementation of ESGAP. These metrics are the Strong Environmental Sustainability Index (SESI) (see Figure 1) and the Strong Environmental Sustainability Progress Index (SESPI). This work is part of the 'Sustainable resource-efficient economies and societies' research theme of ISR.

As this last PhD was underway, research was picked up by the French Development Agency (Agence française de développement, AFD), who reached out to Prof. Ekins about the possibility of implementing the framework in less industrialised countries. Guided by the methodology developed for European countries, the work with AFD has led to national pilot studies in New Caledonia, Vietnam and Kenya. These pilot studies have shown the potential of ESGAP to highlight threats to environmental sustainability in those countries, while at the same time have revealed relevant data limitations that need to be addressed. Through internal UCL funding, additional pilot

studies are being undertaken in China and Japan, and a new PhD is using the Bahamas as a case study. As can be seen, the ESGAP framework is gaining momentum. It has been featured in the second Measuring Progress report of the United Nations Environment Programme and there is an increasing interest from a range of national and international organisations.

The ESGAP framework and the underlying metrics have the potential to embed strong sustainability in countries' environmental targets, to contribute to the 'Beyond GDP' debate and to better communicate the urgency around reducing environmental degradation.

SESI comprises 21 indicators arranged in four layers. Thus, indicators are aggregated into environmental and resource topics (T). The topics are aggregated into sustainability principles (P), while the latter are aggregated into broad environmental function categories. Finally, this information is aggregated into a single index, SESI.

Ten years of innovation and sustainability

What have we learnt from 10 years of innovation and sustainability? Associate Professor Will McDowall from our 'Directing innovation for sustainable development' research theme looks back over the last decade and what it has taught us in this field.

Exactly a decade ago, in October 2011, Sir Dieter Helm expressed what was then a widely held view in the Guardian: "It is also wrong to assume that renewables… are going to be cheap alternatives". Ten years later, renewable costs have fallen faster and further than most observers—even technical experts—expected. Energy innovation has transformed the policy landscape, overturning deeply embedded assumptions about the relative costs of renewables and fossil fuels, and providing some optimism that energy systems change can come about more cheaply and quickly than had previously been assumed.

So what has this decade taught us?

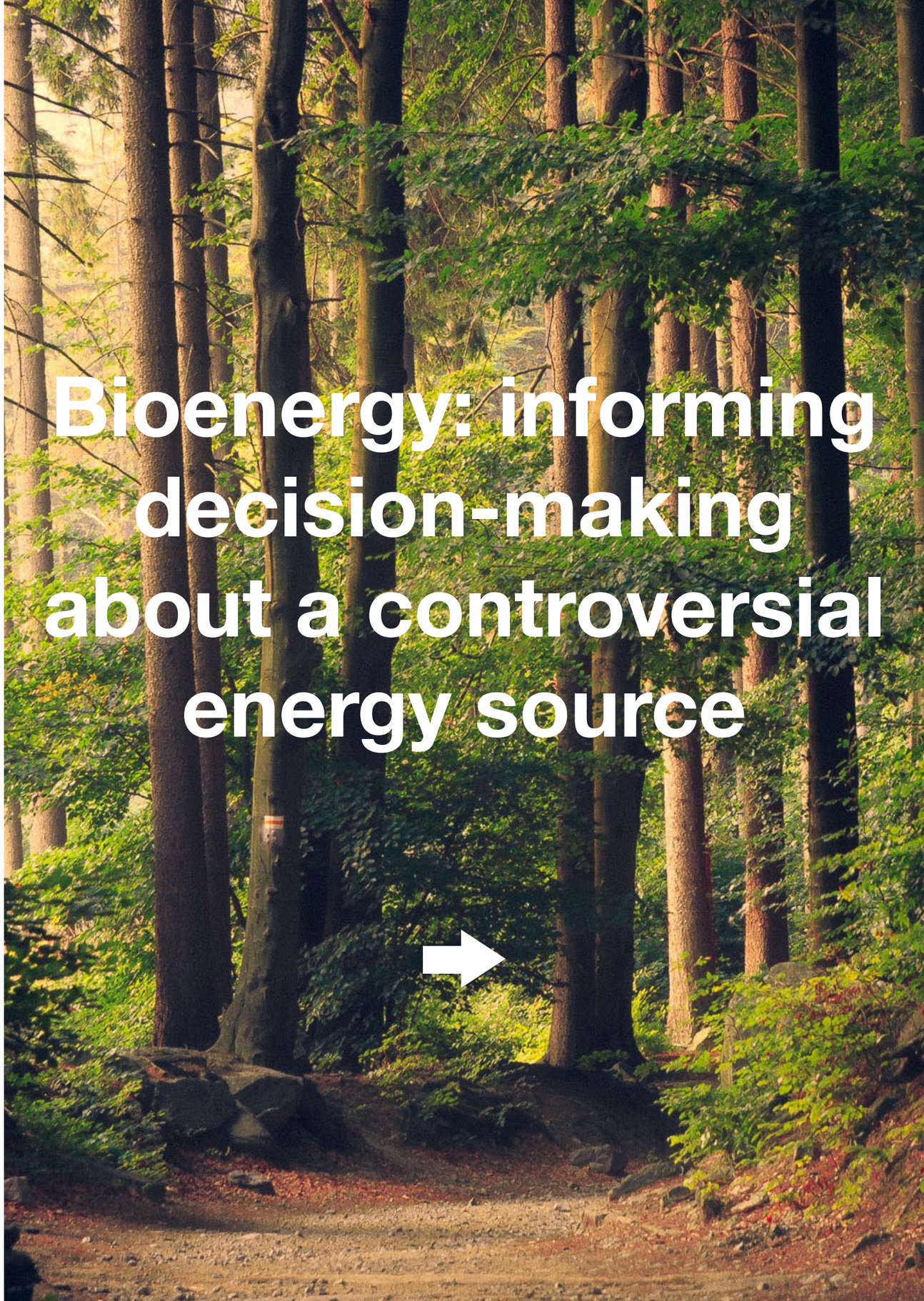
First, it has shown that consistent and stable policy support can play a big role in accelerating the development of emerging technologies. The creation of early markets, fostering a diversity of options, and supporting R&D have all been critical. We have a much better idea of the policy portfolio than we did a decade ago.

Ten years ago, it was still common to hear the concern that government attempts to 'pick winners' would inevitably fail. But strategic government support for the deployment and commercialisation of specific areas of technology has played a central role in the revolution in renewables costs. Those that fear government failure weren't wrong to be concerned, but the new era of green industrial policy support has been designed to avoid many of the pathologies of the 1970s, like choosing specific 'national champion' firms. Today's UK government is much more comfortable with—and much better at—directing innovation to achieve sustainability goals.

Second, we often ignored the fact that innovation, once achieved, can enable ambitious green policies. Ten years ago, a policy to phase out internal combustion cars would have been political suicide. Now it's uncontroversial. Bismarck famously remarked that politics is 'the art of the possible'. The magic of innovation is that it makes what was once politically impossible seem easy.

Third, it was once common to hear people contrast 'technological' solutions with social and behavioural changes. But in so many cases, we see technological and social changes co-evolving and reinforcing each other. A great example comes from more sustainable foods: social movements around veganism helped spur innovation in non-milk dairy products, which have now enabled a much wider penetration of dairy alternatives and vegan lifestyles. Technological innovation does not sit in isolation from social change, but is embedded within it.

At ISR, these lessons reinforce our commitment to an interdisciplinary and systemic perspective on innovation, which acknowledges the interactions between policy, society and technological systems. As we look forward to another ten years of research on innovation at ISR, new challenges are emerging – it's going to be a busy decade.



Bioenergy: informing decision-making about a controversial energy source

The complexities of bioenergy systems explained by researchers Jen Cronin, Oliver Broad, Isabela Butnar and Julia Tomei from our 'Energy system transitions to achieve net-zero' research theme

Recent news coverage around the IPCC report and the conversion of Drax power station to biomass have brought bioenergy to the forefront of public debate. But the topic is far from new. It has been discussed in the UK, Europe and globally for many years.

Modern bioenergy can provide low-carbon electricity, biogas, liquid transport fuels and hydrogen. In some cases, it can even remove carbon from the atmosphere if combined with carbon capture and storage (CCS). It is now increasingly argued that this will be vital for addressing the climate crisis, a statement that continues to raise concern. One reason is that bioenergy supply chains are complex – stretching from areas of biomass production, through processing and conversion to power and fuels, and CCS. Poor planning along these chains can lead to emissions that partly or fully negate the carbon originally captured by the plants. Another is that the business practices involved can cause negative impacts on communities and biodiversity.

Because bioenergy systems are complex, interdisciplinary research – a key strength of ISR – is vital.

ISR has researched bioenergy since the institute was established. At that time, conversations centred on EU mandates for biofuel blending in transport fuels. But the discussion was restricted: it privileged certain types of knowledge (i.e. technical assessments) and narrowed the framing of important topics, such as biomass sustainability, to focus solely on unforeseen carbon emissions. This affected the political debate, overlooking the social impacts that rapidly expanding biofuel production could have on local communities around the world.

To shine light on this issue, ISR research focused on first-generation biofuel producer countries such as Brazil, Guatemala and Mozambique, and assessed livelihood and community impacts of growing demand. This evidence on environmental and social impacts raised awareness, highlighting the consequences that "land grabs" and changes to land use could have for local communities.

This issue remains highly relevant and advanced uses of biomass risk repeating similar mistakes if we do not learn from earlier experience. To address these risks, ISR researchers, together with the UCL Energy and Development Group, recently published a transdisciplinary research agenda for embedding justice at all levels in the 1.5C transition.

Advanced biomass solutions are increasingly represented in techno-economic models which underpin national energy strategies. Running these models is a key component of research at ISR and the institute has worked to understand the role these options can play in reaching our national climate targets. We look at optimistic or precautionary assumptions of biomass availability, technology progress, or carbon content. One repeat focus has highlighted the risks involved in high reliance on bioenergy with carbon capture and storage (BECCS) for the UK. A recent ISR report highlighted that in order to reduce the pressure on developing BECCS at scale, policy incentives should focus on reducing energy demand though efficiency measures and support a diverse range

of removal options. Recognising the complexity of BECCS supply chains, policy support should be incremental and conditional, and subject to rigorous evaluation and performance review.

Overall, this extensive bioenergy and modelling expertise has positioned the institute as a trusted partner to UK policy decision making. Researchers at the ISR now collaborate regularly with the BEIS Central Modelling Team. In 2020, the ISR seconded energy modelling expertise to the Department to co-develop the bioenergy sector of the UK TIMES tool used for Carbon Budget 6 analysis. In July 2021, the institute drew together the social and technical perspectives to produce its response to the government's bioenergy consultation. This highlighted that for a sustainable scale-up of bioenergy in the UK, it is key to prioritise social justice and land use. In the face of changing climate, it is paramount to prioritise solutions which enhance ecosystems, promote sustainable livelihoods and support resilience of natural environments. Accepting that biomass is a scarce resource, it should only be used in applications which sequester carbon in the long term, or where there are few low carbon alternatives.

Some of the above recommendations are being taken forward into a new UK greenhouse gas removal (GGR) hub, CO2RE Hub, dedicated to investigating routes of sustainable scale up of GGR options in the UK. ISR researchers are coordinating the development of a multi-disciplinary GGR evaluation framework, drawing the latest science from teams across the CO2RE Hub, UK and abroad, GGR Demonstrators, and feedback from a wide group of stakeholders, including the general public. The evaluation framework will develop robust and harmonised criteria for assessing the removal provided by different GGRs at different scales, also characterising the permanence of that removal and trade-offs with social and environmental goals, and policies and regulations which need to be developed to foster sustainable GGR scale-up in the UK.

Excitingly, much more research is ongoing and further ideas are brewing. It is vital to ensure we make robust decisions about the potential for biomass to sustainably lower our emissions. Important questions remain, such as how to represent the complexity of the carbon cycle in our long-term energy models to include the impact of carbon debt? How do we broaden our understanding of what "sustainable" means to place global social justice and land governance front and centre, and how do we embed these in policy? What about permanence of carbon storage in natural systems as the climate changes? These are questions the ISR is working hard to answer – watch this space!

Assessing the impact of UK Government energy and climate policies

How has the Econometric Assessment research theme evaluated policies implemented on the back of the Climate Change Action, the Paris Agreement and the Net Zero Strategy? Professor Paolo Agnolucci reflects on the work of the 'Econometric Assessment' research theme team over the last decade.

Climate targets set in the Climate Change Act, the Paris Agreement and later in the Net Zero Strategy have required the introduction of a robust and effective set of policies, affecting energy consumption and emissions across the sectors of the UK economy. As part of the policy cycle, effective policies need to be designed, carefully implemented and eventually their process, outcomes and impacts need to be evaluated so that the next set of policies can learn from 'what works' while existing policies can be fine-tuned to obtain maximum impact.

Working as part of interdisciplinary consortia, the Econometric Assessment theme at the UCL Institute for Sustainable Resources (ISR) has played a key role in the evaluation of several schemes introduced first by the Department of Energy and Climate Change and then by the Department for Business, Energy and Industrial Strategy. The UCL team, led by Professor Paolo Agnolucci, started with a focus on Quasi-Experimental Analysis (QEA), where the impact of a policy is assessed by comparing actual outcomes to what would have occurred if the policy had not been introduced. We later expanded into economic evaluations and machine learning analysis. Our expertise has played a role in schemes affecting the public, the industrial and the residential sectors.

Budget and finance constraints can have a significant impact on the ability to adopt technological solutions which reduce energy consumption and energy bills but require upfront payments. This can be a serious obstacle for households unable to access financial products and institutions in the public sector. ISR has delivered the evaluation of the impact of the Public Sector Energy Efficiency Loans Scheme (PSEELs) Evaluation, quantifying how the scheme affected energy consumption across Local Authorities, NHS / Foundation Trusts, schools (including academies), and further and higher Education Institutions (FEIs and HEIs). ISR work has been key to ensuring that lessons learnt from PSEELs were borne in mind when introducing the Public Sector Decarbonisation Scheme (PSDS) in response to the Covid-19 pandemic.

The UK Government has an established track record of facilitating the reduction in energy consumption in the industrial sector while recognising potential negative effects on competitiveness. As part of the UK Climate Change Levy (CCL), a tax on the consumption of energy in the business sector, Climate Change Agreements (CCAs) were offered to UK firms where a reduction in the levy was agreed in exchange for enforceable commitments taken by UK firms to achieve pre-defined energy reductions. After the expiration of the first scheme in 2011, the second scheme started in 2013 and will run until 31 March 2025. ISR has delivered the QEA evaluation of the second CCAs showing how stringent targets can deliver reductions comparable to those that would have been obtained by UK firms facing the full CCL levy, without the competiveness risks which they would have faced if full CCL rates had been paid.

As households on low incomes are at particular risk of fuel poverty, the annual £140 off the electricity bill of eligible households as part of the Warm Home Discount Scheme (WHDS) is very important, especially when market prices show strong upward trends. The implementation of

the policy has benefited from the QEA evaluation delivered by the team at ISR with regard to the way eligible households spend the money they receive. This is key in establishing how the scheme impacts energy consumption, therefore quantifying its effectiveness in mitigating the risk of fuel poverty.

Looking forward to future UK energy and climate policies, the introduction of the UK Emission Trading Scheme (ETS) has been a key change in the national landscape; a change which requires careful co-ordination not only across UK departments but also between the UK government and the devolved administrations. ISR is proud to be leading the scoping work of the forthcoming UK ETS evaluation therefore helping to ensure that a solid framework is put in place to learn key lessons about process, outcomes and impacts of the scheme.

Finally, implementation of the Net Zero Strategy will require innovation to play a key role in the UK energy system in the coming decades. Stable and consistent policies will be required not only to facilitate the development of new innovations but also their diffusion and adoption by UK customers and firms. ISR is proud to lead the scoping of the counterfactual evaluation of the government's Net Zero Innovation Portfolio (NZIP) of research, development and demonstration funding. We will also be part of the consortium which will be called upon to support the design of the evaluations of single schemes part of the wider portfolio.

Ten years of energy transition and energy access in the Global South

Changes and innovations in energy transitions in the Global South over the last decade, written by Senior Research Associate Xavier Lemaire as part of our 'Improving energy access and resource use in the developing world' research theme.

In 10 years, there has been a complete change of paradigm in the rural and urban electrification field in developing countries. The unrealistic goal of connecting the rural and urban population of developing countries to the central grid has given way to the concept of hybrid electric systems combining stand-alone systems, micro and mini-grids alongside the main grid with a mix of renewable and conventional sources.

This shift has also been accompanied by a significant increase in research on improving energy access through low carbon infrastructure. ISR's research on this theme has also grown rapidly in the past ten years, including through involvement in major programmes, such as Climate Compatible Growth and the Understanding Sustainable Energy Solutions (USES) in developing countries programme, under which STEPs – focused on thermal energy services – SAMSET – focused on energy transition in African municipalities and MECON – focused on energy efficiency in Southeast Asia – were funded.

Now, and all around the world, centralised renewable sources like large-scale wind and solar farms are competing with the cheapest conventional sources, such as coal. This is linked to the constant decrease in the cost of solar and wind which is the logical consequence of the increase of manufacturing capacity and of learning experience resulting from regulation and contracts to support renewables. One of the aims of the REEEP / Sustainable Energy Regulation Network, which was initiated by the late Dr Gill Owen, was to help disseminate and promote these policies.

Economies of scale and learning curves will continue and will contribute to further cost reductions not only for renewable energy generation, but also storage capacity. This will help to guarantee better energy security in the long-term for cash-strapped developing countries against high prices and the fluctuation of prices of conventional sources. Indeed, once subsidies are removed, with proper funding, specific incentives, contracts and auctions and carbon taxation, renewable energies can displace coal, as has happened in the UK.

Spectacular disruptions in the energy landscape have also happened with decentralised sources. Mini and micro-grids are now part of energy plans and policies in many developing countries, as they enable the rapid electrification of communities which would have otherwise remained out of reach of the conventional grid for decades.

Stand-alone systems, such as small solar photovoltaic systems, have not only benefited from the reduced cost of solar panels, but also from technological innovations which have enabled the remote control of solar systems and electronic payments. Such innovations have helped to reduce maintenance and transaction costs, saving renewable energy companies the logistical headache of sending technicians to remote places to diagnose system failures and collect payments. Reduced generation costs, combined with efficient technologies, have also enabled the provision of more energy services for domestic and small productive uses. With the progress of the miniaturisation of electronics and the advent of LEDs (Light-Emitting Diodes), pico-photovoltaic like solar lanterns are now

widespread and millions of solar lanterns are sold every year.

Another major change has been the emergence of renewable energy service companies based on innovative business models which, instead of selling a product (i.e. the solar home system), sell the service (i.e. the electricity). In this way, companies can reach large segments of the off-grid population. Alternative business models where solar companies work hand in hand with micro-credit companies have also been successful as they remove the barrier associated with the up-front cost of solar systems. The STEPs project examines whether these innovations in electrification can be replicated in the provision of thermal energy services.

In a field traditionally dominated by engineering considerations, a greater emphasis on end-users' needs and on sustainable business models has been, alongside a favourable regulatory environment, a key shift in helping to scale up the dissemination of small-scale renewable energy technologies. Combined with the technological innovations mentioned above, better marketing with products designed, not just in labs, but tested in the field with feedback from local communities has been essential to the adoption of small renewable technologies and in overcoming the accumulation of failed projects in developing countries. However, the large-scale dissemination of small-scale solar in the Global South also raises a number of challenges, including how the vast amount of electronic waste generated by the multiplication of small systems in remote areas will be recycled. Furthermore, due to demographic growth and the COVID-19 pandemic, the achievement of universal access to modern energy services by 2030 appears unlikely, especially in sub-Saharan Africa.

One final area of research under the ISR theme on improving energy access and resource use in developing countries relates to the spectacular growth in large-scale renewable technologies and the associated land use changes. Just as with the shift in land use from food to bioenergy, this land use change has the potential for conflict – particularly with local communities. It is an open question whether decentralised sources will leave more space for public participation and whether energy transitions will lead to the democratisation of the energy sector. While the current energy transition undoubtedly represents a huge opportunity to significantly increase electrification rates and the reliability of energy services in urban and rural areas of the Global South, examining the unintended consequences remains an important area of research at the ISR.

Economics and Policy of Energy and the Environment MSc

In 2022, we will welcome the tenth cohort of our MSc programme "Economics and Policy of Energy and the Environment" (EPEE). Over the years, EPEE has become an internationally recognised programme, repeatedly praised by external examiners as one of the best in its field. Hundreds of students have learnt from our world-class academics, becoming leaders and innovators in business, policy and research.

Thanks to our interdisciplinary and diversified environment, our programme equips MSc EPEE students with what is needed to excel and make their own contribution to making this world a better place. At the same time, in-class discussions make our research-led teaching special for our staff, with many colleagues still collaborating with alumni after several years. We know that the programme will continue to evolve and improve and, together with our alumni, will contribute to making our societies more sustainable and equitable.

Our alumni's journeys

VIVEK PAREKH, ANALYST AT INFLUENCE MAP, GRADUATED 2020

Before pursuing the EPEE MSc, I studied economics and worked at Nottingham City Council on the refugee resettlement team.

I chose EPEE as it offered an excellent range of modules that were taught by industrial and academic experts. The course also provided numerous insightful guest speaker events from a range of businesses and organisations external to UCL. This enabled me to tailor the course to my interests and potential career pathway. One such tailoring choice was studying the Energy, Environment and Resources in Developing Countries module. This module allowed me to develop my knowledge and skills from the core modules and apply them in the context of the Global South particularly focussing on social justice and economic development.

After graduating I started work as an Analyst at InfluenceMap, an independent think tank that provides data and analysis on how business and finance are affecting the climate crisis. Studying a range of modules during EPEE that included EU and international policy enabled me to work on developments in EU climate legislation in my new role.

What advice would I have for future students? Maintaining a work life balance that suits you is extremely important for your mental health and will help you to sustain good productivity. When it comes to employment, I would suggest being flexible and not fixating on one industry - many companies appreciate different experiences and transferable skills.

SHANALI PETHIYAGODA, ENVIRONMENTAL ECONOMIST AT THE FAO, GRADUATED 2019

My undergraduate degree was in Economics, with a focus in econometrics, and after graduating I worked briefly in health economics research before shifting towards a career in environmental economics.

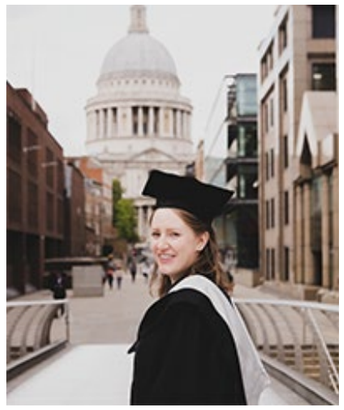
One of the best things about the EPEE MSc was its excellent teaching staff that elevated the degree to world-class levels. I particularly enjoyed the Behavioural Economics module and, thanks to the great teaching staff and course structure, I was able to deepen my understanding through a combination of theory and practical application which was very exciting. I still use what I learned in that module in my current endeavours!

My MSc was pivotal in forging my current career path. It had been a long-standing dream of mine to work for the United Nations and I am currently working as an Environmental Economist at the Food and Agriculture Organization in Rome. I am a part of the adaptation team working on the "Scaling up Climate Ambition on Land use and Agriculture through NDC and NAP (SCALA)" programme, which focuses on addressing climate change adaptation and mitigation related to the agricultural sector.

Of course, pursuing a Master's degree is not only about progressing academically and professionally. It is also about meeting new, interesting, and like-minded individuals to share the journey with. I was exceptionally lucky to build some wonderful friendships during EPEE and have enjoyed celebrating in their many successes since graduating!

IRINA SEMYKINA, SENIOR ANALYST AT THE SUSTAINABLE DEVELOPMENT CENTRE OF THE RUSSIAN ENERGY AGENCY, GRADUATED 2020

Prior to starting the EPEE MSc, I had been working as a research fellow at the Russian Academy of Sciences where I explored the economy of oil and gas dependant regions. The MSc gave me a chance to deepen my knowledge on energy economics and policy and I really appreciate how intense and comprehensive the programme was. One of my favourite modules was 'Energy, Technology and Innovation' because it explained the theory behind technological development. The concepts which I learned in the module I use the most in my everyday work.



After graduation, I joined the Oil and Gas Climate Initiative (OGCI) as Strategy and Policy Team intern, where I focused on natural gas sector methane emissions mitigation. I currently work as a Senior Analyst at the Sustainable Development Centre of the Russian Energy Agency. We provide analytical support to the Ministry of Energy on a range of issues pertaining to energy and the environment. Indeed, the MSc equipped me with a set of cutting-edge knowledge and skills, which are unique for my home country. From Levelised Cost of Energy models to energy policies, I am now fully prepared to work in the growing field of the energy transition!

The concept of a Circular Economy was in its infancy a decade ago, now it's regarded as a core aspect of a sustainable future. Discover UCL ISR's involvement in this research area over the last ten years, outlined by Associate Professor Teresa Domenech from our 'Sustainable, circular and resource-efficient economies and societies' research theme.

Ten years ago, the Circular Economy (CE) was a nascent concept. Although the theoretical foundations of the term can be traced back to early work of Boulding (1966) and the genesis of the industrial ecology field, at that time its compelling policy narrative was still in the making. Although the first Circular Economy law dated back to China in 2008, in Europe momentum for the concept started to build around 2011-12. This was aided by contextual factors such as a surge in resource prices, which had increased over 80% since the early 2000s, and security of supply issues around what were then labelled as 'critical materials'. In 2012, the European Resource Efficiency Platform was formed with the objective to provide high level advice to the European Commission on resource efficiency, with Professor Paul Ekins as one of his members (and me acting as his 'Sherpa'). Other members included four European Commissioners, Vice President Tajani and representatives from industry, policy and academia.

Those were the times of face-to-face meetings and in those long discussions CE started to grab attention to articulate clear pathways for resource use which were aligned with planetary boundaries. CE helped to create a golden thread around areas which had previously been isolated policy silos: climate change, resources, and waste. It pointed to a better understanding of the inextricable connections between the use of resources and emissions, pollution, and waste generation. The short- and long-term list of recommendations proposed by the Platform included promotion of industrial symbiosis, Extended Producer Responsibility, sustainable sourcing and investment in resource efficiency and, perhaps most importantly, creating commitment and leadership for embedding circularity thinking at the core of policy making processes.

Most of the recommendations were then integrated in the first European Commission Circular Economy Package, which was presented in July 2014. The Package was caught in a political upheaval which culminated in its withdrawal by the new Junker commission. This resulted in a rather unexpected and unprecedented reaction wherein industry associations, business organisations and other stakeholders wrote open letters to support ambitious policy commitments in the area of resources and waste. The political turmoil forced the newly appointed first Vice-President Timmermans to commit to a revised and 'more ambitious' Circular Economy Package which was presented in 2015 and the new CE Action Plan was approved in its final form in 2020.

In 2015, UCL ISR launched one of the first MSc degrees focused on the Circular Economy – the Sustainable Resource: Economics, Policy and Transitions MSc. This course aims to educate the next generation of leaders with strong scientific and technical foundations and understanding of broader policy and economic dimensions of the transition to a low carbon, circular economy. In 2016, UCL became one of the Global Pioneering Universities for the Circular Economy, part of the Ellen MacArthur Foundation's CE100 network. Teaching is nested in leading research activity of UCL ISR revolving around three core research themes:

Advanced modelling of the circular economy. This combines Material Flow Analysis, Life Cycle Assessment, and macroeconomic modelling approaches to quantify and better assess the potential of the circular economy to reduce environmental impacts and accelerate the low carbon transition (as well as understanding of its socio-economic implications).

Application of CE approaches into new business models, regional and urban development and policy mixes progressing knowledge around framework conditions for the emergence of new forms of organisations, spatial planning, and policy landscapes.

Research into socio-technical and technological pathways for deep transformation of industrial activity and supply chains through the lenses of industrial ecology, industrial symbiosis, and circularity towards regenerative, circular manufacturing.

ISR has consolidated its research leadership in the area of the Circular Economy through its contribution to the UKRI Circular Economy Centres in Metals, Construction Minerals and most recent collaboration with the UKRI Circular Economy Centre for Textiles.

Sustainable Resources: Economics, Policy and Transitions MSc

Over the years the Sustainable Resources: Economics, Policy and Transitions MSc (SR:EPT) has been attracting ever more highly skilled and talented applicants who wish to dedicate their careers to sustainable resource use. Those teaching on the programme, both academics and practitioners, have often been amazed by the students' expertise and abilities. Alumni regularly go on to get jobs in organisations and positions highly relevant to SR:EPT topics and concerns, and they frequently come back to share their insights with current students and faculty. This network of thought leaders and practitioners has become an important feature of the SR:EPT MSc, directly connecting the programme to latest development in business, policy making and civil society.

Our alumni's journeys

MICHAEL PECHSTEIN, INVESTMENT ASSOCIATE AT GLENMONT PARTNERS, GRADUATED 2019

I am originally from the United States and, after studying economics and finance, I worked for several years at an investment bank in New York. I learned a lot and enjoyed my time there but, wanting to specialize and do something more impactful, I decided to come to UCL to study Sustainable Resources.

Since graduating in 2019, I have been employed at Glennmont Partners, a clean energy investment fund working to invest institutional capital into the deployment of large scale generation infrastructure. Being able to make a direct impact on the advancement of renewables and learning about the complex and interconnected drivers of the energy transition has been fantastic.

SR:EPT certainly helped me to steer my career in this new direction. I think that, in addition to helping me explore potential new avenues, the programme gave me a strong base of knowledge on a number of energy and decarbonisation topics and allowed me to speak competently with employers about these nuanced areas. I am working every day to understand how our firm can stay on the cutting edge of the rapidly evolving clean energy space, and SR:EPT helped to lay the groundwork for this type of thinking.

My advice to current students would be to remain very open minded for the first half of the programme, but choose an area to focus on in depth for the second half and the dissertation. The MSc covers a lot of ground, but by specialising and becoming an expert in an area you're passionate about, you will be much more competitive in the job market.

JAMES TOTTON, UNDERWRITING ASSISTANT AT GCUBE, GRADUATED 2018

Before undertaking a BSc in Geography at Royal Holloway, I spent a year working at an environmental consultancy firm in Dhaka, Bangladesh where I developed a passion for climate change and understanding how it's impacting our future. The SR:EPT MSc masters provided the perfect opportunity to refine the knowledge and skills I had learnt through my undergraduate degree and work placements.

Since graduating in 2018, I have been working as an Underwriting Assistant for one of the leading insurance companies specialising in renewable energy. This job has allowed me to use a lot of my different skills and interests from climate change to energy and natural disasters on a day-to-day basis. Many of the skills I refined during my masters are now used daily from excel through to delivering presentations and report writing. Most importantly, it taught me how to learn new things quickly and efficiently. An invaluable skill in a job where new problems need solving every day.

My advice to future students would be to put 100% of your efforts into your studies while you can. Help each other out and reach out to the lecturing staff when you can't. As you progress through the course, begin thinking of what you would like to afterwards whether this is a career or further study. Start to roughly map out what skills and experiences are conducive to get into that next phase. If you are looking for a job after you finish, I would suggest that only after you have submitted your dissertation should you begin to seriously look for jobs. This way you can treat your search for what it is - a full-time job in itself.

VERONICA GONZALEZ, SUSTAINABILITY SPECIALIST AT ANTOFAGASTA MINERALS, GRADUATED 2017

Before starting the SR:EPT MSc, I had studied economics and had worked as a researcher and consultant at a university and NGO in Chile. Today, I work as a sustainability specialist for Antofagasta Minerals. The MSc provided me with the analytical skills and specific knowledge about the mining industry that have been really valuable for my current job.

I really enjoyed the content of the course - I acquired a lot of knowledge regarding sustainability trends. I also enjoyed the lectures and the way in which professors taught the subjects. I particularly enjoyed the module on 'Metrics, Modelling and Visualisation of the Resource Nexus'. For this module, I was able to do research on an island, in my case the Galapagos, and produce a report that included a methodology developed by me.

I would advise future students to enjoy your time at UCL and to commit to your studies. The academic staff have valuable expertise and the ISR is a key research institution that can provide solutions to the current challenges that we face as a society, and it is fantastic to be part of that as a student.

Keeping fossil fuels in the ground: the transition to a net zero economy

The transition from a high carbon energy system to a low carbon energy system will be challenging but could also provide huge opportunities - Researchers Dan Welsby, James Price and Steve Pye talk about the transition to a net zero economy as part of our 'Energy system transitions to achieve net-zero' research theme.

Our global energy system is dominated by fossil fuels. Coal, oil and fossil methane gas (natural gas) accounted for around 85% of primary energy consumption and anthropogenic CO2 emissions in 2019. Since its founding in 2011, the UCL Institute for Sustainable Resources has provided interdisciplinary research on the sustainable use of natural resources, both renewable and non-renewable, including under the Energy System Transition research theme.

Recent research from the IEA, UNEP/SEI and UCL state that if global temperature rise is to be limited to 1.5°C and net zero CO2 emissions are to be achieved by the middle of the century, then the planned growth in fossil fuel production must immediately reverse course and start declining now with the majority of fossil fuels remaining in the ground. This would require interventions on both the demand- and supply-side:

- Demand side interventions – carbon pricing mechanisms, removing fossil fuel consumption subsidies and regulation to, for instance, phase-out/ban certain technologies (e.g. gas boilers, internal combustion engine (ICE) vehicles (e.g. petrol and diesel))
- Supply side interventions - removing tax breaks and production subsidies, moratorium on new developments/exploration licenses
- The required transition away from fossil fuels is complicated by numerous factors, not least:
- The availability of alternative sources of energy and technologies
- The extent to which fossil fuels are embedded in the social, economic and political spheres
- The need for accessible and affordable energy access, particularly in developing regions where energy demand is projected to increase substantially as energy access improves
- The risk of stranded assets (fossil fuel infrastructure, fossil fuel reserves and resources) particularly for countries whose national economies are heavily dependent on hydrocarbon revenues

In the short term, 'low hanging fruit' to reduce emissions from the fossil fuel supply chain are readily available, including minimising methane leakage from oil and gas production and transportation networks. At COP26, over 100 countries signed up to reduce methane emissions by 30% by 2030. Given the energy system contributes around 62% of non-agriculture human-caused methane emissions, much of this reduction will be realised in the upstream fossil fuel sector. In limiting methane leakage, this essentially means that companies can sell more gas downstream, and therefore there is a distinctly economic rationale behind the drive to limit methane emissions from oil and gas supply chains. Additionally, the World Bank "Zero Routine Flaring by 2030" Initiative has been endorsed by large oil producers including Iraq, Nigeria, Russia, Saudi Arabia and the United States.

Whilst reductions in emissions from fossil fuel supply chains are welcome and necessary, the scale of CO2 reduction required to meet net zero CO2 emissions means that fossil fuel production must decline if that goal is to be achieved. The question of who can and cannot produce their fossil fuels under different carbon budgets

has been explored by researchers from ISR in two papers in 2015 and 2021. In both pieces of research, a global energy model was used to determine the regional distribution of fossil fuel reserves and resources which must remain in the ground to keep global temperature rise to 2oC (2015 paper) and 1.5oC (2021 paper). The model uses a least cost framing to allocate the volumes of fossil fuels which must remain in the ground. This means key aspects of equity, just transitions and the need to manage the decline of production in economies that are heavily dependent on hydrocarbon revenues, are not considered.

Whilst the scientific consensus on the need to drastically reduce fossil fuel production (and consumption) is broad, the pathways by which production cuts are achieved are far more uncertain. In particular, the Beyond Oil and Gas Alliance and the Fossil Fuel Non-Proliferation Treaty have put an emphasis on a just transition, arguing for a more managed decline of fossil fuel production in countries heavily dependent on hydrocarbons for tax revenue and employment. This includes developed economies (e.g. Europe, the United States, etc.) playing a crucial leadership role in the required transition given the level of accumulated historical emissions and the associated benefits in these regions. The issue of a just transition and historical responsibility for cumulative emissions was implied in the final wording of the Glasgow Climate Pact, with the relatively ambiguous reference to a "phase-down" of coal and the removal of "inefficient" fossil fuel subsidies. There seems to also be increased realisation that economies with a heavy reliance on fossil fuel production are significantly at risk should the required energy transition be realised (not to mention nearer-term fluctuations in global fossil fuel prices). Iraq is amongst the 'petrostates' calling for economic diversification but also for international support in the transition. There has also been increased research and policy interest around 'retrofitting' some existing infrastructure and jobs in fossil fuel industries toward the low carbon economy - for example with transferrable knowledge and infrastructure from offshore oil and gas extraction to offshore wind in the United Kingdom, thus maintaining key jobs in areas where the oil and gas industry currently provide employment.

The transition from a high carbon energy system to a low carbon energy system will undoubtedly provide huge challenges, but also opportunities, and what is clear is the absolutely critical need to reverse the current trend of global fossil production from one of growth, to one of decline.

UK TIMES: a model that underpins government climate policy

Planning the route to a low-carbon economy in the UK is a complex task. Professor Paul Dodds from our 'Energy system transitions to achieve net-zero' research theme explains how the UK TIMES Model created at UCL ISR in 2012 is used to help achieve this goal.

The Climate Change Act 2008 requires the UK government to reduce UK greenhouse gas emissions by 80% by 2050 compared to 1990 levels. In July 2019, the UK adopted a more ambitious net-zero emission target to meet its Paris Agreement commitment.

In 2021, the UK Government released its Net Zero Strategy. Such national climate strategies should identify coherent and cost-effective policies to credibly meet emission targets. They should ideally describe how each part of the economy should evolve at each stage of the transition to net zero.

The UK TIMES model

At UCL ISR, we created the UK TIMES energy system model in 2012 to explore the transition to a low-carbon economy in the UK. UK TIMES has a snapshot of the UK energy system in the year 2010, including all energy flows, technologies, and emissions. All emissions and their mitigation options outside the energy system were modelled for the first time, including those from agriculture, land use, refrigerants, and waste.

The energy system exists to meet energy service demands, such as heating, lighting and transport. For UK TIMES, we need to forecast how each energy service demand will change in the future.

We define a wide range of possible decarbonisation technologies in the model (e.g. renewable generation; hydrogen production and use; heat pumps to heat homes and offices). The model then calculates the cheapest possible way to meet all of the energy service demands, in a 50-year transition to the year 2060, while also meeting our greenhouse gas emission targets. It identifies investment strategies in a range of new technologies over the transition. These can then be put into practice by appropriate government policies.

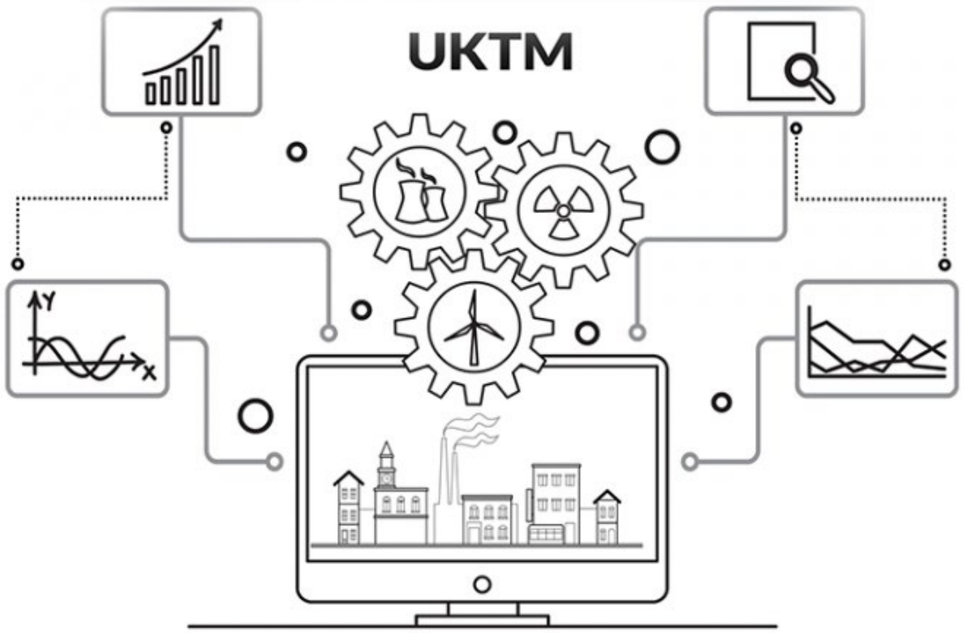
Use of UK TIMES by the UK Government and other stakeholders

UK TIMES has been adopted by the UK government as their principal in-house tool for generating long-term energy scenarios. It directly contributed to their decision to adopt a net-zero target and underpinned the Net Zero Strategy, the Clean Growth Strategy, and their decisions to agree the fifth and sixth carbon budgets proposed by the Climate Change Committee.

In October 2017, the Department of Business, Industry and Industrial Strategy (BEIS) published the Clean Growth Strategy, which set out how the government planned to meet the Fourth and Fifth Carbon Budget commitments. BEIS used UK TIMES to explore scenarios for energy system decarbonisation, and to identify key energy technologies that could contribute to decarbonisation and provide growth opportunities.

For the Net Zero Strategy, BEIS used UK TIMES to create a range of internally consistent scenarios that met emission targets. Each part of those scenarios was then reviewed by the appropriate expert team in BEIS, or elsewhere in government (e.g. DEFRA for agriculture; DfT for transport). This helped BEIS to coordinate its various teams and inter-departmental stakeholders around a more coherent decarbonisation strategy.

National Grid have similarly adopted UK TIMES to provide evidence for their annual Future Energy



Scenarios for the last few years. ISR has created a UK TIMES expert user group that meets annually and includes 20 stakeholders from government, business and academia. Academics are able to join the expert user group and use the model.

The future of the UK TIMES model

UK TIMES is continually being improved as we learn more about novel low-carbon technologies, and consider how we can more accurately represent the UK energy system in the model.

UK TIMES represents the whole UK as a single region. UCL are working with BEIS to develop a new multi-region version that will enable us to explore the implications of different parts of the UK adopting different policies to achieve decarbonisation targets (e.g. if England invests in nuclear power while Scotland looks to offshore renewables).

In the longer term, we would like to take this further by modelling each local government region separately so we can produce local decarbonisation plans. These would reflect the characteristics of each local area while ensuring that the sum of all of the plans across the country would achieve net zero.

We are exploring how we can use UK TIMES in novel ways. One example is to consider how the transition pathways might change if energy service demands were to substantially reduce in the future as a result of widespread behavioural change. Another is to use different types of uncertainty analyses to explore the range of potential future pathways, and to understand which of these are most plausible from a socio-political perspective.

While UK TIMES is already available to the expert user group, we are keen to make the new model completely open source. It will soon be hosted on a website with full documentation. We also hope to make key transition scenarios available to the public via a new website. Watch this space!

Computable General Equilibrium (CGE) models are widely used for policy formulation and analysis. Associate Professor Alvaro Calzadilla reflects on the contribution of the macro-economic modelling team in this area.

Policy decisions involve choices that will not necessarily benefit all actors in an economy. A public policy to improve the distribution of income, for example, will imply trade-offs, which may differ across different socio-economic groups. Domestic policies may also have repercussions on international markets; for example, critics of the 2003 EU biofuels policies, which aimed to decrease CO2 emissions in the transport sector, highlighted its consequences for indirect land use change outside Europe. Policy makers and stakeholders need to balance trade-offs and promote synergies arising from the delivery of policy objectives.

Empirical economic models based on theoretical foundations, such as Computable General Equilibrium (CGE) models, offer the possibility to inform evidence-based policy making. In fact, as economy-wide models quantify the direct, indirect and induced impacts of policy interventions and exogenous shocks (e.g. climate change, Covid-19), policy makers and stakeholders have the possibility to assess and compare the expected impacts of alternative policies and adaptation options across households, sectors and countries. The use of CGE models for policy analysis dates back to 1960, when Leif Johansen developed a model for Norway.

The UCL Environmental Global Applied General Equilibrium (ENGAGE) model, developed by the macro-economic modelling team at ISR, is one of the main tools supporting the analysis of climate, environmental, resource, energy and economic policies. While the multi-sector, multi-region nature of ENGAGE allows the evaluation of policies across sectors and across regions, ISR's macro-economic modelling team also uses detailed country CGE models to assess the impacts across different socio-economic groups. The policy analysis of the macro-economic modelling team supports different ISR research themes and has focused on the following areas:

• Climate change and decarbonisation. By assessing the investments required for the decarbonisation of the energy system and the ways in which the transition could be financed, our research shows that the economic impacts of decarbonisation are unevenly distributed between high-income and low-income countries, with the latter group experiencing a larger economic slowdown than the former. The impact is larger when the climate ambition is increased. As low-income countries rely more on fossil fuels out to 2050, financial support for decarbonisation from high- to low-income countries can play a significant role in rebalancing impacts with minimal cost.

• Global food production. Land degradation affects a quarter of the global land area. Together with climate change, it is expected to increase the risks to food security in many regions of the world. Our research shows that land degradation impacts are considerable in developing countries, where the decline in soil nutrients are not compensated with fertilizers. Land degradation could significantly amplify the negative impacts of climate change, as the magnitude of its impacts are comparable to worse-case climate change scenarios. However, our research also highlights the role of international trade as a mechanism for adaptation—a functioning global food market is essential for food security. Policies to promote sustainable soil management practices may help to reduce the negative impact on yields caused by land degradation. However, the overall impact on crop production worsens as agricultural workers are exposed to extreme heat conditions, leading to loss of labour productivity.

• Resource nexus. By linking a water and a CGE model to capture the dynamic interactions between the Nile's hydrology, the Grand Ethiopian Renaissance Dam (GERD) and Egypt's economy, our research shows that coordinated filling and long-term operation of the dam increases the total electricity generation from both the dam and the Nile system. It also sustains Sudan's water consumption, decreases Egypt's irrigation water deficits, and increases Egypt's GDP. Our research highlights the role of cooperation in such a dynamic and complex system, particularly to cope during severe periods of water scarcity.

• Circular economy. Our research in this area is particularly innovative. By developing the first global CGE model that represents the circular economy in the steel sector, we found that a green shift towards steel recycling in China brings significant competitiveness and economic gains. However, this shift needs to be aligned with an energy transition in the power sector to avoid carbon emissions generated during the production process. Our analysis contributed a section on the OECD report "Global Material Resources Outlook to 2060: Economic Drivers and Environmental Consequences", highlighting the economic, resource and environmental gains of increased efficiency of steel-intensive industrial sectors in China and India to similar levels observed in advanced economies.

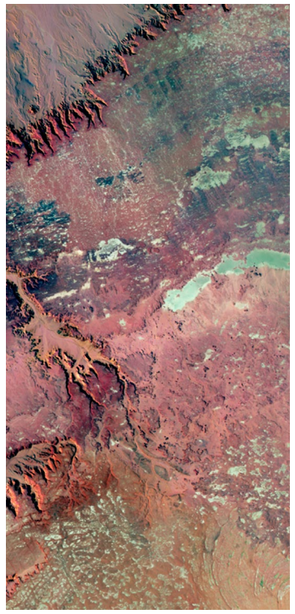
As part of two of the five new UKRI Interdisciplinary Circular Economy Centres and the Climate Service for a Net Zero Resilient World Programme, the macro-economic modelling team will continue to support policy formulation and evaluation towards a sustainable future.

10 years of doctoral research

Our PhD programme has been a key pillar of our work since the institute was established in 2011. The BHP Billiton Foundation provided a donation to support 20 PhD students to research topics related to sustainable resource use. Most of these early students have now graduated and have gone on to have successful careers in research, government, industry and with international organisations. Today, the ISR has more than 25 PhD students studying topics as diverse as crowdfunding private public partnerships for energy access to the politics of urban water governance. The ISR aims to not only train our students to become independent, accomplished researchers, but also to become leaders and entrepreneurs in their chosen fields. Below we hear from some of our graduates who reflect on their PhD experiences, pressing resource challenges, and provide valuable advice to future students.

Our alumni's journeys

DARSHINI RAVINDRANATH, GRADUATED 2018



Prior starting a PhD at UCL ISR, I had an MSc in Environment and Development and a BA (Hons.) in Economics. I also had work experience with diverse organisations including international development agencies (ADB and UNDP), research institutes (LSE), private sector consulting, and NGOs in India and the UK.

The best part of the PhD was being a part of a cohort of students working towards a joint goal of understanding some of the greatest complexities and challenges we are faced with. More personally, I relished the opportunity and freedom given to me by ISR to conduct my field research in a manner of my choosing. I spent close to a year in the desert villages of Rajasthan in India researching land use, climate change and its impacts on the people in the region. It challenged me and changed my perspective in the most meaningful way.

After graduating, I joined the UK Civil Service where I spent a couple of years as a senior policy advisor on energy policy. I moved teams and I am currently working in the International Climate and Energy team, where I lead on green finance policy. Completing my PhD helped me enhance my analytical skills, both qualitative and quantitative, and particularly the ability to think through and grasp complicated concepts, develop solutions through analysis, and importantly communicate solutions in an accessible manner.

My advice to future students would be to take delight in the time and space provided at the university to focus on a subject matter you are passionate about, and to be a part of as many conversations as you can!

What do I think are the biggest sustainable resources challenges and opportunities facing society today? I will quote the UNCCD - "It is essential to understand and address the dual challenges of land degradation and climate change if we are to meet targets, such as proposed by the sustainable development goals, tackle poverty and address many of the most pressing environmental challenges of the 21st century".

JUN RENTSCHLER, GRADUATED 2017

Before starting my PhD at UCL, I completed a BSc and MSc in Economics and spent two years working in government and international development. I was looking to strengthen my technical skills and expand my expertise in the economics of climate change, energy and development.

I enjoyed many things about the PhD. For example, being able to invest time in sharpening my technical skills was a luxury and stand-out feature of my time at UCL – especially as I was supported by some world class academics and experts. Being based at ISR also meant that I was able to conduct applied research on pressing sustainability and development challenges, rather than being isolated in the "ivory tower". Overall, ISR, and UCL more broadly, offered a terrific network of colleagues and fellow PhD students from diverse personal and academic backgrounds. Our lunchtime conversations covered everything from geopolitics to bread baking, and I rarely left a day at the institute without having my mind boggled and horizon expanded.

After my PhD I joined the World Bank at its headquarters in Washington DC. Currently I'm a Senior Economist in the Bank's Sustainable Development group. Our work is all about supporting developing countries in eliminating poverty and promoting green, resilient, and inclusive development. In practice that means working with client governments around the world to identify and tackle their most pressing development and sustainability challenges.

My PhD prepared me for the role. It provided a rigorous training in economics, and offered me an opportunity to collaborate with and learn from experts of other disciplines – statisticians, social scientists, energy engineers, climate modelers, and spatial data scientists. The PhD taught me to find robust yet pragmatic solutions to complex challenges, drawing on the tool of rigorous analytics combined with the insights of local knowledge and experience.

For future students, my advice would be – if in doubt – follow and learn from the people that inspire you. It might lead you to places that you didn't expect, and the path is likely to be meaningful and rewarding.

What do I think are the biggest sustainable resources challenges and opportunities facing society today? It is striking that the solutions to climate change and broader sustainability challenges are often well known and available, and yet progress seems to be painstakingly slow and complicated. Why is that? For instance, to tackle climate change we know that we need to scale up renewable energies, decarbonize transport, insulate buildings, conserve carbon sinks, etc. We also know that we need social support systems to ensure that transitions don't come at the expense of vulnerable and poor groups.

Broadly speaking, for all these purposes we have a good understanding of the available policy and regulatory instruments. The necessary technologies mostly exist already, and the financing needs are not impossible. That is not to say that we don't have knowledge gaps – further research will be crucial, for example to identify more effective policies and further reduce costs of clean technologies. But it does suggest that in practice we struggle with taking action in the messy reality of politics, power relations, vested interests, misinformation, and behavioural biases.

Finding better ways to overcoming these implementation challenges will be essential for making meaningful progress in all areas of sustainable development. Strong institutions, open access to objective information, and inclusive decision making will be key to this puzzle. And if managed well, we stand to benefit from safer, cleaner, and more equal and prosperous societies.

FLORIAN FLACHENECKER, GRADUATED 2018

Before joining ISR, I obtained an MA in European Economic Studies from the College of Europe (Belgium) and an BSc in Economics from the University of Mannheim (Germany) and the Tecnológico de Monterrey (Mexico).

My favourite part was that the ISR culture gave me the perfect combination of the freedom to pursue my own research interests, and academic excellence through my brilliant supervisors and inspiring colleagues to exchange ideas, develop skills and build long-lasting links. My PhD helped me in numerous ways, but crucially it provided me with the required analytical background to support evidence-based policy making. It also helped me further develop a strong sense of self-motivation.

After graduating, I joined the Young Professionals Programme of the OECD as an Economist, working on the circular economy, environmental taxes and the monitoring of the UN's Sustainable Development Goals. Since then, I have been working at the European Commission, first as an Economist in the Joint Research Centre on environmental innovations and firm growth, and now as a Policy Officer in the Recovery & Resilience Task Force on ensuring a green recovery. I never fully left ISR since I continue to be an Honorary Lecturer.

What doI think are the biggest sustainable resources challenges and opportunities facing society today? In my view, the biggest challenges facing society today– and at the same time biggest opportunities – are linked to ensuring that the green transition fosters social cohesion and the active participation of citizens.

TOBIAS REINAUER, GRADUATED 2019

Before undertaking a PhD at the ISR, I completed a BA in political science and law in the Netherlands and ISR's MSc in Economics and Policy of Energy and the Environment. I also spent time in southern Africa doing a year-long volunteer service in Mozambique and an internship/semester study abroad in South Africa, which made me curious about how developing and emerging economies can transition towards sustainable, low-carbon energy systems.

After finishing the MSc, I began a PhD focusing on the development of the sector for industrial-scale biogas systems in Thailand. Building on this research, after finishing, I was a postdoc at the UNEP DTU Partnership in Copenhagen, Denmark, where I studied the markets for small wind turbines and household solar devices for off-grid electrification.

What do you think are the biggest sustainable resources challenges and opportunities facing society today? In my opinion, one of the biggest challenges today concerns the prospect of low-carbon growth in emerging economies. High-income countries that have made progress in lowering their greenhouse gas emissions need to ramp up their collaborations with emerging economy partners in order to share the lessons they have learnt.

The shape and pace of change

Solar PV, wind power and electric vehicles are increasingly prevalent in attempts to address climate change. But what are the future prospects for these crucial low carbon technologies? Senior Research Fellow Dr Nick Hughes, as part of the 'Directing innovation for sustainable development' research theme, elaborates on the future of these carbon cutting tools.

The task of cutting carbon emissions to address climate change has for decades been perceived primarily as a costly activity. This is because low carbon alternative technologies have typically been more expensive than their conventional fossil-fuelled equivalents.

This underlying perception has continued to animate international climate negotiations. If cutting carbon is costly, then the question of who has the responsibility to cut furthest and fastest remains deeply political, and strongly connected to questions of responsibility for past emissions, and current access to the financial resources necessary to fund action. But how strongly does the assumption that cutting carbon is costly still hold?

Two recent ISR reports, commissioned by the We Mean Business coalition, examined the future prospects for three crucial low carbon technologies – solar PV, wind power and electric vehicles – by considering their recent progress in deployment and cost reduction, and the implications if these trends were to continue.

In recent years, significant cost reductions in low carbon technologies have been observed. Whilst low carbon technologies often still have higher upfront costs, when their much lower running costs are included, and all costs averaged out over the lifetime of the technology, low carbon energy is increasingly emerging as cheaper.

This data from IRENA shows how the cost per unit of electricity produced from solar PV, onshore wind and offshore wind, averaged over the lifetime of the plant, has been falling over recent years, and is now highly competitive with the range of equivalent costs from fossil fuel plants – in some cases cheaper than even the most efficient fossil fuel plants.

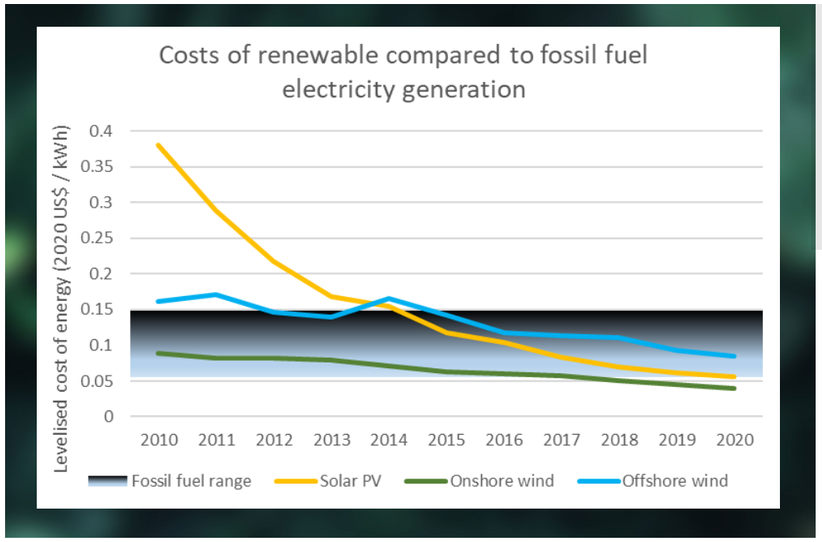


Figure 1: The global average 'levelised cost of energy' for electricity produced from solar PV, onshore wind and offshore wind, compared to the range of costs of fossil fuel-based electricity generation.

Data from IRENA (2020)

So, renewables and electric vehicles make increasingly good economic sense.

Despite this they are still far from taking over on a global scale. Currently, the combined electricity production of solar PV and wind supplies about 10% of global electricity demand, and electric vehicles are about 1% of the global car fleet.

But in addition to considering the shares as they stand at the moment, it also relevant to consider the rate at which these technologies have been growing. Between 2010 and 2019, the amount of electricity produced from solar PV and wind increased at average rates of 41% and 17% per year respectively; and the share of electric vehicles within the total global car stock has been increasing over the last 5 years at average rates of 44% per year. The IEA projects that renewable sources of electricity will account for "95% of the increase in global power capacity through 2026."

If these kinds of growth rates were to be maintained over the next few years, these technologies would fairly rapidly acquire dominant market shares, as illustrated in the figure below. It shows the possible future implications for the growth of each technology, on the basis of the continuation of annual growth rates similar to those of recent years. The projections start by adopting the annual average growth rates since 2010 for solar PV and wind, and since 2015 for electric cars. The growth rates used to extend these projections out to 2050 never exceed these recent historic averages – on the contrary, the growth rates are gradually reduced from their recent historic levels, as the market share of the technology increases. As the market share nears its full potential, the growth rate declines toward zero, causing growth to level off. This produces an "s-curve" shape, characteristic of many real historical technological transitions.

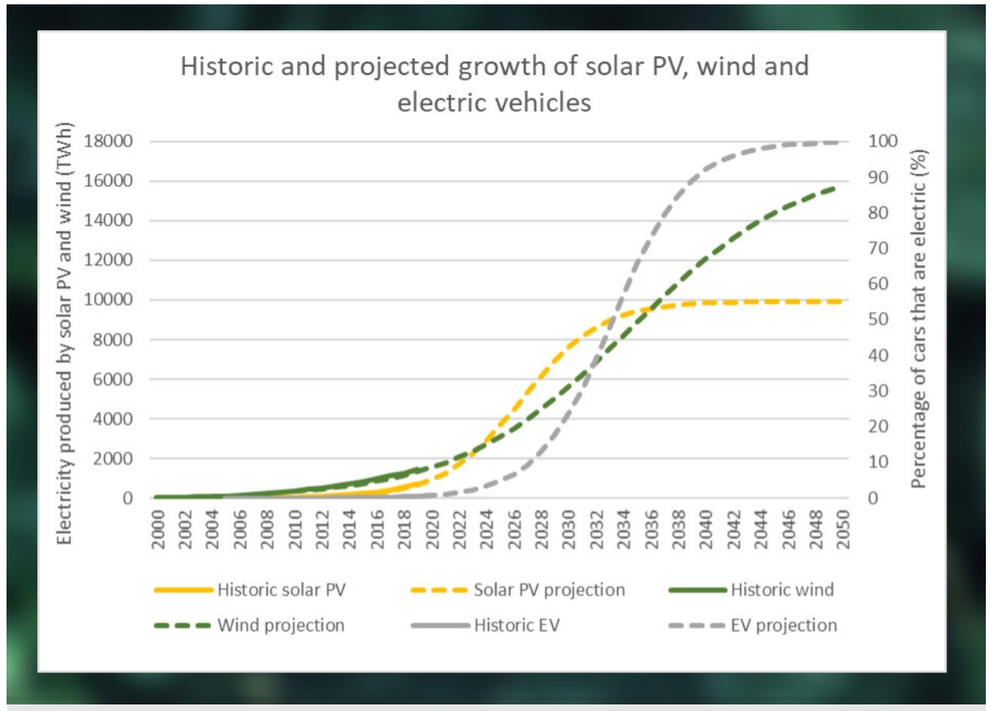
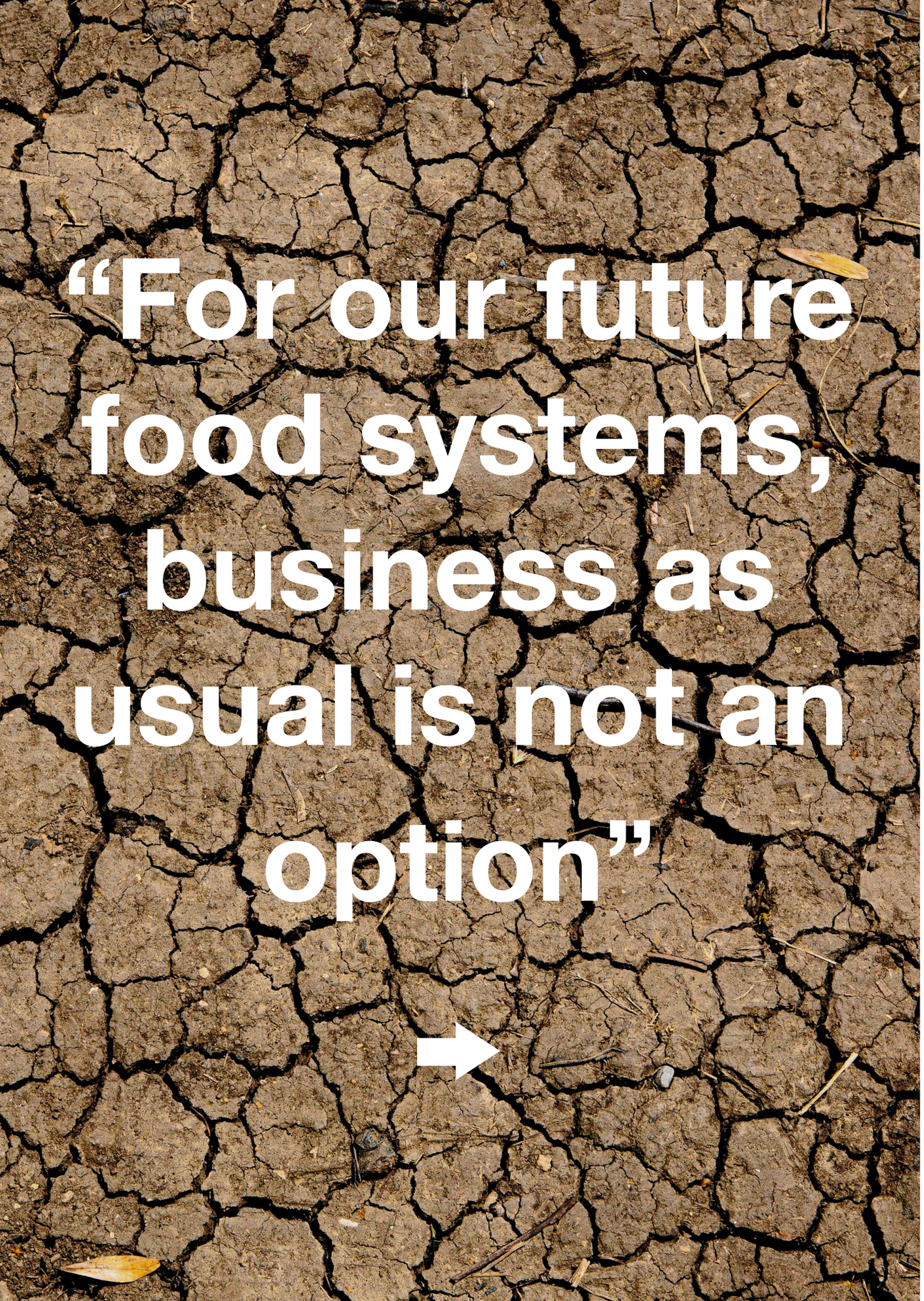


Figure 2: Recent historic growth of global electricity generation from solar PV and wind, and of electric vehicles as a share of total global cars, and future projections of each based on their recent historic growth rates, fitted within an s-curve diffusion shape, typical of technological transitions. Adapted from analysis presented in recent ISR reports for the We Mean Business coalition, on the electricity and transport sectors.

Of course these are purely illustrations – but they help to show the speed with which new technologies can acquire market share, if anything like the kind of growth rates recently observed for solar PV, wind and electric vehicles, can be maintained.

The increasing cost competitiveness of these technologies provides one strong reason to think that these powerful rates of growth could indeed be maintained. But cost reduction alone is not sufficient – there are a number of other conditions that will also be required to bring about the kind of transformational change illustrated by the above graphs.

The continuation of these rates of growth will depend on the availability of finance to both large and small actors in different regions of the world, at reasonable rates of interest; on coordinated and strategic planning of infrastructure both in the electricity and transport systems, which also takes into account the interactions between these systems; on a similarly integrated review of policy and regulatory frameworks that support the full integration of renewables in the electricity system, including by encouraging and rewarding load-shifting, and take account of the increasing synergies between the electrified transport system and renewables-led electricity system; and on both national and international measures to ensure that the supply chains supporting these technologies are sustainable and just, and that the benefits of green job creation, and the upfront costs of necessary infrastructure investments, are fairly shared.



Ending hunger, ensuring water security, restoring biodiversity whilst tackling the climate crisis is no easy task. Associate Professor Carole Dalin discusses how some of her research at ISR hopes to help achieve this goal in the ‘Sustainability at the water-food-land nexus’ research theme.

“For our future food systems, business as usual is not an option” (Global Food Security programme)

Food systems are crucial to reach the United Nations’ (UN) 2030 Sustainable Development Goals (SDGs): to end hunger, but also to mitigate and adapt to climate change, to ensure water security, to protect and restore biodiversity, to ensure human health and well-being, to end poverty, and to support sustainable communities.

While hunger has receded – undernourishment decreased from 15 to 10% between 2005 and 2015 and has remained stable since – food systems are causing increasingly severe damage to our environment, and contributing to our overshooting of environmental limits. Indeed, agriculture and associated land use changes are the largest threat to biodiversity, a significant contributor to climate change (21-37% of greenhouse gas emissions), the most water-consuming sector (70% of abstraction, 90% of consumption), and a key source of water pollution via fertilisers.

In 2021, the UN held the first Food Systems Summit, recognising the fundamental importance of food systems not only to eradicate hunger, but also to tackle the pressing challenges of environmental sustainability. Major policy and scientific international organisations, such as the IPCC, OECD and IPBES, have also recognised the vital role of food systems for our lives, economies, and planet, and the urgent need to improve them, notably as part of recovery from the Covid-19 pandemic.

Different platforms, from scientific communities to wider societal and political spheres, are calling for evidence and for solutions based on a systemic approach, that can mitigate trade-offs and maximise co-benefits. Within the theme of Sustainability at the Water-Energy-Food Nexus, ISR is tackling this important challenge by carrying out interdisciplinary research to measure sustainability and to consider important systemic interlinkages, between agriculture and water, biodiversity, energy, human health and climate change. It is essential to consider all major environmental aspects of agricultural sustainability to avoid the unintended consequences of strategies focused on a single aspect.

The FOODIES project, for example, has provided critical improvements in our understanding of the multiple environmental impacts of agriculture (on the climate, water quality and quantity, and land ecosystems) by accounting for different practices and local conditions across the world. This enables a comprehensive assessment of agricultural sustainability, and helps to quantify trade-offs associated with different agricultural management strategies. The research also accounts for the crucial role of trade in global agricultural systems, which led to the development of major export-oriented agricultural regions, by integrating it into the evaluation of potential pathways to achieve environmentally sustainable agriculture.

To effectively progress towards the SDGs, it is necessary to understand the interactions between changes in biodiversity and human food security. While agricultural land use puts pressure on biodiversity, biodiversity changes may also impact food production, because many different

species provide important ecosystem services that support agriculture. The BIOTA project is advancing global-scale biodiversity models to explain the interactions between biodiversity change and food production across the globe. This project also investigates how global trade in agricultural products is linked to biodiversity change, by identifying where food consumption has particularly strong biodiversity impacts, measuring the impacts of both trade-related land use and climate change on biodiversity.

Agriculture not only affects the environment, but also our health; indeed, diet-related diseases are increasingly prevalent worldwide. The SHEFS project is a multi-partner research consortium, led by the London School of Hygiene and Tropical Medicine, which analyses the interactions between human health, food and the environment in the UK, South Africa and India. Research and stakeholder engagement activities focus on determining what components of the interactions between environment, food systems and health are critical for achieving sustainable and equitable health outcomes. The project also considers which (inter)sectoral policy options are most able to deliver healthy food systems under future environmental and demographic changes. It also contributes to the co-development of evidence-based policies with stakeholders, with the goal of improving access to sustainable and healthy diets for all.