EDITORIAL

For the Special Issue of *Climate Policy*

Policy Instruments for Low-Carbon Development
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based on work from the EUFP7 project
CECILIA2050: Combining Policy Instruments to Achieve Europe's 2050 Climate Targets

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The Paris Agreement of December 2015, which entered into force on 4 November 2016, has committed countries collectively to keep global warming to well below an average of 2^{o}C. So far countries' Nationally Determined Contributions (NDCs) to GHG emissions reduction fall far short of that required to achieve this target, and in many countries the policies to achieve even these NDCs are not in place. This has made more important than ever an understanding of the wide range of available GHG abatement policies and how they may be combined for an efficient and effective delivery of the very large cuts in GHG emissions that delivery of the 2^{o}C target will require.

The aim of the CECILIA2050 project[1], which concluded in October 2015, was precisely to understand how climate policy instruments work in interaction, what factors determine performance, and how the European Union (EU)'s climate policy mix should evolve to transition to a low-carbon economy. In doing so, it aimed to take a broader view on policy instruments and their performance – not only to describe what would work best in theory, but also to investigate the various technological, legal, political or cultural constraints that climate policies need to overcome – or to work around. Although the focus of the project was the countries of the EU, many of the lessons of the project may be applied more widely. This collection of papers contains many of the most important insights from the research undertaken by the different CECILIA2050 project partners[2].

That said, it is clear that the papers in this Special Issue can do no more than explore some of the many issues raised by the complexities of climate policy. These issues include the conceptual basis and political economy underlying climate policy instrumentation; the various options of different energy system architectures and their practical implications; stakeholder perceptions of policy approaches to emission reduction, and public willingness to bear any costs incurred; financial barriers to low-carbon innovation; and the international implications of EU climate policy in the absence of similar policies in other countries.

The eight papers in this Special Issue are organised as follows. The first four papers (Huppes et al., Mehling et al., Drummond and Ekins, Kalfagianni et al.) examine from different

[1] The project received funding from the European Union's Seventh Programme for Research, Technological Development and Demonstration under Grant Agreement no. 308680
[2] The project was led by the Ecologic Institute (Germany), and its partners were the UCL Institute for Sustainable Resources, University College London (UK); the Institute of Environmental Sciences (CML) at Leiden University (Netherlands); Charles University in Prague (Czech Republic); GWS (Germany); Institute for Environmental Studies, VU University Amsterdam (Netherlands); CIRED (France); University of Warsaw (Poland); Basque Centre for Climate Change (BC3, Spain); University of Ferrara (Italy)

perspectives EU climate and energy policy, in relation to both CO_2 and non-CO_2 GHG emissions, while placing such policy in a global context. Such policy must deliver increasingly transformative change, as illustrated by energy system modelling conducted by Solano-Rodriguez et al., who find an important role for bioenergy with carbon capture and storage (BECCS) in achieving emissions reductions in the EU consistent with meeting the 2°C target globally. Costs associated with such a transformation are also computed and reported. There then follows a paper (Ščasný et al.,) that looks at households' willingness to pay for the EU's climate policy with different emission reduction targets.

One of the objectives, and necessary results, of climate policy is the stimulation of low-carbon innovation. The subject of the paper by Mazzanti et al. is the financial barriers to such innovation and the policies that can address them. The final paper in this Special Issue, by Gonzalez-Eguino et al., reveals the danger that reducing GHG emissions from land use in one part of the world could lead to significant terrestrial leakage of carbon emissions, as other countries increase food and bioenergy production. The papers are briefly discussed in turn so that the overall narrative of this Special Issue becomes clear.

Huppes et al. note that climate policy can easily fall into incoherence if policy instruments intended to reduce emissions efficiently (for example, the EU Emissions Trading System, EU ETS) are combined with instruments seeking to promote particular low-carbon technologies. Price reduction of the emission permits, rather than additional emission reduction, is the likely result. In thinking about overall policy design, Huppes et al. draw a distinction between *Institutionalist* approaches, and those based on *Planning and Control.* Huppes et al. identify the latter with utilitarianism and welfare theory, and hence with the neo-classical approach to policy, but with a focus broadened to cover ethical issues as well. The Institutionalist approach focuses on centralised arrangements, such as legal systems, the design of markets, and the boundaries between the public and private sectors. With this distinction he then categorises different climate policy instruments across different energy-using sectors, and compares them for effectiveness, efficiency and feasibility. Huppes et al.'s conclusion is that, while these two approaches can be combined, for coherence the governance of climate policy needs to be predominantly based on one or the other. While both approaches can be effective, efficiency depends on keeping the policy mix as simple and internally consistent as possible, while covering all emission sources.

One of the main differences between Huppes et al.'s two approaches is that his Institutionalist strategy "concentrates on decentralized independence and the role of civil society", while the Planning and Control approach involves more centralisation of technology decisions. This is the main policy distinction explored in detail by Mehling et al., asking whether EU climate policy has become more centralised as it has increased in ambition, with centralisation identified as the degree of legal bindingness, European harmonisation and EU-level institution-building. The paper discusses the relative advantages and weaknesses of both centralisation and decentralisation, considered as a spectrum rather than a dichotomy and as part of a broader framework of multi-level governance, from the global to sub-national levels. It also explores these advantages and disadvantages especially in relation to the EU ETS and renewable energy policies. The two areas exhibit opposite policy tendencies, the EU ETS having become more centralised through its phases, while renewable energy policy has become more decentralised in consideration of the 2020 and 2030 targets, the former being binding on individual MS, the latter binding only on the EU as a whole. Mehling et al. conclude that there is no necessary correlation between centralisation and level of ambition, with the position of climate policy on the centralisation-decentralisation spectrum being as much determined by broader EU-Member State (MS) relations as by energy and climate considerations.

The third of the broader policy papers (Drummond and Ekins) conducts a sectoral analysis of the different climate policies in the EU, with a view to assessing whether the policies currently in place at the EU level, and at MS level as a direct result of EU-level policies, are likely to meet the decarbonisation requirements of a number of low-carbon scenarios. All the scenarios considered point to almost total decarbonisation of the power sector by 2050. The principal EU-level instrument aimed at power sector decarbonisation is the EU ETS. Despite the current surplus of allowances, the EU ETS emissions trajectory to 2050 is consistent with near-zero carbon emissions from the sector by 2050. Derailment of this outcome is most likely to come from a failure to reform the EU electricity market to take account of the increasing proportion of near-zero marginal costs renewables on the system, which is making all forms of power generation capacity difficult to finance. EU electricity market reform therefore emerges as a policy priority.

The EU ETS is also the main EU-wide policy instrument for reducing emissions from the industrial sector, with the difference from power generation that most of the industries in the EU ETS are considered at risk of carbon leakage and therefore receive free permit allocation, rather than having to buy them. In theory this should not affect the incentive for firms to reduce their emissions, but in practice, taking into consideration also the low permit price, firms are unlikely to prioritise emissions reduction as a result of this policy instrument. Certainly the projected 2030 permit price of €30/tonne CO_2 is not adequate to stimulate wide take-up of the types of decarbonisation technologies, at the scale that is required to meet the long-term decarbonisation objectives – such as industrial carbon capture and storage (CCS) technology, which many scenarios consider to be essential to reach the very high levels of emission reduction envisaged for the EU in 2050 (80-95% from 1990's level). While the Energy Efficiency Directive of 2012 mandates industry to identify energy efficiency opportunities, it remains voluntary for firms to take up these opportunities once they have been discovered, and it remains to be seen whether firms do this on a large enough scale for this to lead to significant reductions in energy consumption.

The EU ETS does not apply to the final two sectors considered: buildings and transport. With respect to buildings, improvements in energy efficiency from building fabric insulation, and from the performance of energy-using appliances are likely to be the main source of emission reductions. Both of these are driven by regulation (including mandatory efficiency standards) combined with information for consumers. In the case of transport, the main tool at the EU level is fleet average emission standards expressed as gCO2/km. However, the effectiveness of this approach was seriously compromised by the revealed difference between emissions performance in tests and on the road. Another tool is road fuel duties, minimum levels of which are set by the Energy Tax Directive - yet raising these minimum levels has proven difficult, due to the required unanimity from MS.

While power generation, industry, buildings and transport are the main CO_2 producing sectors, the principal source of non-CO_2 greenhouse gas (GHG) emissions is the agri-food sector. With a strong emphasis on CO_2 emission reduction in the EU, non-CO_2 GHGs are estimated to comprise a significant proportion of the remaining overall EU GHG emissions in 2050. Reducing non-CO_2 GHGs is difficult due to the large number of diffuse emitters and the lack of readily available abatement options, and there are currently no EU-wide policy instruments in place to achieve significant emission reductions – let alone the roughly 45%

reduction in these emissions that will be required to reach the 80% overall GHG emission reduction target for 2050. By interviewing representatives from four groups (government, private sector, interest groups and experts) in four EU countries (UK, Netherlands, Italy, Spain), Kalfagianni et al. explore stakeholder views as to the environmental effectiveness, economic efficiency and political feasibility of different policies to reduce non-CO_2 GHGs.

In all the countries, voluntary approaches to non-CO_2 GHG abatement predominated and were most favoured by farmers. The most developed voluntary approach was in the Netherlands, where negotiated agreements, or covenants, involving targets, tax incentives and subsidies, and sometimes backed up by regulations, are a common means of implementing environmental policies. Even so, in the Netherlands as well as in the other countries, there was dissatisfaction with the prevailing policy approach, and some disagreement as to how further policies should be developed. Although there was recognition of the need for action on emission reduction, there was also, perhaps not surprisingly, general antagonism to policies that would raise costs. The research revealed a desire for the EU to develop policy in this area, that provides a level playing field for all EU farmers and a fair distribution of costs between the different parts of the food supply chain.

These four papers setting the EU climate policy scene prepare the ground for the energy system modelling reported in Solano-Rodriguez et al. They use the UCL European TIMES model (ETM) to explore relative reductions in sectoral CO_2 emissions in a cost-optimal pathway of EU decarbonisation that achieves the EU target of an 80% reduction in GHG emissions by 2050. The main result here is that the power generation sector leads the energy system decarbonisation, making extensive use of bioenergy with carbon capture and storage (BECCS), generating net-negative CO_2 emissions from the sector. CCS is also deployed in industry because of the lack of cheaper means of reducing industrial process emissions. There are options that could substantially reduce the need for BECCS, which is at present a largely unproven technology: this includes, for instance, mode switching (for example to walking and cycling) in urban transport, or options for increasing the energy efficiency of the urban fabric. Both of these, however, are absent in the model because of the difficulties of representing them effectively. Moreover, the modelling approach chosen essentially examines the options for decarbonising the power sector based on a centralised power system plus BECCS, rather than a wider system transformation based on the declining cost of renewables, system management (including the demand side) and integration technologies. It is currently unclear which of these options, or what mixture of them, will be the outcome of innovation, policy measures and consumer preferences.

The policy implications here are threefold. First, policy makers should increase the stringency of the kinds of decarbonisation policies for transport and buildings that were described in the earlier papers, in order to reduce the extent to which they need to rely on the still very uncertain BECCS technology. Second, that even with transport and buildings playing a major role in decarbonisation, CCS is likely to be necessary, for both for the power and industrial sectors. This underscores the desirability of the EU reinvigorating its currently stalled CCS deployment strategy. And third, that policy makers and those in charge of grid balancing and system operation need to be aware of any shifts away from centralisation of power generation towards more distributed networks, and be prepared to act to encourage these to the extent considered desirable while maintaining grid integrity and stability.

The energy system decarbonisation simulated in the Solano-Rodriguez et al. paper is not prohibitively expensive. Although a carbon price of USD300/tCO_2 in 2050 may seem high by today's standards, in the 2050 economy, which has undergone a structural transformation to a low-carbon economy, with a large increase in energy productivity, such a price signal, spread out over a number of years, would be economically manageable and considerably less disruptive than some of the price volatility regularly seen in oil markets. Likewise, a 14% increase in energy system costs is substantial – but since this rise will be spread out over 30 years, the year-to-year impact would be modest. Nonetheless – the low-carbon transformation will not come for free, which leads naturally to a consideration as to whether households are likely to be willing to pay these costs. Ščasný et al. carried out discrete choice experiments with households in three European countries (Czech Republic, Poland and UK) in order to ascertain their willingness to pay (WTP) for the EU's climate policy, with the choices being the EU's 2020 emission reduction target (a 20% reduction from 1990's level by 2020, identified as the status quo); the EU's 2030 target (a 40% reduction from 1990's level by 2030); and the EU's 2050 climate policy (an 80% reduction from 1990's level). The choices also included various cost distribution profiles among the countries and households with different income levels or emission volumes.

The results highlighted considerable differences between countries, with UK households' mean WTP being around EUR45 per month for both the 2030 and 2050 emission reduction targets; Czech households having a mean WTP of EUR13 for the 2030 choice, and EUR17 for the 2050 choice; and Polish households having a mean WTP not significantly different from zero for either of the post-2020 options. However, the mean values obscure highly heterogeneous preferences, with some groups strongly or modestly in favour of abatement, and others against. In terms of cost distribution there was broad favour of the polluter pays principle, both between and within countries (countries and households with higher emissions pay more). As a consequence, the total WTP for the 40% and 80% reduction policy package linked to various cost distribution and burden sharing profiles varies considerably for the British and the Czech households (EUR36–171 per month in the UK, or EUR8–77 per month in the Czech Republic), while it is negative for almost all policy packages in Poland. Such results indicate that there are considerable political challenges to be overcome in the EU if it is to be able to meet its climate targets.

The kind of systemic energy system transformation envisaged by Solano-Rodriguez et al. will require substantial innovation if it is to occur in a manner that is not considerably more costly than a fossil fuel-based energy system. Rolling out these innovations will require substantial finance if it is to occur across a wide range of low-carbon technologies and result in the deployment of the most promising of these technologies at scale. And yet deployment at scale will be required to bring about the cost reductions that often result from large-scale cumulative deployment of new technologies. The paper by Mazzanti et al. considers the financial barriers to these innovations, and how these barriers may be removed.

While financial barriers exist to all kinds of innovation, there are a number of reasons why they particularly affect environmental innovations, including higher perceived technological risk, higher capital costs with relatively long pay-back times, uncertainties around public policy frameworks, the existence of environmentally perverse subsidies that benefit competing technologies, the immaturity of both markets and business models, and the 'locked-in', deeply embedded nature of carbon-intensive technologies.

The paper by Mazzanti et al. reports the results of two regression estimations. Data from the first comes from a survey of entrepreneurs in the field, who estimate the relative strength of a number of these variables' effects on the financial barriers to environmental innovation, with the variables comprising the extent of technological lock-in, uncertainties around market demand and return on investment, barriers to entry, the size of firms, and expectations about energy prices and regulatory stringency. The second regression estimates how environmental innovation is affected by these financial barriers, as well as how it depends on a firm's turnover and on its technological and managerial capabilities, the demand for eco-products, the regulatory framework and the availability of external technological information.

The results of the regression seem to confirm two of the paper's initial hypotheses: that the variables from the first regression do act as financial barriers to eco-innovation; and, from the second regression, that these barriers do have a significant overall effect on the quantity of environmental innovation. These results suggest that public policy will be required address and remove the barriers to environmental innovation if the necessary increases in investments in such innovation are to be realised.

While the dominant focus of the papers in this Special Issue is EU climate policy, the implications of such policy for global GHG emissions are of course important. It is therefore appropriate that the final paper in this Special Issue broadens its focus by considering the potential impacts on emissions outside the EU from EU policies to increase carbon sequestration, and reduce GHG emissions, from land use change within the EU. Gonzalez-Eguino et al. use the GCAM Integrated Assessment Model (IAM) to explore the possibility and extent of terrestrial carbon leakage (TCL), whereby CO_2 mitigation from land use or land use change in Europe increases the production of food and bioenergy, and associated CO_2 emissions, in other parts of the world. This TCL is compared with the more commonly explored industrial carbon leakage (ICL), i.e. increasing fossil fuel use outside Europe as a result of EU climate policy.

The climate policy that is implemented in the EU is a carbon tax on all CO_2 emissions, including those from land use, which when implemented globally results in a convergence in per capita emissions in all regions to $0.5tCO_2$ per head, which is consistent in GCAM with a 2^oC stabilisation of global average temperature. The paper then explores the outcomes of different scenarios in which some regions do not participate in this climate policy. This simulation produces three main findings: 1) leakage (both TCL and ICL) is largest in absolute terms when the biggest developing regions do not implement the climate policy; 2) the leakage rate decreases the more regions implement the climate policy; and 3) the TCL dominates over ICL up to 2050, but ICL becomes dominant over the second half of the century. Clearly these results have important policy implications. While it underlines the common finding that the widest possible participation in climate policy is desirable to avoid leakage, it also shows that, if broad participation proves not to be possible, significant leakage can occur in respect of terrestrial emissions, as well as the more often estimated industrial emissions.

In conclusion, it may be noted that the CECILIA2050 project, from which these articles emanated, commenced in 2011, and was carried out from 2012 to 2015. It thus took place at a time when a global climate policy agreement seemed rather unlikely; at the same time there was reason for optimism regarding the EU's capacity to pursue ambitious, coordinated climate and energy policies. In the meantime, things have evolved differently: the adoption of the Paris Agreement, including the USA and other major emitters, and with significant involvement by the EU, was the first surprise. It remains to be seen whether and to what extent the election of President Trump will do damage to the Agreement itself, and/or to the new-found enthusiasm for multilateral cooperation on climate policy that inspired it. At the same time, the EU finds itself in a turbulent situation: following the Brexit vote, and the rise of EU-sceptic parties and movements (some of which also oppose ambitious climate policies), the EU's capacity to lead is challenged – which includes its capacity to lead on ambitious climate policies, domestically and internationally.

But while the circumstances are changing, the findings of these papers remain relevant to the new situation as well as the old: the future of EU climate policy will hinge on its perceived environmental effectiveness, economic efficiency and political feasibility; its economic efficiency will depend on the extent of environmental innovation and its financial attractiveness; and the environmental effectiveness of climate policy globally will depend on the extent and nature of participating by the major emitters. This Special Issue with the results of this EU research project therefore appears when climate policy is at a crossroads. While the focus has been on the EU, the insights generated by this Special Issue are broader; which road is taken is likely to depend just as much on how other regions grapple with similar issues.