The Climate Economics Chair presents

Climate Economics in Progress

2013 edition

Climate Economics in Progress 2013

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Climate Economics in Progress, 2013
Editor in chief: Patrice Geoffron
Coordinator: Preety Nadarasapillay
Scientific Direction: Pierre-André Jouvet, Christian de Perthuis
Team Coordinators:
Raphael Trotignon, Section 1: Carbon prices and markets
Philippe Delacote, Section 2: Agriculture, Food, Forestry
Alain Ayong le Kama, Section 3: Mobility in a low-carbon society
Claudie Boiteau, Section 4: Law, Regulation, Climate
Marc Baudry, Section 5: Ecological Transition
Jean-René Brunetière, Section 6: Housing

Translation: Michael Westlake and Geoffrey Finch
Publishing and graphic design: Les Pointilleuses,
Camille Didelon and Aurélia Monnier
Photo credit : Raphael Trotignon

Sommaire

Introduction 7

Part 1: Carbon Prices and Markets 15

Chapter 1: Carbon prices and markets around the world 17
1) Introduction 17
2) Emissions trading schemes 19
3) Carbon taxes 41
4) Conclusion 51

Chapter 2: Short-term emissions reductions in the electricity sector 53
1) Introduction 53
2) Determinants of abatement potential by technological substitution 53
3) History of the abatement potential in Europe over the period 2005-2012 55
4) Estimated abatement in phases 1 and 2 of the European market 59
5) Geographical distribution of abatement 61
6) Conclusion 63

Chapter 3: Free allocation benchmarks in phase 3 of the EU ETS 65
1) Introduction 65
2) Two implications of switching to benchmarking 66
3) Two potential flaws of implemented benchmarking 70
4) Conclusion 74

Chapter 4: Governance of CO_2 markets: lessons from the EU ETS 77
1) Introduction 77
2) The three causes of current market weaknesses 79
3) Expectations tend to overestimate the constraint
and ignore future uncertainty 81

4) Evaluation of the Commission's proposals with the ZEPHYR model 83
5) The case for an Independent Carbon Market Authority (ICMA) 87
6) Conclusion 90

Part 2: Agriculture, Food, Forestry and Climate Change 95

Chapter 5: Biomass for power generation in Europe: addressing the potential 97
1) Introduction 97
2) Key issues and economic considerations in biomass power generation.. 98
3) Biomass in the current European power generation: potential demand, associated abatement, and cost estimates 105
4) Matching European biomass supply with potential demand from the power sector: uncertainties and competition for biomass resources 118
5) Conclusion 121

Chapter 6: Forest transition and REDD+ in developing countries: challenges for climate change mitigation 125
1) Introduction 125
2) Forest transition theory, REDD+ and deforestation 126
3) Different REDD+ strategies for different phases 134
4) How REDD+ policies can lead to different forest transitions 141
5) Conclusion 145

Part 3: Mobility in a Low Carbon Society 149

Chapter 7: Specific challenges of the transport sector for implementing carbon regulation 151
1) Introduction 151
2) An integrated approach to the complexity of the transport system...... 152
3) Inertia in the transport system 157
4) Factors influencing behavioural change in the short and medium term......160
5) Conclusion 165

Chapter 8: Low-carbon policies for road transportation in Europe 167
1) Introduction 167
2) Command and control levers 169
3) Economic instruments 173
4) Summary table 183
5) Conclusion 184

Part 4: Law, Regulation, Climate 188

Chapter 9: The obligation to purchase electricity produced by wind energy and legislation pertaining to State aid 191
1) Introduction 191
2) Evading the issue 194
3) Time to reconfigure the system 199

Chapter 10: The financial markets and energy: European cooperation between energy and financial regulatory authorities 209
1) Introduction 209
2) Regulating energy markets in an evolving environment 210
3) Cooperation mechanisms between energy and financial regulators ... 213
4) Conclusion 215

Part 5: Ecological transition 217

Chapter 11: Theoretical grounds for coupling environmental policies and innovation policies......219
1) Introduction 219
2) The intrinsic interdependency between innovation and environmental policies when facing "green" inventions 220
3) Efficient taxation of fossil fuels to finance "green" innovation 226
4) Conclusion 233

Chapter 12: An overview of policy instruments for green innovation 235
1) Introduction 235
2) Instruments supporting the supply of renewable energy 238
3) Instruments supporting the demand for renewable energy 247
4) Conclusion 256

Part 6: Carbon economy in the construction sector 261

Chapter 13: Climate economics in the construction and housing sector 263
1) Introduction 263
2) What ways to reduce emissions in the building sector? 267
3) The general framework of the research 271
4) Helping to clarify strategies 273
5) First lines of research for RI6 of the Climate Economics Chair 275

Author's bios 279

Introduction

Paving the road towards "Paris 2015"

Patrice Geoffron, Pierre-André Jouvet

Inaugurated in 2010, the Climate Economics Chair (CEC) is a joint initiative of *CDC Climat* and *Paris-Dauphine* University. With this project, our common objective is to stimulate innovation in the field of climate change economics, by linking academic and empirical approaches with political decision-making.

In October 2011, the first edition of *Climate Economics in Progress* was published, delivering an initial package of research work, at a preliminary stage of the Chair's project. With this second edition, two years later, the scope of our collective work has been extended, with new industrial partners involved in the project and with an expanded research team of both senior and junior researchers.

Between these two editions, the evolution of the international landscape has (unfortunately) confirmed the need for massive efforts to fight against climate change and, for our purposes, to develop and improve an innovative economic toolbox, appropriate to the challenge.

— **The assessment provided** by the Intergovernmental Panel on Climate Change (IPCC) in September 2013 reaffirmed (with a higher degree of certainty) that human influence has been the predominant cause of observed warming since the mid-20th century, with each of the last three decades being successively warmer at the Earth's surface than any previous period, and with a 40% incremental CO_2 concentration since pre-industrial times (due to the combustion of fossil fuels and net changes in land use).

— **The European situation** is paradoxical. The EU is the only part of the world with a clear political commitment to promote a low-carbon model of society through, in the medium term, the "20-20-20" targets for 2020 and, in the longer term, the goal of an 80% emissions reduction by 2050 ("Factor 4"). In the meantime, however, the EU is experiencing a severe economic crisis with drastic budgetary limitations for implementing this transition, that are having negative side effects on the functioning of EU ETS (the key tool in the

European strategy). Even in Germany, following the implementation of the *Energiewende* in 2011, a debate has arisen as to the economic sustainability of such a U-turn, potentially calling for investment of 1000 billion euros over the coming decades.

Clearly, when the first edition of our work was published, efforts to combat climate change were subject to severe financial constraints, requiring economists (alongside engineers) to be involved in this long-term challenge. Because "Paris 2015" will take place in this context of international stress, the future success of the COP will directly depend on the ability to design, in the meantime, innovative economic schemes to finance the low-carbon transition. *Climate Economics in Progress* 2013 is our contribution to this collective effort.

◊

The book is organized in accordance with the structuring of the Chair in terms of "Research Initiatives" (RI), which represent the fields currently covered by the project.

Part 1: Carbon Markets and Prices

The Carbon Markets and Prices Research Initiative is concerned with evaluating carbon pricing instruments and the conditions for their expansion in the world. The programme is organized around four topics:

"Functioning of the EU ETS": The aim is to analyse the rules of the European emissions trading system, through the monitoring and analysis of the compliance and the transaction data of the facilities covered. It involves analysing the mechanisms of price formation, the use of flexibility mechanisms and the impact of regulatory developments.

"Extension of carbon pricing in the world": The aim is to provide a mapping of emerging carbon markets (including recent developments in North America and Asia) and to consider their "linkage" (both from theoretical and practical standpoints). Carbon price signals are also covered through project-based mechanisms.

"Introduction of carbon taxes": The purpose is to trace the evolution of environmental taxation in the world, in particular by analysing existing carbon taxes in Europe and studying their impact on the countries and sectors concerned.

"Governance and coordination of economic instruments": The objective is to observe and understand the interactions between the European carbon market and other climate-energy policies (renewable energy, energy efficiency, domestic carbon taxes, etc.) and to assess the implications for the governance of carbon instruments. The research team is also discussing these aspects at a more global level in preparation for the 2015 COP in Paris.

To address these issues, the team has developed a simulation model – *Zephyr-Flex* – that provides a better understanding of the EU ETS (emissions reduction, supply and demand equilibrium) and its implications for the entities covered. In addition, *Zephyr-Switch* is a complementary module aimed at describing European countries' electricity sectors at the technology level.

Part 1 contains four chapters:

— Chapter 1, *Carbon prices and markets around the world*, is a panorama of the existing economic tools for targeting greenhouse gas emissions. The case of carbon markets is first examined, with an overview of the various market-based carbon pricing initiatives around the world and with a focus on the evolution over time of covered emissions and of carbon prices. Carbon taxes are also analysed in a similar manner.

— Chapter 2, *Short-term emissions reductions in the electricity sector*, offers an ex-post evaluation of short-term emissions reductions from electricity generation over the first two phases of the EU ETS (2005-2012). The analysis is conducted using the *Zephyr-Switch* simulation model, with a representation of the equilibrium of short-term electricity supply and demand.

— Chapter 3, *Free allocation benchmarks in Phase 3 of the EU ETS*, deals with the shift from free allocation to auctions adopted in Phase 3, focusing on transitional free allocation associated with the move from *grandfathering* to *auctioning*.

— Chapter 4, *Governance of CO_2 markets: lessons from the EU ETS*, looks at the lessons drawn from the last eight years of the EU ETS from a broader point of view, focusing on the governance and coordination of climate instruments.

Part 2: Agriculture, Forests and Food

Agriculture, forests and land-use change contribute to a large proportion of GHG emissions worldwide (13% for agriculture and 17% for forests), while providing humankind with essential social and eco-system benefits (food, biodiversity, energy, water provision, livelihoods, etc.). The main aim of this Research Initiative is to assess the contribution of these activities to climate change mitigation, taking into account the multi-criteria nature of these sectors. The programme covers three main areas:

"Mitigation options in French and Chinese agriculture" addresses, on a comparative basis in an emerging and a developed economy, the tension between emissions mitigation and the sector's efficiency in terms of feeding the population.

"Multi-criteria impact assessment in forest and biofuel projects". The aim is to analyse synergies and trade-offs, since forests provide many eco-system services and socio-economic co-benefits and agriculture provides food, biomass and livelihoods.

"Land-use, product competition and forest-agriculture interactions". The goal is to scrutinize patterns of short-term and long-term interactions between agricultural expansion and deforestation and their potential synergies through agro-forestry.

There are two chapters:

— Chapter 5, *Biomass for power generation in Europe: addressing the potential*, analyses the potential for introducing bioenergy in European power generation. It considers both the potential demand of existing European power-plants and the potential supply provided by agriculture and forests.

— Chapter 6, *Forest transition and REDD+ in developing countries: challenges for climate change mitigation*, presents the "forest transition" hypothesis, which describes the long-term change of forest cover in a given country, and analyses the implications of this theory within the REDD+ framework.

Part 3: Mobility in a Low-Carbon Society

"Mobility in a Low-Carbon Society" covers the transition to sustainable mobility, which requires a major structural shift in both passenger and freight transport systems. Road transport is responsible for roughly three quarters of the CO_2 emissions produced by the transport industry, which itself accounts for 25% of total CO_2 emissions in Europe. To introduce the right signals, economic theory offers public policy makers a number of levers and tools, though these are often highly theoretical. The general idea guiding the work is that the future competitiveness of the transport industry is directly related to its ability to attach greater value to external environmental factors, especially carbon emissions. The research programme is structured around three topics:

"Meeting the overall challenge of climate change at the level of urban mobility" aims at organizing local governance for low-carbon mobility and estimating the potential demand for and the environmental impact of innovative urban mobility solutions (technological, organizational and infrastructural).

"Industry approaches to low-carbon mobility" analyses the process of creating innovations (products, processes, organization, etc.), thus enabling industry to adapt to new regulations, and more widely promoting the role and participation of private actors in building carbon regulations.

"New technologies and innovative mobility services for urban travellers" investigates individual mobility in different geographical areas, and estimates the potential for development among urban households and the environmental impact of new mobility services. The role of businesses in determining the mobility behaviour of urban households is emphasized, as well as fleet management policies.

Part 3 contains two chapters:

— Chapter 7, *Specific challenges of the transport sector for implementing carbon regulation*, addresses the complexity of transport systems, which is dependent on multiple objectives, externalities, sectors, levels and players and is subject to inertia. Despite this complexity, the chapter focuses on key factors likely to influence behaviour in the medium and longer term and examines the relevant issues when implementing economic tools for carbon regulation in road transport.

— Chapter 8, *Low-carbon policies for road transportation in Europe*, proposes a classification of policy tools based on the form of action taken by the instrument (e.g. whether it is binding or non-binding). This leads on to the differentiation of regulatory constraints, price incentives, collaborative tools and information policy and an assessment of their potential impact on the demand and supply sides.

Part 4: Law, Regulation, Climate

This Research Initiative advances knowledge on the legal aspects of economic instruments for addressing climate change. With a focus on European energy and carbon markets, it provides legal analyses of the economic instruments that may be favoured in the transition to a competitive, low-carbon economy, with a focus on three topics:

"Law and regulation of energy markets and 'carbon reduction'" examines the operation of regulated energy markets which, while ensuring the liberalization of the sector, help to achieve carbon reduction.

"Law and regulation of carbon markets". This research theme contributes to studies aimed at analysing the conditions for increased legal protection for both regulated and voluntary carbon markets and proposing solutions for the optimal operation of these markets.

"Regulation and institutional coherence", in relation to the regulation of the energy and carbon markets, addresses new issues around regulating institutional systems, using an approach based on comparative law.

Part 4 has two chapters:

— Chapter 9*, The obligation to purchase electricity produced by wind energy and legislation pertaining to State aid,* deals with the tensions between the promotion of renewables and competition issues, around the definition of State aids.

— Chapter 10*, The financial markets and energy: European cooperation between energy and financial regulatory authorities,* presents and discusses the regulatory framework of European financial energy markets and the existing European model of cooperation between energy and financial authorities.

Part 5: Ecological Transition

The fifth Research Initiative aims to better account for the key role of "natural capital" and to put the economy on a sustainable growth path, with specific attention to "green innovations" and the economic tools to promote them. Three research tracks have been identified:

Efficiency and innovation in the use of natural resources is intended to provide a detailed analysis of "green innovation", including the study of the profitability and the dissemination of renewables and carbon-mitigating technologies, such as carbon capture and storage. The emphasis is more specifically on the role of innovation for ensuring their economic viability.

Natural capital and eco-systemic services aims at broadening the perspective through research themes that encompass climate change but are not restricted to its direct consequences, such as "energy efficiency" or "biodiversity".

Long-term financing and the involvement of investors investigates the interplay between finance and an environmentally sustainable economy. It mainly focuses on whether "green innovation", as measured by the number of "green" patents in a firm's patent portfolio, adds value to intangible capital or whether investors disregard it.

There are two chapters:

— Chapter 11, *Theoretical grounds for coupling environmental policies and innovation policies*, argues that policy instruments aimed at addressing the free-riding problem characterizing innovation economics and the pollution externality that is the basis of environmental economics have to be jointly analysed in shaping efficient "green innovation" policies.

— Chapter 12, *An overview of policy instruments for green innovation,* offers an overview of the main policy instruments for promoting "green" innovation and the spread of "green" technologies. Though this chapter does not reject the standard dichotomy between "demand pull" and "technology push" instruments, it argues that the distinction is not as obvious as it seems. Emphasis is placed on the crucial role of details in designing instruments, illustrated by *feed-in tariffs* and of *tax credits*.

Part 6: Climate economics in building and housing

According to UNEP (United Nations Environment Programme), building is the sector offering the best prospects for reducing greenhouse gas emissions in the medium and long term. In the French case, residential and tertiary buildings account for almost 45% of the energy consumed in France and emit about 28% of greenhouse gas. The Climate Economics Chair is preparing a new Research Initiative focused on this area, so as to provide a more comprehensive view of sectoral analyses (industry and electricity for RI1, agriculture and forest for RI2, transport for RI3). This research programme will address the following questions:

What proportion of energy is permanently lost in domestic use and what proportion of this consumption is recoverable (and is the energy consumed a relevant measure from an overall management perspective)?

What typologies should be used to assess the cost-effectiveness (taking account also of energy uses) of each type of building?

How does one evaluate the real potential for energy savings in relation to costs (taking account of all types of cost)?

What are the economic effects of structural rigidities and other barriers (architectural constraints, legal provisions, financial capacity, relations between landlords and tenants, relations among joint owners, subdivision regulations, etc.)?

What are the optimal strategies over time to bring a building up to a given level of performance in 2050? What might be the stages of this strategy?

Chapter 13, *Climate economics in the construction and housing sector*, presents an overview of the main issues and considers the key research questions that need to be addressed in this programme.

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This 2013 edition of *Climate Economics in Progress* thus represents a contribution to the trial-and-error process in constructing and fine-tuning efficient economic tools for mitigating emissions and for developing adaptation strategies. While the content is indebted to the cooperation of our highly committed European corporate partners, we pay great attention to putting forward solutions that can help transform the social and political outlooks of our societies regarding environmental issues by means of economic tools.

Part 1

Carbon prices and markets

The economics literature contrasts "command and control" policies, in which the public authority sets up standards and rules to directly reduce environmental damage, and policies based on "economic tools" that aim at changing the behaviour of economic agents through the modification or introduction of prices, which reflect the cost of environmental damage in a context where traditional markets fail to account for environmental externalities. There is a broad consensus among economists in favour of economic tools that aim at protecting the environment in the most efficient way, i.e. by minimizing the total cost of pollution abatement. Despite those recommendations, most current environmental policies continue to favour command and control policies. However, since the 1990s, climate change policy has been a notable exception. There are two ways of introducing a price that incorporates environmental externalities into the markets, namely price-based regulation and quantity-based regulation. Price-based policies generally consist of taxes or comparable levies; quantity-based policies usually consist of cap-and-trade or baseline-and-credit programmes, which create tradable emissions rights. Both have been implemented in various countries and in various economic sectors.

The four chapters of Part 1 address a wide range of issues related to the implementation of carbon pricing tools within and outside Europe and to the impact of their development.

— Chapter 1, *Carbon prices and markets around the world*, is a panorama of the existing economic tools for targeting greenhouse gas emissions. The case of carbon markets is first examined, with an overview of the various market-based carbon pricing initiatives around the world and with a focus on the evolution over time of covered emissions and of carbon prices. Carbon taxes are also analysed in a similar manner.

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— Chapter 3, *Free allocation benchmarks in Phase 3 of the EU ETS*), deals with the shift from free allocation to auctions adopted in Phase 3, focusing on transitional free allocation associated with the move from *grandfathering* to *auctioning*.

— Chapter 4, *Governance of CO_2 markets: lessons from the EU ETS*, looks at the lessons drawn from the last eight years of the EU ETS from a broader point of view, focusing on the governance and coordination of climate instruments.

Chapter 1

Carbon prices and markets around the world

Simon Quemin, Jill Madelenat, Jeremy Elbeze, Wen Wang

1. Introduction

Global action to tackle and mitigate climate change has never been more urgent. As global GHG concentrations continue to rise in the atmosphere, the buffering capacity to maintain temperatures at decent levels becomes ever more eroded. The window for concerted action to avoid dangerous and irreversible climate change is growing ever thinner. Though the international consensus is that global temperatures should not exceed 2°C above pre-industrial levels, the current and inadequate level of mitigation around the world is likely to lead us towards a world that is 4°C warmer by 2100. Such a situation would profoundly impact human life and ecosystems in the long term. There is a growing gap between the 44 $GtCO_2e$ that should be emitted annually at the global scale by 2020 if we want to stand a chance of being on track for the 2°C target and the 52 to 57 $GtCO_2e$ now deemed to be the possible emissions by 2020 if we stick to the current level of action. The true challenge is therefore to agree on a policy that will be both able to bridge this gap and to achieve this at the lowest cost.

Three families of instruments are available to control greenhouse gas emissions. The first is that of "command and control" regulations, which consist of setting specific standards to emission sources, enforced by administrative controls and penalties. Although they are particularly well suited to specific products for which technologies are similar and emissions are easily verifiable, they are less adapted to controlling greenhouse gas emissions at a larger or global scale, given the extreme variety of emissions sources and processes involved. Accordingly, the total cost of reductions achieved with this method is likely to be high given the difficulties encountered by the public authority when deciding the most efficient distribution of efforts among actors in a context of high uncertainty.

As an alternative to command and control policies, economists have suggested incorporating the cost of climate change into economic choices through a carbon price. In theory, this price should be equal to the damage done to the atmosphere by the additional emission of one tonne of carbon dioxide. Carbon pricing should compensate for a failure of the economy, by recognizing the scarcity of a global common good which had hitherto been considered infinite: the amount of CO_2 that can be emitted into the atmosphere.

To generate this carbon price, governments have two instruments available, which can address a wider range of emissions sources and take into account their heterogeneity: carbon taxes and carbon markets (Emission Trading Schemes, or ETSs). These two economic tools allow the total reduction cost to be minimized by the arbitrage of economic actors facing the carbon price. Emitters with low reduction costs (below the carbon price) will reduce emissions first because it is cheaper for them to reduce emissions than to pay the price associated with emissions. Conversely, actors with high reduction costs will pay the carbon price, and reduce their emissions later when the price level becomes attractive. Emissions are thus reduced from the cheapest to the most expensive and the total cost is minimized.

If it is impossible to assess the “right” carbon price to the nearest penny, it should however be the one that fosters low-carbon measures, both in the short and long run. In the short term, emitters can adapt their existing production facilities and production processes, for example by fuel-switching. In the longer term, the carbon price encourages low-carbon capital investments. In short, the price is meant to guide a change of behaviour: as a carbon price is incorporated into the production costs of goods and services, it provides an incentive for both companies to manufacture their products while emitting less and households to shift their consumption from emission-intensive goods to cleaner ones.

Carbon taxes and carbon markets are two symmetrical ways of generating a carbon price. In the case of taxation, the public authority determines the carbon price, and observes the effect of this price on emissions. Symmetrically, in a carbon market, the public authority determines an emission reduction target (a limit on the quantity of emissions allowed, or more commonly a cap) and allows the exchange of emission rights on the market to reveal the corresponding carbon price. Theoretically speaking, there is a mirroring relationship between the cap and the tax level. Consequently, this chapter is divided into two symmetrical parts. The first section examines the case of carbon markets. We begin with an overview of the various market-based carbon pricing initiatives around the world. We then complete this initial overview with a particular emphasis on both the evolution of covered emissions over time and that of carbon prices. With that in place, we conclude the first section by summarizing the main lessons that can be drawn from both the existing markets and recent market proposals. The second section deals with carbon tax in a similar manner.

2. Emissions trading schemes

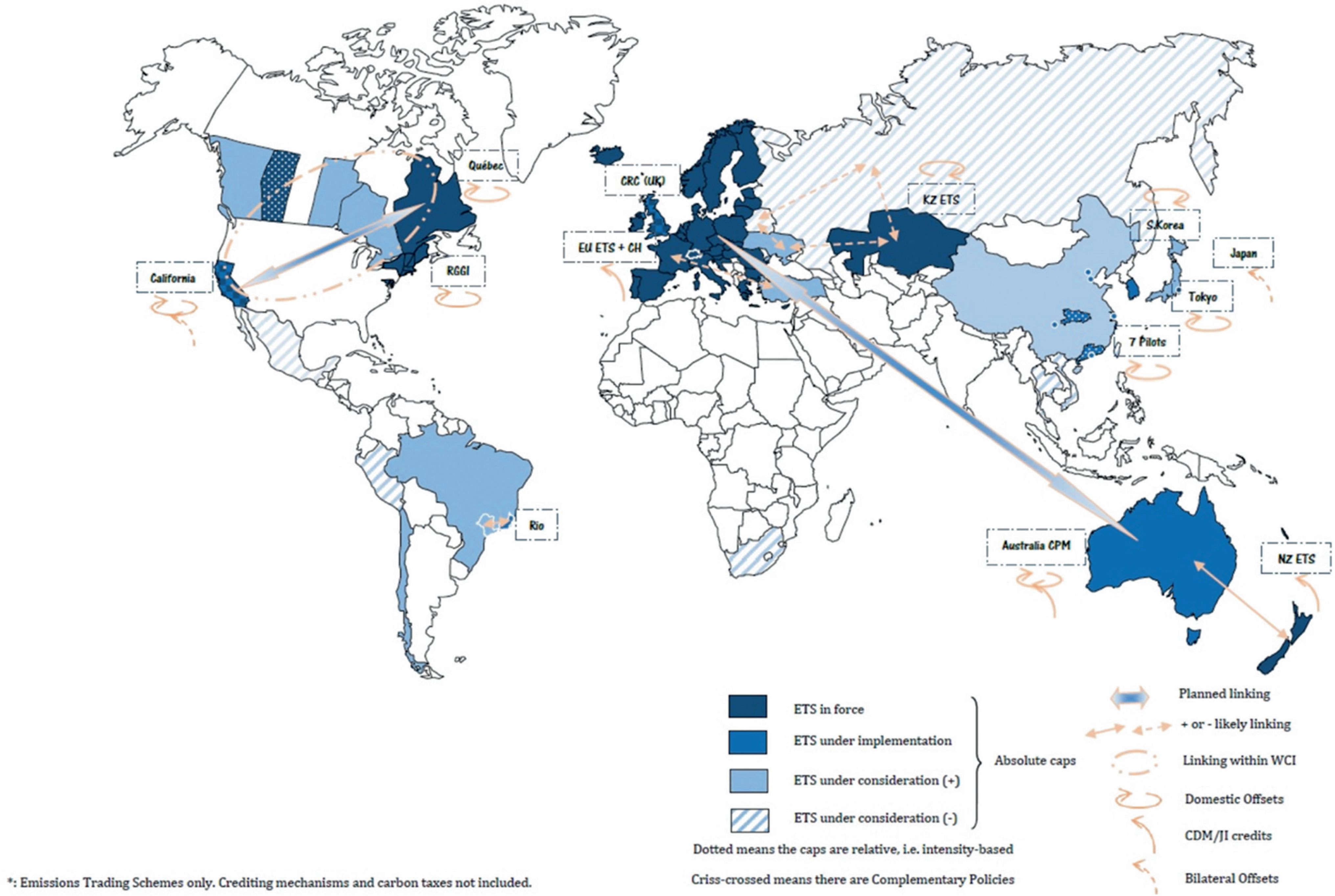
In the last decade or so, greenhouse gas Emissions Trading Schemes (ETSs) have proliferated. While international climate negotiations have stalled in the search of a successor for the Kyoto Protocol and the deadline of Paris 2015 continues to loom over a necessary agreement process, this proliferation has even gained momentum recently as a multiplicity of regional, national and even sub-national schemes have appeared. Some with a high level of harmonization and others with very little in common, these different schemes vary both in terms of shape and design and reflect the various economic, cultural and political environments in different regions of the world. Beyond the level of ambition or stringency proper to each scheme, incipient initiatives have been designed based on both the successes and failures of older ones like the European Union Emission Trading Scheme (EU ETS). In particular on the issue of supply-side flexibility, which has shown to be a crucial point in terms of resiliency of the emission constraint over time, recent or soon-to-be schemes’ proposals are quite different from one another, but all are innovative in their own ways.

The current situation heavily contrasts with what was deemed to be the most efficient way to tackle climate change in the late-1990s, that is a single global carbon market minimizing the cost of reductions across the globe. Back then, as major industrialized countries pledged to take actions to diminish their GHG emissions under the Kyoto Protocol, the very core of the then on-going debate was slanted towards how to design this scheme in the most effective manner and at the lowest costs. In the fragmented, decentralized carbon market and climate policy emerging landscape, this approach seems far behind us now, if not unachievable. However, the multiplicity of markets raises the question of implementing transmarket dynamics by linking them up and progressively arriving at a single global market. Bearing in mind the unequal and recent developments in carbon pricing in a growing number of countries around the world, a thorough overview of these initiatives is needed.

Overview of market-based carbon pricing initiatives around the world

To date there are ten ETSs worldwide, regardless of their ages, their statuses or their respective covered emissions. In this section, we will first focus on the various ETS developments around the world and on the most determinant setting of those schemes, which is the nature of the reduction targets.

◊ **Figure 1: A mapping of the various ETSs around the world**



Note: Emissions Trading Schemes only. Crediting mechanisms and carbon taxes not included.
Source: Climate Economics Chair

► Table 1: Comparative Table

	National & ETS Targets	Cap Setting*	Scope**	Form of Allocation
EU ETS 2005 Mandatory	2020: -20% /1990 lvl 2050: -80% /1990 lvl 2020: -21%/1990 lvl	About 2.2 Bt. Cap decreases by 1.74% per year, except for aviation. Absolute hard cap.	Power, heavy industry + new ind. in 08 and 12. Aviation since 12. T=20MW; %=45.	NAPs à EU-centralized process. Dominant free alloc. à dominant auctions + free alloc for EITE (to be phased out)
NZ ETS 2008 Mandatory & Voluntary	2020: -10/20% /1990 lvl 2050: -50% /1990 lvl Not defined.	About 40 Mt for now. Could reach 80 Mt by 2015 Absolute soft cap.	Gradual inclusion. All economy by 2015 (forestry since 2008, agriculture in 2015?). T=2ha; %=40 in 2011.	Free allocation except for fuel and power. Will decrease. No auctions. Point of obligation as far upstream as possible.
RGGI 2009 Mandatory	Depends on State. 2014: 2009 lvl 2018: -10% /2009 lvl	About 110 Mt. Cap: likely to be slashed by 45%, from 2015: -2.5%/yr Absolute hard cap.	Power sector only. T=25MW; %=22.	Mainly auctions (90%). No free allocations.
California 2013 Mandatory & Voluntary as of 2018	2020: 1990 lvl 2050: -80% /1990 lvl 22% of overall target achieved via ETS	Absolute cap set at 160 Mt in 13-14, then at 390 Mt in 2015, then decreasing by 12 Mt per year.	Power, heavy ind. (2013) à + fuel distr. (2015). T=25kt/yr; %=36 in 2013, 85 in 2015.	Mainly auctions with some free allocation to power and industry decreasing over time.
Kazakhstan 2013 Mandatory & Voluntary	2020: -5% /1990 lvl 2050: -25% /1990 lvl Unknown yet.	167Mt in 2013. Cap: unknown for 2014 on yet. Absolute hard cap.	Power + heavy ind. (Agriculture and transport later included?) T=20kt/yr; %=77.	100% grandfathering in P1 à in P2 EU-like benchmarks. Remainder auctioned.
Australia 2014/2015? Mandatory & Voluntary	2020: -5% or -15/25% /2000 lvl 2050: -80% /2000 lvl Unknown yet.	About 330Mt. 5-year rolling cap from 20124/2015 on. Absolute hard cap.	Power, heavy ind., transport, waste. Agri and forestry out. T=25ktCO2e/yr %=60.	Dominant auctions. Free allocation (transitional assistance + EITE) gradually phased out
South Korea 2015 Mandatory & Voluntary	2020:-4%/2005 lvl 2050: unknown Unknown yet.	About 350Mt. Cap: set in 2014; in line with reduction target. Absolute hard cap.	Energy, ind., trade, building and waste. %=60; T=25kt then lowered to 15; 125 for business entities.	100% free allocation in P1 à EU-like bench-marks. Remainder auctioned, except for EITE.
Chinese 7 Pilots 2013 & 2014 Mandatory	2015: intensity target ~ -18% /2010 lvl Irrelevant.	About 700Mt. Relative Cap. Could transition to absolute cap by 2020.	Depends on pilot. Power and heavy ind. T=20kt/yr on average; % range from 35 to 60.	100% grandfathering for pilot phase in general. Corrected for expected output and growth. Afterward: unknown.

	Banking & Borrowing	Price Management	Offsets (x%=limit of use)	Peculiarities
EU ETS 2005 Mandatory	Unlimited banking. Borrowing allowed within CP, limited to amount of next year's free allocation.	No price stabilization mechanisms but possible via structural reforms under discussion. Backloading approved.	CDM (LDCs)/JI (KP2 OK) offsets allowed with restrictions. Limit per instal not set (50% of overall obligation)	1st multi-national and largest ETS. Structural & flexibility reforms being discussed. Suffers from lack of clarity.
NZ ETS 2008 Mandatory & Voluntary	Unlimited banking. Forbidden for fixed price NZUs. Borrowing forbidden.	Possibility to buy NZUs at a fixed price (NZ$25). Corresponds to a price ceiling. The "one-for-two" rule applies.	EU-like restrictions for CDM/JI (100%) allowed until 2015. Deforestation can be offset by planting trees	Includes land-based sectors. Soft cap: ETS helps meet KP targets but Gvt liable for ensuring target is met.
RGGI 2009 Mandatory	Unlimited banking. Borrowing forbidden but possible via advance auctions.	Minimum auction price. Cost Containment Reserve (proposal). CP can be extended.	RGGI-based offsets only up to 3.3%. Intl offsets allowed + limit increased if prices exceeds thresholds.	Total cap=aggregation of state-level cap. Non-binding participation. Was subject to heavy over-allocation.
California 2013 Mandatory & Voluntary as of 2018	Banking allowed but sbjt to holding limit. Borrowing forbidden but possible via advance auctions.	Reserve price for auctions. Price Ceiling Mechanism (allowance reserve).	Only US-based offsets allowed (8%). Applies to 4 areas, including forestry. REDD (2%). Will be widened.	ETS = back-up, as part of a broader plan. Original treatment of land/REDD via offsets. Linking with Québec as of 2014.
Kazakhstan 2013 Mandatory & Voluntary	Both are forbidden during P1. Banking likely to be allowed from P2.	Currently: a share of the allowance reserve can be sold at a fixed price. To be further developed.	Only domestic offsets allowed (100%). ERUs and CERs may be used later, depending on Intl negotiations.	1st Asian country to implement an ETS, relatively unhindered so far. KAZ belongs to Annex 1 but not Annex B.
Australia 2014/2015? Mandatory & Voluntary	Unlimited banking. Borrowing limited to following vintage year, up to 5% of current year obl.	5-year rolling cap. Price floor cancelled. Ceiling set at $20/t above EUA price.	Only CFI-issued offsets allowed (5%) until 2015. Then, UN credits (12.5%) and EUAs (50%) allowed.	Fixed price until 2015. Ambition depending on Intl efforts. Designed to be highly linked. CFI land-sector offsets.
South Korea 2015 Mandatory & Voluntary	Banking restricted (1 year span of next CP). Borrowing allowed within a CP, for up to 10% of emissions.	Clear mechanisms and explicit triggers (reserve, limits on borrowing and banking, offsets, holding; Price floor & ceiling).	Only domestic offsets allowed (10%) until 2020. Then, Intl offsets included but use of UN credits uncertain.	1st Asian country to pass an ETS into law. Unique inclusion threshold. Strong opposition from industry.
Chinese 7 Pilots 2013 & 2014 Mandatory	In general: banking allowed in pilot phase. Banking forbidden.	Still under discussion. May include price ceiling/floor, fixed price, reserve, supply/demand adjustment every year.	Only domestic offsets (CCERs) allowed. Limit depends on scheme, never exceeds 15%.	1st ETS building itself from the bottom-up (provincial à national). High execution speed, implemented in 2 years.

* EUETS=aviation included (210Mt), RGGI= 09-11 averaged emissions (RGGI COATS).
** T = Inclusion threshold; % = percentage of GHG emissions covered in terms of overall GHG emissions.
Legend: EITE=Emissions-Intensive and Trade-Exposed; CFI=Carbon Farming Initiative; CP= Compliance Period; KP=Kyoto Protocol; LDC= Least Developed Country; NAPs=National Allocation Plans; P1,2,3=Phase 1,2,3.

Note: For clarity, only major ETSs are included. The Swiss ETS and the Québec cap-and-trade respectively resemble that of Europe and California, and are therefore not included. Monitoring, Reporting and Verification (MRV) procedures are not discussed as it would require a thorough and detailed comparative analysis, which is beyond the aim of our work.
Source: Climate Economics Chair

The various statuses of the ETSs

Figure 1 maps the various ETSs around the world and Table 1 summarizes their key features. There is a wide range of stages of development since some are already in force while others are to be launched in the years to come or still under negotiation. Even among ETSs in force, the statuses differ greatly. Some are at a very advanced stage, such as the European Union Emission Trading Scheme (EU ETS) or the Regional Greenhouse Gas Initiative (RGGI), which respectively started in 2005 and 2009 and have already been through reviews and amendments, while others like California and Québec (2012) or Kazakhstan (2013) have only just got started. The seven Chinese pilots, for instance, are expected to be launched over the course of 2013. The Australian Carbon Pricing Mechanism (CPM) has a special feature: it came into force in 2012 but cannot be seen as a fully implemented ETS as it is now in a fixed-price period in which government sells permits at fixed prices but is expected to transit to a flexible-price period either by July 1st, 2014 or 2015 as the current Prime Minister intends to scrap its carbon tax to bring the flexible price period forward by one year. Likewise, in South Africa, existing taxes could possibly be converted into a domestic ETS. In general, recent or soon-to-be schemes have been built based on experiences gathered from older ETSs, mostly the EU ETS (general lessons on the design of such schemes are drawn at the end of this chapter).

Many other countries are also considering the implementation of national ETSs with various degrees of likelihood, sometimes as part of multinational dynamics. A blatant example of this is Turkey, which would be required to implement an ETS should it join the EU. Similar to the case of Turkey is that of Ukraine, which should prepare a new ETS draft law for the end of the year 2013. 2017 seems to be a realistic start date should the forthcoming proposal be accepted. Some countries also opt for testing cap-and-trade through pilot schemes, eventually expanding to the federal/national level. The most telling example is that of China (see Box 1). Brazil seems to be taking a similar path as an ETS is expected to be initiated in Rio de Janeiro in the next couple of years. A similar scheme could also emerge in Sao Paulo and in the Acre region, which could then pave the way toward a national ETS. Finally, some of World Bank Partnership for Market Readiness participants such as Chile, Mexico, Peru for the Americas but also Vietnam and Thailand in Asia are all eyeing the implementation of an ETS. Among these, Chile is the most developed project. An in-depth analysis of those schemes is available in Quemin (2013).

Absolute versus intensity targets

Absolute targets impose a defined cap on overall emissions, meaning that the maximum authorized amount that covered sources can emit is explicitly stated. This is the rationale for most emissions trading schemes and is the rule for example in the EU ETS, RGGI and California. An exception is New Zealand, which has an absolute but currently unspecified reduction target, what is thus called a “soft” cap. It means that there are significant exceptions that allow certain entities to exceed the cap or to benefit from special treatments. This goes hand in hand with the “two-for-one” rule allowing liable entities to surrender one permit for every two tonnes emitted, or the unlimited use of offsets. However, the NZ government is currently drawing up a proposal for auctions, which implicitly implies that a 5-year overall hard cap will be provided.

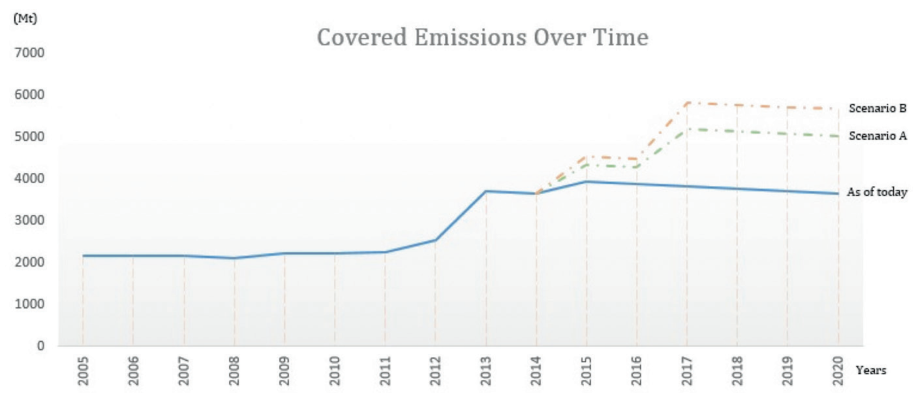
Conversely, intensity-based targets do not impose a defined cap on overall emissions. They consist in capping the carbon content of GDP or energy consumption without imposing an absolute limit on quantities. Such targets have been implemented since 2007 in the Canadian province of Alberta, where liable entities must reduce their emissions intensity by 12% from their government-approved 2003-2005 baseline emission intensity. Emission Performance Credits (EPCs) are generated by facilities that have gone beyond the 12% baseline and can be traded. The seven Chinese pilots are also built on this model before possibly shifting toward an absolute target by 2020. As reduction targets are expressed as a percentage of the carbon intensity of production or of the GDP, emissions may not be decreasing in absolute terms in the end, hence raising the question of the environmental effectiveness of such schemes.

Emissions coverage around the world

The emissions covered by ETSs

The graph below shows three paths of emissions coverage over time at the global scale. The solid line represents the evolution of coverage including schemes in force as of 2013, while the two dotted lines are hypothetical scenarios accounting for future and likely schemes.

Figure 2: Various emissions coverage paths

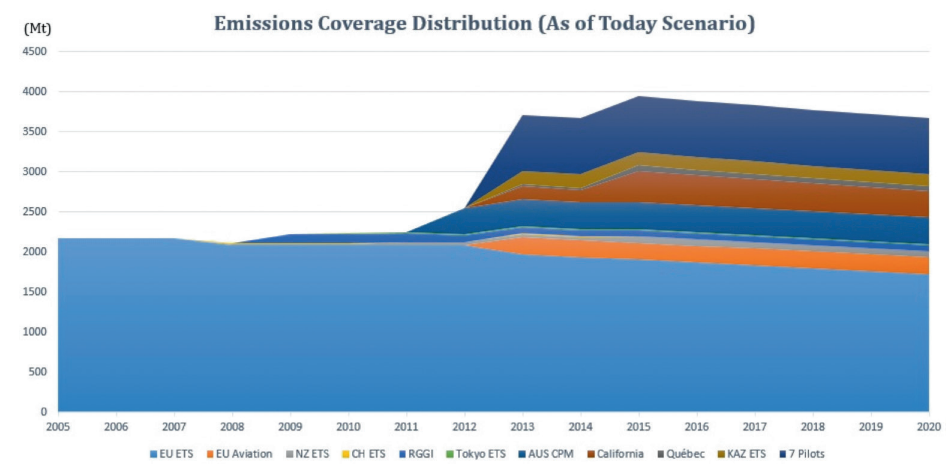


Legend: As of today = EU ETS+aviation, NZ ETS, CH ETS, RGGI, Tokyo ETS, Australia, California, Québec, Kazakhstan, 7 Pilots
Scenario A = As of today + South Korea, Chile, Brazil, Ukraine
Scenario B = Scenario A + Mexico, Turkey, Ontario, British Columbia, Manitoba
Source: Climate Economics Chair

The “As of today” scenario encompasses ten schemes that have already kicked off or are about to over the course of the year, namely EU ETS + aviation, NZ ETS, CH ETS, RGGI, Tokyo ETS, Australia, California, Québec, Kazakhstan and the seven Chinese Pilots. Scenario A includes “As of today” schemes plus schemes whose implementation is already scheduled (South Korea) or deemed likely (Chile, Brazil, Ukraine) given the current state of negotiations. In addition, scenario B takes into account other schemes that might start before 2020, including Mexico, Turkey, and three WCI states (Ontario, British Columbia and Manitoba). Despite the recent announcements made by the White House that could possibly lead to a cap-and-trade targeting power plants at a federal level and the Chinese intention to implement a national scheme, those were not included as their hypothetic scopes or start dates are subject to high uncertainty.

Sticking with the “As of today” scenario and thus limiting our hypotheses on the future of carbon trading, the EU ETS will keep on having the lion’s share of emissions trading by 2020, roughly covering half of the globally capped emissions, down from almost 95% in 2011 (see Figure 3). As of 2013, existing ETSs (including Australia carbon tax and the seven Pilots) cover approximately 3.7 $GtCO_2e$ annually, that is around 7% of the 50 $GtCO_2e$ emitted globally. However, the share of covered emissions could soar in the years to come, of course with countries like Brazil, Korea, Ukraine or Chile currently crafting their own schemes, but notably with big emitters like China and the US possibly joining the club as they have recently unveiled carbon-policy plans. Ambitious as they may be, these initiatives still fall far short of what is needed to limit the temperature rise below 2°C.

Figure 3: Emissions Coverage Distribution, “As of today” scenario.



Source: Climate Economics Chair

ETS Scope & Target

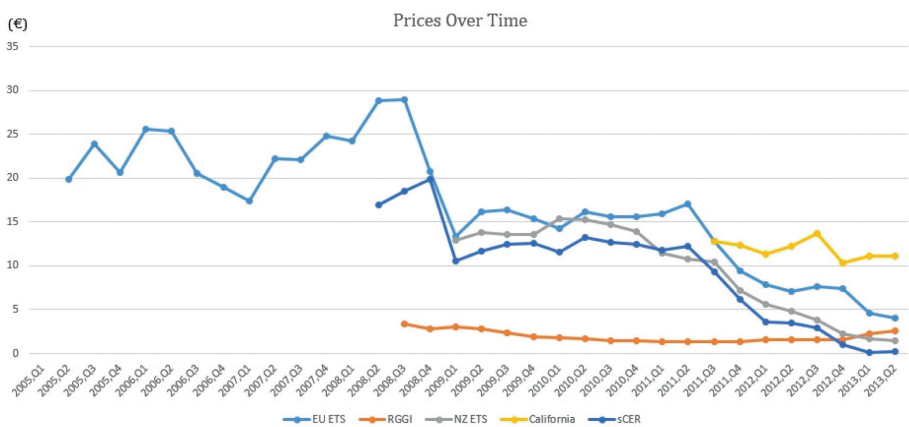
The ETS-specific target and therefore the cap might be more or less stringent than the overall nation-wide reduction target, if such a target exists. It is therefore important to review the various ETS scopes around the world. Energy generation and industrial processes, broadly defined, are always included, except for RGGI, which is only focused on power plants. The highlights from Table 1 can be summed up as follows: because they are often already and easily monitored and account for a large share of emissions, power plants and heavy industry are initially included, then gradually joined by other parts of the industry sector and other sectors of the economic pie.

As noted above, a gradual inclusion is generally being made based on the phases’ timeframe. These may be rather restrained as in the case of Europe, where only aviation and a few industrial activities were included in Phases 2 and 3 or, conversely, be rather comprehensive as in New Zealand where the entire economy will be included by 2015. Forestry and agriculture are generally excluded as emissions reductions are regarded as rather uncertain and complex to quantify in the long run. However, the NZ ETS is the exception as it kicked off in 2008 only with forestry (counted as a carbon sink), later joined by liquid fossil fuels, power generation, industrial processes and fishing in 2010 and waste and synthetic GHG in 2013. Currently, agriculture only has a reporting obligation but should it join the ETS in 2015, the whole economic pie could then be covered. In Australia, the agricultural sector is also covered but in an indirect manner, from the Carbon Farming Initiative. For its part, California has planned to include distributors of fuels for combustion in the transportation and building sectors as of 2015. The South Korea scheme will also span trade, building and waste sectors, in addition to the usual ones. Another important feature (not discussed here) is the inclusion threshold that allows the exclusion of small emitters whose participation costs could exceed the benefits of inclusion. Finally, it is noteworthy to mention that provisions for voluntary opt-in (and conversely opt-out) are sometimes included.

Carbon prices around the world

In contrast to the economists' ideal of a unique carbon price, several ETS have emerged in the last decade thus leading to multiple carbon prices around the world. The graph below shows the evolution of carbon prices in the main market-based carbon pricing initiatives around the world. A brief explanation for each scheme prices follows.

Figure 4: Various carbon prices evolution on a quarterly basis since 2005



Legend: EU ETS: Dec 12 contract price, then spot price; RGGI: quarterly auction price; NZ ETS: NZU spot price; California: quarterly auction price; CDM: secondary CER spot price.
Source: Climate Economics Chair, from CITL, RGGI COATS, Point Carbon.

EU ETS

First, EUAs traded at around €20-25 as the market was deemed "short" (emissions › cap). However, when 2005 verified emissions were released in 2006, market players realized the market was in fact probably over-supplied. Phase 1 allowances could not be banked into Phase 2, therefore prices dropped, with Phase 1 contracts spot prices converging to zero as a result of the no carry-over provision. In the beginning of Phase 2, prices soared again due to discussions on the 2020 target and expectations of a tighter cap. The prices reached €30 per tonne before collapsing to €12 in early 2009 due to the economic and financial crisis. This massive drop was followed by 2 years of relatively low volatility and stable prices, i.e. a new equilibrium in a context of slow recovery. Prices rose a little in mid-2011 after the Fukushima catastrophe as nuclear power endured a blow (a substitute for fossil-based electricity production), but prices fell again in late 2011, never to be propped up to such levels again. This fall was caused by discussions about an energy efficiency directive and by the effects of the renewable energy directive — possibly overlapping with the ETS target, but also by the debt crisis along with the degraded growth outlook. Prices were then halved in early 2013 due to the European Commission "backloading" proposal being rejected by Parliament. Since then backloading has been voted by Parliament but the effect on the EUA price has been very modest. EUAs trade now at around €4.5, a little above $6.

The EUA price is the main driver for the CER price, notably because Europe is the major source of demand for CDM (Clean Development Mechanisms) credits. Over the course of 2012 though, the CER prices collapsed to rock-bottom levels. The main reasons for this collapse are:

the tightening of qualitative regulations on CERs and ERUs in the EU that caused a massive use of post-2012 non-eligible credits for pre-2013 compliance before they lose their values as substitutes for EUAs

a post-2012 credits supply that covers the potential demand more than twice: after 2012 compliance, only about 700 $MtCO_2e$ in total for 2013-2020 can be covered with offsets compared with the EU-allowed CDM credits supply estimated at around 1,700 $MtCO_2e$;

the almost non-existent and uncertain demand from other carbon markets or countries until 2015 at the earliest, should new ETS allowing international credits emerge, for example in Australia, where they have been combined with a steadily increasing supply of offsets as CDM projects have produced more than what was expected.

NZ ETS

Roughly speaking, the NZU prices have been driven by CDM credit prices. Given the small size of its economy and the subsequent limited potential for cheap abatement, New Zealand designed an open ETS. As part of their "soft" cap, the use of international offsets is allowed for up to 100% of obligation, which explains the NZU dependence on CER. Via indirect linking through the CDM and given the size ratio of both schemes, the drop in EUA prices therefore impacted the NZ ETS, driving the NZU prices very low. The decrease has been steady since the beginning of 2011, following the CDM prices movements. NZUs now stall at record lows and are locked-in their downward spiral.

As New Zealand refused to renew its commitments under the second period of the Kyoto Protocol (2013-2020), CDM/JI credits are thus likely not to be usable after 2015, but carry-over provisions for vintages from CP1 into CP2 are still under discussion. Consequently, foresters monetize their NZUs by swapping them into UN offsets, planning to surrender the cheaper offsets for compliance while reaping the benefits from the NZU sales before eventually exiting the market they entered on a voluntary basis. Although emitters are taking advantage of the current low NZU prices by purchasing them from foresters and then banking them lest future prices should rise, analysts do not foresee the prices taking off, even after 2015, unless the opposition (Labour + Green) regain power in the 2014's elections and tighten up the scheme.

RGGI

After more than three years locked at the minimum auction price of $1.93 (subject to increase with inflation), the prices reached $3.45 at the last quarterly auctions. The low price and the thin liquidity were caused by a growing allowance supply glut which reflected the unforeseen evolution of natural gas markets in the US, the economic slowdown and efficiency gains. The RGGI partners are now discussing tightening the cap by 45% down to 91 from 165 millions of short tonnes of CO_2 as part of an updated model rule. The RGA price has steadily increased since the bolstering announcement last February, clearing at + 74% from where they had stalled before. Prices are foreseen to keep on increasing. The reduction is to be effective as of January 1, 2014 as all nine of the partners are on track to pass it into law and update the related regulations.

California

Even if it is too early to assess the performance of the scheme, as it only kicked off this year, one can observe that CCA prices have been quite steady since the first auctions held in late 2012. The prices have stood a little higher than the auction reserve price (settled at $12 in 2012, increasing by 5% per year plus inflation onwards). As of today, California is now where the carbon price is the highest in the world, almost twice the price of an EUA.

Box 1: Carbon markets development in China

As the world's largest energy consumer and GHG emitter, China has been gradually adopting policies to control its GHG emissions growth and to shift to a low-carbon development pathway. Its climate commitment submitted under the Copenhagen Accord was translated into the national carbon intensity targets, written into the national 12th Five-Year Plan. Since the traditional command-and-control regulatory approaches demonstrated their limits in achieving energy intensity goals, the government intended to expand the scope of the policy measures to use market-based mechanisms to control emissions.

In October 2011, the national development and reform committee (NDRC) designated five cities (Beijing, Tianjin, Shanghai, Chongqing, and Shenzhen) and two provinces (Guangdong and Hubei) as the pilots to test carbon emission trading. Local authorities are required to coordinate the draft of overall ETS design and implementation plans, formulate ETS oversight guidelines, determine emission caps based on local GHG inventories, draw up allowance allocation rules, establish registry and governance systems, and develop market infrastructure.

Later in June 2012, the interim VER Rules were officially published to provide a basis for project-based offset markets in China. Credits complying with the VER Rules will be labelled China Certified Emission Reductions (CCERs) and the entire approval process resembles that of the UN offset mechanism, i.e. CDM, with the NDRC acting as the CDM Executive Board (EB) to approve methodologies and projects registration as well as host national registry for issued credits. The VER Rules foresee that pilot regions may elect the type of CCERs to be allowed under their ETSs.

As to August 2013, most of the pilots have released their ETS implementation plans, which set the overall framework to foster efforts around detailed market design and implementation schedules at a later stage. On the one hand, the ETS implementation plans converge on many design elements; on the other hand, diversities do exist to accommodate regional situations. All pilot regions shall set an absolute emission cap, which constitute 35%-60% of local CO_2 emissions. Although all pilot ETSs intend to cover energy/carbon intensive sectors, the list of sectors varies greatly among regions. For example, Tianjin ETS concentrates on several energy and industrial sectors while Shenzhen will bring 26 sectors under its scheme given the important role of service industries in this city. It should be noted that public buildings are included in the Beijing and Shenzhen plans and Shanghai states it will bring aviation into its regulatory ETS. Energy use or carbon emission thresholds were set to identify liable emitters with Guangdong ETS tending to cover over 800 entities while the number being only 100 in Tianjin.

All pilot ETSs will only cover CO_2 gasses, at least in the initial stages.

Allowances for individual entities are primarily to be determined based on their emission inventories of previous years. In all pilot regions, most of the permits are to be freely allocated to emitters and auction is considered as a complementary method. Released ETS plans indicate banking is authorized while borrowing is not permitted.

All pilots allow eligible CCERs offset as a compliance instrument, with upper limits of 5%-15% of overall cap. Most local governments require the majority of eligible CCERs to be generated from projects located within their jurisdictions. Authorities are also considering introducing price regulation mechanisms to avoid negative price fluctuations, including the hold of quota reserves and setting a price ceiling/ floor.

Although most schemes are scheduled to start over the year of 2013, only Shenzhen officially launched its pilot ETS on June 18th. The scheme covers 635 industrial enterprises and 197 public buildings, which account for about 40% of the total emissions of Shenzhen. Allowances of 100 million tonnes of carbon are allocated to the 635 industrial enterprises in the span of 2013-2015. A "Grandfathering" approach is adopted to identify emission quotas for electricity generators and water and gas suppliers. As for manufacturers, carbon emissions of per Unit Industrial Added Value were developed for allowance allocation.

In addition, measurement and verification methodologies were also formulated to quantify emissions from large-scale public buildings in the city. The local government also drew up the MRV guidelines. The Shenzhen Emissions Exchange is entrusted as the emissions trading platform. On the first day of transactions, 8 deals were completed with a total amount of 21,112 tonnes of CO_2e at a price of 28-32 Yuan per tonne (around €3.7). PetroChina and Hanergy Holding Group became the first buyers, purchasing 10,000 tonnes of allowances each.

However, no other transaction was reported until the day of writing. In spite of the announcement of ETS commencement, many key elements have not yet been ready for the full function, including detailed operations rules, registry management, and third-party verification processes. All these are expected to be gradually developed and released in the second half of 2013 and 2014. Nevertheless, the launch of China's first market for compulsory carbon trading is a landmark step for China in building a nationwide carbon emission trading market.

Notwithstanding significant progress, various obstacles remain and are likely to delay the launch of effective pilot regional ETSs and a national ETS. The core concern is about the feasibility of a pure market-based tool applied in a system with an immature market economy. Price-control systems for the power sector and coordination among government agencies are also hindrances to effective ETS. In addition, extensive capacity building work is also needed for the MRV, including the design of an effective and robust registry system.

As for the national ETS scheme, the implementation of pilots ETS will surely provide the national government with experiences and lessons to examine the potential development of a national market. Apart from this, the viability of a national scheme is also dependent on progress in international climate negotiations and domestic capacity building. Given the difficulties encountered in establishing ETS trials and current climate negotiation status, a national scheme is not likely to start before 2020.

Some lessons on the design of carbon markets

Level of ambition – Environmental Cap

Setting the cap at the dawn of the scheme is a fundamental but thorny issue. The regulator must determine a clear and predictable level of emissions to be cut within a given time frame and over a given panel of sources. The trouble is that there is no methodology to set the "right" cap when it comes to a global pollutant. It is all the more so debated given the stringency of the cap largely influences the resulting price. The choice of a cap is therefore more political and strategic than it is scientific. Indeed, political decisions aside, many parameters (such as economic forecasts, overlap with other policies, etc) must be factored in to get to the cap, rendering it hard to fathom. As predictability is key to foster long-term investments, the EU ETS and RGGI both have a linear reduction factor applied to the cap. In making an arbitrage between predictability and resiliency, Australia came up with an innovative idea: a 5-year rolling cap, meaning that 5 years worth of caps will be known at all times. Thus, the cap could be annually adjusted for new market overview and context. One last point: as highlighted in the EU ETS, starting with a decentralized process later turning into a centralized one might help the scheme get started.

Form of allocation

Permits can be distributed for free, which has hitherto been the mainstream method, or through auctions, which has considerably gained momentum lately, or by a combination of the two. In the early stages of the EU ETS for example, free allocation has been the dominant way to allocate allowances as it helped garner support for the scheme. Because free allocation implied explicit distributional effects (significant windfall profits, particularly in the power sector) and also created within-sectors differences *within* the scheme as similar facilities received varying amounts of free allowances depending on the nations they were located in, it was called into question. It was dealt with by replacing free allocation by auctioning as the basic principle of allocation. The share of auctioned allowances is to increase over time as some transitional free allocation based on an EU-wide and centralized benchmarking approach is still allowed for Emissions-Intensive Trade-Exposed (EITE) sectors, gradually phased out by 2020 for power plants and by 2027 for industrial facilities. The EU ETS case has been inspiring, as many schemes have opted for similar allocation approaches.

MRV Standards

Monitoring, Reporting and Verification (MRV) procedures will not be discussed in detail, as it would require a thorough analysis, which is beyond the aim of our work. However, one can observe a convergence of MRV standards as new schemes tend to design their procedures based on international standards, generally embodied by European ones. A case in point is Turkey, which has a comprehensive MRV Regulation in place in line with that of the EU. It covers 50% of its CO_2 emissions but it does not establish any emission limitation/reduction target. The first year for monitoring obligations is 2015 and, based on this framework, a domestic ETS could emerge prior to 2020.

Banking & Borrowing

Allowing flexibility over time through two symmetrical provisions, banking and borrowing, can smooth out carbon prices and compliance costs with restrained environmental impacts. Banking allows liable entities to hold unused allowances for future compliance. It is an incentive for early action and prevents the price to drop to zero in case of an oversupply as long as the anticipation horizon is distant or unsettled. Therefore, unlimited banking has been implemented in almost every scheme. However, as banking links expectations over time, the question of to which extent banking ought to be allowed begins to emerge. Banking is thus restrained in new schemes (California, South Korea). Symmetrically, borrowing allows entities to use allowances from future compliance periods in advance. If it can be an efficient short-term response, notably in case of price surges, it bears the risk of future non-compliance since covered firms are not incentivized to reduce their emissions in the early stages of the scheme. Therefore, when allowed, borrowing is usually limited.

Direct Linking Opportunities

As of today, only three linkages between schemes have officially been planned, the first between Europe and Australia, the second between California and Québec and, more marginally, the third between Europe and Switzerland.

First, a link can either be direct or indirect in nature. Direct linking allows for explicit allowance use between schemes, either unilaterally meaning that only one-way use is allowed or bilaterally when a full two-way link is implemented. The link proposal between Europe and Australia sheds light on this point particularly well. In August 2012, the European Commission and Australia announced their intention to link the EU ETS and the Australian CPM. A first partial link should be established from 1 July 2015, allowing Australian entities to use European allowances (EUAs) for compliance but not vice versa. The full two-way link would start on 1 July 2018.

If not directly, schemes can be indirectly linked through independent links to a common third system. If the CDM is generally taken as an example to illustrate indirect linking, (as shown for example by the interrelation between EUA, CER and NZU prices), the third common system needs not be an offset source[1]. Even through another ETS, two schemes can be linked since the supply and demand in one scheme will indirectly influence those in the second one. Second, linking has implications that need to be quickly overviewed (for a more in-depth analysis, see Quemin (2013)). Linking schemes is expected to lead to a price harmonization or convergence. On the aggregate level, compliance costs and competitive distortions are reduced and market liquidity increases, as more abatements options are available. However, from a single player's point of view, linking can have drawbacks as some participants can become permits buyers, volatility can be imported from the other scheme and sovereignty over its own scheme is reduced.

Let us now dwell on linking initiatives around the world. The discussions between the EC and Australia will certainly be sped up compared to what was initially planned as Australia recently announced it is to scrap its current tax in favour of an ETS a year early, i.e. as of 1 July 2014 or 2015, in a bid to alleviate the "burden" borne by its economy to win over voters before the coming election. Further negotiations are needed to find common ground on key issues such as total fungibility of allowances, use of offsets, MRV standards, carbon leakage treatment, etc. Talks between Switzerland and the EC will be over by the end of 2013, likely leading to a full two-way link as of 2015. The Swiss ETS has already been reformed to make the linking viable and will marginally expand the EU ETS scope and lift its coverage by only 0.3%. As for California and Québec, a green light was given to implement direct and bilateral linking in April 2013. The linking will be effective and allowances fungible as of January 1, 2014. It will be the world's second largest carbon market behind the EU ETS in terms of volumes. This major step forward should lead the way and set an example for other Western Climate Initiative (WCI) partners to follow[2].

Indirect linking: The use of offsets

Often referred to as spatial flexibility, linking a cap-and-trade with an offset mechanism allows covered entities to use offsets generated by project-based mechanisms reducing emissions outside the scheme's perimeter, for compliance under a cap-and-trade scheme. By investing in emission reduction projects in countries/sectors where abatement costs are cheaper, covered sources can thereby lower their compliance costs. In principle, offsets allow a transfer of knowledge and technology and unlock investments abroad while the scope of possible mitigation sources is expanded, thereby reducing compliance costs within the scheme. As they offer a financially

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1 See following subsection.

2 The WCI is a cross-border program between US states and Canadian provinces aimed at combating climate change at the regional level.

interesting compliance option, qualitative and quantitative limits can be set in order to control the effect on the ETS cap. Qualitative limits also allow environmental integrity to be secured. Depending on the origin of the offsets, three offset mechanisms categories can be identified: international credits, domestic offsets and offsets generated via bilateral agreements.

Established under the Kyoto Protocol, international credits have hitherto been the most widely used offset type. They originate from Clean Development Mechanism (CDM) and Joint Implementation (JI) projects. More specifically, the CDM (resp. JI) allows Annex I countries to use Certified Emission Reductions (resp. Emission Reductions Units) stemming from projects hosted by non-Annex I (resp. another Annex I) countries to meet part of their compliance requirements. Currently, international credits are only allowed in the EU ETS, the NZ ETS and marginally in Japan under the domestic voluntary cap-and-trade schemes (J-VETS, K-VAP, VCCTS). Given the relative sizes of these schemes, the EU ETS accounts for the bulk of demand for these offsets.

The recent drop in international offsets demand is counterbalanced by a growing demand for domestic offsets as well as for offsets credited on a bilateral agreement basis. Although domestic offsets were the only offset option within RGGI, a shift of focus toward domestic offsets is obviously taking place in recent schemes. As they ensure domestic green investments and emissions reductions but also help reach sectors otherwise hard to include in ETS, they are favoured by nascent schemes, at least in the first years of functioning before eventually considering the inclusion of international offsets. On the downside, local projects are often more costly and reduced in number of opportunities. Australia (Carbon Farming Initiative), China, Kazakhstan and South Korea are four cases in point. As for bilateral offsets, their use is more limited for now as only Japan and California allow for them to be used within their respective schemes. Japan is at a much more developed stage as it implemented the Bilateral Offset Crediting Mechanism (BOCM). Such offsets rely on bilaterally negotiated contracts, i.e. directly between countries without intermediary that are thus similar but simplified versions of those under the CDM.

Price management

Price management mechanisms play a central role since the robustness of the price signal is necessary for triggering investments in low carbon capacities, and because volatility can deteriorate agents' confidence in the price signal.

The EU ETS does not provide for explicit price management tools, but allows banking, borrowing and offsets. Facing the current situation, however, the EC has recently been given power to backload the auctioning of 900 $MtCO_2$ as it finally passed through Parliament. In addition, the Commission also started negotiations to expand the scheme's flexibility and will build a proposal upon the outcomes of a consultation it launched (see Chapter 4). In RGGI, however, flexibility can operate via two price-triggered measures. First, the three-year Compliance Period can be extended to 4 years, should prices reach a certain upper limit. Second, the cap can be relaxed since the 3.3% of an entity's obligation threshold for compliance that can be met with offsets can go up to 5% (+ access to offsets from another region) in case the allowance price exceeds $7 or up to 10% (+possible use of international offsets) in case it goes beyond $10. Both measures have never been used since prices have never exceeded the threshold. As it blurs the exact expansion of the cap and depends on the offset markets reaction to additional demand, it was deemed not to operate in a sufficiently transparent and predictable way. Therefore, a recent review sets forth proposals to replace both measures by a Cost Containment Reserve. The CCR would work as a fixed additional supply of allowances. Its availability is triggered if prices go beyond certain price levels ($4 in 2014, $6 in 2015, $8 in 2016, $10 in 2017, and rising by 2.5% yearly thereafter).

Newer schemes also opted for including additional tools to ensure more flexibility. Similarly to the CCR, a first approach is to impose a price ceiling. In practice, it is *de facto* applied through allowances sold at fixed-prices by regulators. California is a case in point with the Price Ceiling Mechanism. This mechanism allows up to 4% of the total 2013-2020 allowance volume to be released to contain costs. The reserve is divided into three equal-sized tiers and allowances from each tier can be sold subject to triggering constraints and at fixed prices ($40, $45, $50 for 2013 and then growing at 5$ per year plus inflation). In Australia and New Zealand, the volume of allowances available at a fixed-price (AUS$24.15 and NZ$25 per permit i.e. around €18) is unlimited, which may undermine the scheme's environmental effectiveness. Nevertheless, a binding cap will be placed in Australia as of 2014/2015 and the price ceiling will then be set at $20 above the international carbon price (expected EUA price in the current context). Another approach is to set up a price floor, as in RGGI where it prevented the price to drop to exactly zero under a non-binding cap. Such a mechanism also applies in California and Québec. Within the EU ETS, the UK has placed a carbon price floor on its domestic electricity producers to compensate for the currently low price, which cannot foster long-term investments in low-carbon technologies and infrastructure. However, such a unilateral measure tends to accentuate the EUA price fall, as more expensive (relative to the European objective) reductions will be triggered.

Interactions with complementary policies

EU ETS: The EU ETS is the central pillar of the EU Energy and Climate package, which is a set of binding legislation aimed at combating climate change by ensuring European targets are met by 2020. These targets, better known as the "3x20" targets, comprise three key objectives: a 20% reduction in EU GHG emissions compared to 1990 levels, raising the share of EU energy consumption from renewable sources to 20% and a 20% improvement in the EU's energy efficiency. The EU ETS is therefore heavily interdependent with complementary policies, such as the Renewable Energy Directive and Energy Efficiency Directive, which both influence its demand side while the Linking Directive also provides some limited flexibility on the supply side through the global GHG credit market. Both this overlap between policies and lack of supply-side flexibility are at the very core of the current debates (see Chapter 4).

California: Signed in 2006, the Assembly Bill 32 provided the California Air Resources Board (CARB) with broad authority to develop policies that it determined were necessary to reach the goals part of the legislation. CARB thus developed a Scoping Plan (SP) that includes a GHG cap-and-trade program and Complementary Policies (CPs) both for capped and uncapped sectors. What is unique to California is the greater extent to which it relies on its CPs to meet its GHG emissions target compared with other schemes. Currently, analysis of the SP assumes CPs will achieve 78% of the 80 $MtCO_2e$ of reductions needed, leaving the other 22% to the cap-and-trade. Therefore, it is important to understand the Californian program as a back-up, ensuring that objectives are met, depending on the CPs' performances. The cap-and-trade related reduction effort might vary depending on CPs' achievements, but also on the volume offsets available within the scheme.

CRC UK: The Carbon Reduction Commitment, which covers 10% of UK CO_2 emissions, applies to emissions not already covered by the EU ETS and the Climate Change Agreements. It creates a specific incentive in large non-energy-intensive organizations both in public and private sectors to reduce emissions that generally fall below the EU ETS inclusion threshold. Consequently, companies have had to buy allowances from the government at a fixed price (£12, i.e. around €14) since 2010. It is often argued that its effectiveness is limited due to its overlap with the EU ETS. Indeed, as companies reduce their electricity consumption under the CRC and power plants consequently produce less, thus needing less EUAs, other EU ETS-liable firms can use the latter for their own compliance purposes. If the CRC price is above the EUA price, the mechanism leads to further decreasing the price of EUAs while triggering reductions at a higher cost than those under the cap and trade.

3. Carbon taxes

As stated in the introduction, economics textbooks describe two ways of pricing greenhouse gas emissions: allowances markets and taxation. These two methods are generally presented as alternatives, whose respective merits must be weighed up before one or the other approach is adopted. In the real world, extending carbon pricing seems to lead to hybrid systems in which allowances markets and carbon taxes have to coexist. Allowances markets are instruments best suited to regulating emissions concentrated in large industrial plants. Taxation is the preferred instrument for pricing sources of diffuse emissions in a given area. In this section of the chapter, we will be focusing on carbon taxation systems around the world, how they are designed, and the general lessons we can draw from them.

To avoid any possible confusion, we should add that the "carbon tax" concept used here refers only to taxes placing an explicit price on carbon within a given economic area; i.e. it does not include taxes on the energy content of fossil fuels. The observations we make and the conclusions we draw are not valid for border adjustment mechanisms either.

Carbon taxation mechanisms

A carbon tax aims at assigning a price to CO_2 emissions. Its base is composed of CO_2 emissions. Its rate, expressed in euros per tonne of CO_2 emitted, sets their price. A carbon price alters the relative prices of goods or energy sources on the basis of their carbon content. This change in relative prices helps to orient economic actors toward modes of production and consumption that generate less carbon.

If economic agents are rational, the environmental impact of a carbon tax is strictly identical to that of an allowances trading system, which puts a price on CO_2 emissions through a cap. In practice, the emergence of a carbon price has an established environmental effect if the various agents have alternative technologies and energy sources and have the financial means required for changing their behaviour. Globally, it is more advantageous to introduce a carbon tax (or an allowances market) than regulation if the economic agents have different marginal abatement curves: reductions will be made by those agents for whom such reductions are less costly – which allows the cost of action for society to be optimized.

The incentive mechanism is that if an agent has to pay a tax (or an allowance in a cap-and-trade system) of €20 per tonne of CO_2 emitted, it is in their interest to make all investments (technology changes, switching to alternative energy sources, improving energy efficiency, etc.) that cost them less than €20 per tonne of CO_2 avoided. They thus save the difference between the tax they would have paid without making the investments and the cost of the investment. Actors who continue to emit CO_2 are those for whom the possibilities of reduction are more expensive but who are more likely to "improve" their emissions: only those agents who make sufficient profit from their activity to cover the cost of the tax – in the absence of cost-effective potential emissions reduction investments – are able to continue emitting.

The resulting effect of the tax on emissions is not known in advance, by contrast with a cap-and-trade where emissions are effectively capped. Reciprocally the tax rate is known, where in the cap-and-trade the allowance price changes every day.

An overview of carbon taxes around the world

The various carbon taxes currently in place are shown on Figure 5 and listed in this section along with their main characteristics. The different tax rates are described in Table 2. This section can be divided into two parts, hereby mimicking the two waves of carbon taxation that respectively occurred in the 90's for the former and as of 2008 for the latter. Note that, each time, debates on carbon taxation and subsequent tax enforcement arose in a context of economic crisis in which governments needed more revenues and entire tax systems needed reshaping, both providing room to manoeuvre to coerce firms and consumers to incorporate the cost of carbon in their decision-making process.

In the 90's, the Nordic countries faced an economic and financial crisis. This context enabled them to introduce a carbon tax, as part of a profound change in the national tax system. Finland was the first country to introduce a carbon tax in 1991. The first tax rate was very low, since it was lower than 2€/tCO_2, but it increased over time. Today, all fuels are covered by the carbon tax, including biofuels and kerosene. However, biofuels benefit from a reduced rate and kerosene used in commercial aviation is excluded. Moreover, the rate is halved when fuels are used in combined heat and power (CHP) systems.

Sweden is the country where the rate is the highest and the carbon footprint the lowest. In 1991, when the carbon tax was introduced, the rate stood at about €30/tCO_2. Today, the rate is higher than 100€/tCO_2, except for natural gas. However, EU ETS-covered firms are exempted and non-ETS companies benefit from a 70%-discounted rate. Rail transportation is also exempted from the tax. The introduction of the carbon tax was part of a deep modification of the Swedish tax system. It enabled a tax reduction on labour and on personal income and a generalization of a uniform rate of VAT on energy, which stands at 25%. Moreover, the introduction of the carbon tax has led to the development of urban heating networks.

In Norway, the tax rate is quite high, but an important part of fuels are not taxed, since natural gas and coal are exempted. The revenues of the carbon tax are therefore less significant than those in Denmark, where the rates are lower but the tax base is broader. Note that in Norway, domestic aviation covered by EU ETS does pay a tax, with a reduction of 30% on the rate.

Slovenia is the only Eastern European country with a carbon tax in place, and it implemented it quite early (1996). The rates are around 10€/tCO_2. The tax base includes every fuel except biomass for heating. Firms included in the EU ETS are systematically exempted from the tax. Slovenia is also the only country that included organic compound combustibles in its tax base.

The second round of carbon taxation started around 2008. The introduction of carbon taxes matched the context of the economic crisis. For instance, such a tax was introduced in 2010 in Ireland. In the meantime, the Irish fiscal system was modified profoundly. The carbon tax is part of the national mineral oil tax. Today, the tax rate stands at 20€/tCO_2 for liquid fuels and natural gas. Since May 1st 2013, coal and peat have been included in the tax base, with a rate of 10€/tCO_2 which then rose to 20€/tCO_2 in May 1st 2014. However, households and farmers do not pay the carbon tax on coal. Like all its neighbours, Ireland exempts firms covered by the EU ETS from the tax. CHP systems are also exempted.

In British Columbia, a carbon tax was introduced in 2008 at a rate of C$10/$tCO_2$ (i.e. ~€7) and set to rise by C$5 per year. It now stands at C$30/$tCO_2$ (~€20/tCO_2) and no further increase is planned. It applies to almost all fossil fuel and covers three quarters of BC's GHG emissions. The double dividend theory has been pretty well translated into practice meaning that all revenues generated by the tax are used to reduce other taxes, notably personal and corporate income tax rates. The tax is thought to have driven GHG emissions and fuel consumption down while keeping a strong economy: its per capita GHG emissions dropped by 10% between 2008 and 2011 (hereby outdoing other Canadian provinces).

Switzerland introduced a carbon tax in 2008. Motor fuels like gasoline or gas oil are not included in the tax base. Firms covered by the Swiss Emission Trading System are automatically exempted from the tax, while non-ETS firms must opt for a voluntary agreement to reduce their emissions in return for being exempted.

Australia originally planned to introduce a cap-and-trade system in 2015 as part of its Carbon Pricing Mechanism. Until then, it opted for carbon tax, starting from 2012 on. Because of its transitional nature, the design of the tax mechanism significantly departs from what is generally implemented. As of January 2013, 351 firms were covered by the scheme and about 500 of the biggest emitters are expected to be registered before the switch to the flexible price period. The current tax rate is $A24.15/$tCO_2$ (€19) and will increase by 2.5% yearly until the carbon prices are determined by the market (see Part 1 of this Chapter).

Japan also implemented a carbon tax on October 1st 2012 with a low rate, as it stands below 3€/tCO_2. The tax rate is set to rise three times over a three and a half year period. Gasoline, diesel, natural gas, coal and kerosene are part of the tax base. Both firms and households are submitted to the tax.

To conclude, it is worth mentioning the case of China. After a first proposal in 2010 to implement a 10 RMB (about €1.5) carbon tax, China's Minister of Finance recently put forth a draft regulation to tax fossil fuels in China at 20-25 RMB per tonne. It would apply to coal, oil and natural gas and could be introduced as soon as China's economy improves and inflation diminishes. Given the current state of the project, the interconnection with the emissions market is not envisaged but shall be studied.

Other countries consider establishing such a carbon tax but have not succeeded yet. One of the best examples is that of France, which failed to introduce a carbon tax in 2009, and whose rate was supposed to go from 17/tCO_2 to 100€/tCO_2 between 2010 and 2030. Debates are currently ongoing and a different taxation scheme on carbon emissions could be introduced in the coming years.

► Table 2: Tax rates for the main fuels

Country (date of introduction)	Rate (€2012/tCO_2)			
	Gasoline	**Gas oil**	**Coal**	**Natural gas**
Finland (1990)	60 (motor fuels) and 30 (heating fuels)			
Sweden (1991)	113	133	114	30
Norway (1991)	55		0	0
Denmark (1992)	22		22	20
Slovenia (1996)	10.5		12.5	10
British Columbia (2008)	22.7			
Switzerland (2008)	0		29	
Ireland (2010)	20		10	20
Japan (2012)	3			
Australia (2012)	19			

Source: OECD and National sources

The size of the tax base: from theory to practice

Two methods may be used to tax carbon emissions: applying the tax downstream, on finished products, or applying the tax upstream. This second solution involves taxing emissions through the carbon content of fossil energy sources measured at a point upstream of the production/distribution chain. This method has the advantage of being very simple to implement, since emissions from the use of each fossil energy source can be precisely known. Moreover, in most industrialized countries, there already exist energy taxation systems and therefore an administrative infrastructure that can be directly mobilized to introduce a tax on carbon emissions from energy sources. These countries have therefore widely used this upstream angle of attack when introducing a carbon tax.

In theory, a carbon tax should be levied as widely as possible in order to be effective. It should therefore apply to all emission sources (hence all fossil fuels) and to all agents: the broader the tax bases, the fewer sources of low-cost potential emissions reduction are left outside its reach and therefore the greater the reduction in the total cost to society. In addition, a comprehensive base avoids the risk of "carbon leakage" that can result from an increase in carbon emitting energy sources by agents from outside the tax base.

In practice, however, it seems difficult to apply such a base when the tax is introduced. The experience of countries which have adopted a carbon tax, reveals the existence of exemptions that have reduced the base of emissions subject to the standard rate of the tax. Often justified by the need to achieve a consensus for the introduction of the tax (especially when it involves a parliamentary vote), experience indicates that these exemptions tend to persist over time.

One justification for eroding the carbon tax base is the need to take into account the vulnerability of some economic agents. It is appropriate here to distinguish between two types of agents: households and businesses. In general, existing carbon tax schemes do not deal with households through exemption but through compensation, using traditional social transfer or tax mechanisms to cushion the negative impact of the carbon tax on the solvency of the most vulnerable. The main choice here is between general compensation and compensation targeted at the most vulnerable households. Ireland adopted compensation, which applies only to the 20% of Irish households benefiting from the allowance for energy poverty, revalued at the time of the introduction of the carbon tax.

The use of total or partial exemptions from the carbon tax for companies is, on the other hand, a relatively widespread practice in Europe. It is reflected in a rather complex array of rates differentiated by economic sector or by the type of fuel used, which is not conducive to making the carbon price signal easily

◊ Figure 5: An overview of existing carbon taxes around the world

Source: Climate Economics Chair

readable (see Table 2). Since these exemption systems can vary over time, they also affect the predictability of this price signal in the productive sector.

Apart from vulnerable agents, there can be other reasons for providing exemptions. The wish to develop certain types of energy or to facilitate the substitution of a particular energy source for another can explain why not all fossil energy sources are taxed, or why they are taxed differently (for example, biofuels are often exempted in European carbon taxation systems).

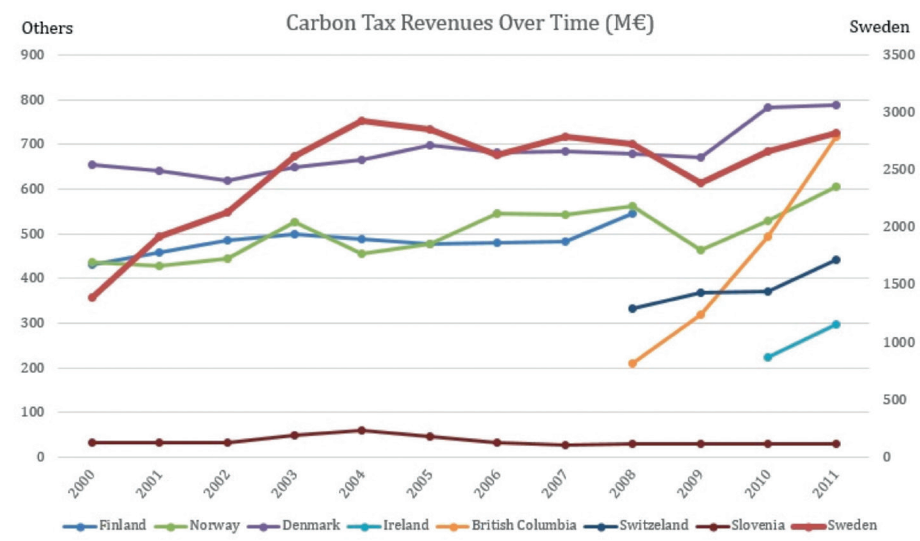
There are two further reasons for the public authorities to reduce the carbon tax base: the search for voluntary agreements and, as in Europe, the existence of an Emission Trading Scheme. Some countries provide an opportunity for industries or companies to partially or entirely avoid the tax in exchange for a voluntary reduction of emissions. This is particularly the case in Sweden and Switzerland. Swiss companies may be exempted from the tax if they agree to reduce their emissions either by measures undertaken within the company itself or by the acquisition of surplus emission rights or emission reduction certificates from other firms. If the company fails to honour its commitment, it must pay the tax plus an additional amount as a penalty. In Europe, the existence of the EU ETS has led all EU countries to introduce specific rules to allow national carbon taxes and the carbon market to coexist. With the exception of Norway, all Europeans countries decided to exempt firms under the EU ETS from carbon taxation, arguing that their emissions were already regulated.

Revenues from carbon taxes

In most countries, tax revenues generated by the carbon tax are modest (see Figure 6 below). In 2010, they represented around €500 million in each country taxing carbon, with the exception of Sweden where the state collected about €3 billion. Overall, carbon taxation in Europe produced revenues of around €5.5 billion in 2010, less than 0.005% of total government income in the countries making up the European Union. By way of comparison, the auctioning of CO_2 allowances under the EU ETS represented a sum of about €1.1 billion in 2010, and is expected to generate annual revenues of more than €5 billion annually from 2013 on.

Though modest since the early 1980s, the overall revenue from carbon taxes has however increased in Europe. First, the rising rates in most countries that have introduced carbon taxation have increased the yield from those taxes. This is particularly the case in Sweden, where the revenue from the carbon tax increased substantially between 2001 and 2005, the period during which the European CO_2 cap-and-trade scheme was being launched. Second, the overall carbon tax base has been enlarged by the arrival of new countries – first Switzerland, then Ireland (even if the tax base didn't increase in countries which have already a carbon tax).

◊ Figure 6: Evolution of the carbon tax revenues over time.



Note: The left axe represents the evolution of the revenues for all the countries that introduced a carbon tax before 2011 except Sweden. The right axe represents the evolution of carbon tax revenues in Sweden.

The use of carbon taxation revenues

The use of revenues from carbon taxation may be grouped into four types. The first two involve offsetting the carbon tax by subsequent cuts in other taxes paid by households or businesses. The third allocates this revenue to the general budget to help reduce deficits. The fourth uses the revenue to fund or encourage further actions designed to combat greenhouse gas emissions. As shown in the table below, countries have generally chosen to combine several uses, with none of them putting "all their eggs in one basket".

The respective weights of the various uses reflect different priorities arising from the great variety of economic and political contexts encountered.

Targeted or lump sum compensation for households. Such compensation may be systematic and take the form of "green cheques", as is the case in Switzerland where the same lump sum is returned to each resident. This mechanism facilitates the social acceptability of the tax but restricts other possible uses for it. That is why Ireland chose to limit household compensation by targeting it toward the 20% of the population receiving energy poverty assistance payments. The countries of northern Europe do not much use this type of explicitly household-oriented compensation. Sweden nevertheless offsets some of the cost of the carbon tax by reducing other indirect taxes paid by households, and Denmark has reduced marginal income tax rates.

Reduced fiscal contributions of labour and/or capital. This type of reduction corresponds most directly to economists' recommendations aimed at generating a "second dividend" to boost economic activity. It has been practised extensively in Sweden and Switzerland to reduce companies' overall wage bills.

Consolidation of fiscal revenues. In practice, payments to national budgets have been the primary use of revenue derived from carbon taxes in Europe. For Sweden and Ireland, this reflects the similarity of the acute economic and financial crises during which the carbon tax was introduced. In both cases, the governments concerned needed to mobilize additional public funds to make good a deficit exacerbated by the need to bail out their battered banking systems.

Funding of environmental policy. This type of use, which is generally better understood by the public, is often recommended by environmental organizations in order to put incentive systems for reducing emissions of greenhouse gases to twofold effect. It has been used relatively little in Europe, except in Denmark where 40% of revenues from the carbon tax have been allocated to the funding of emissions reduction. In Switzerland, all of the carbon tax was returned to households and businesses until 2010, but a third has been spent on financing emission reductions since 2011.

Main lessons on carbon taxes

In theory, a carbon tax is a simple and effective economic instrument for reducing CO_2 emissions. Its base should include all carbon dioxide emissions and its rate should be set so that the marginal benefit to society of emissions reduction is equal to the marginal cost of abatement. In practice, setting up such a system turns out to be much more complex. The social acceptability of the tax, the existence of imperfect information, competitiveness management, and other environmental policy measures or political lobbying are all factors that complicate the original concept.

Studying carbon taxes system over the world reveals the many economic, political and social decisions that are made during the introduction of a carbon tax. We have seen that the choice of the base, the rate and the evolution of the rate often deviate from the recommendations of economists. Several lessons can be drawn from observations of the various European initiatives.

While some exemptions in the base can be justified, they cannot be extended indefinitely because of the risk of reducing the economic efficiency of the system.

More than the choice of the initial rate – which is often a political decision – it is the evolution of the rate that determines the effectiveness of the system. This rate should rise over time and be focused on achieving the environmental goal (the Swiss method is from this standpoint very interesting).

The revenue from the tax may be put to various uses and governments generally adopt a mix between measures to compensate households, tax cuts and additional measures to finance emission reductions. The main pitfall to avoid is changing the carbon tax into a tax aimed at raising funds to augment national budgets in the long term.

4. Conclusion

When reading this Chapter one may feel quite optimistic. Since the 1990s, a number of carbon pricing initiatives have been implemented around the world. There exist today ten emission trading schemes and eight explicit carbon taxes in the world. This review shows that the integration of a certain CO_2 cost in the production processes has been experimented in many countries.

Nevertheless, even if the carbon price coverage progresses as time goes by, it still concerns only around 7% of global emissions with high discrepancies among regions and sectors. These carbon pricing initiatives are concentrated in the developed countries and still very rare in the developing world, with perhaps the exception of China, which is beginning experiments. The two major initiatives are that of Europe since 2005 (with the EU ETS) and that of the Nordic countries since the 1990s (with carbon taxes).

But this optimistic vision should not hide issues concerning carbon prices once they are established. As far as carbon markets are concerned, we see that the price generated by those markets has a tendency to decrease, because for various reasons the perceived constraint gets eroded over time. The fourth chapter of this book will enter into detail concerning this analysis. Concerning carbon taxes, they are often eroded by exemptions and the adoption of specific rates, which may hamper their overall efficiency. Quite often, their introduction is much more a way to replace other distortive taxes in a context of economic crisis than a fundamental shift towards the pricing of environmental externalities.

Nevertheless, it is impossible to jump directly from a world with no carbon constraint to a world where all emissions are capped and have a direct cost. The extension of the carbon price from the first pioneering initiatives to the generalization of pricing schemes around the world requires experimenting, making errors, and improving schemes. History will tell if the experiments presented in this chapter lead to progress in controlling carbon emissions at low cost, or if on the contrary they will eventually disappear.

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Chapter 2

Short-term emissions reductions in the electricity sector

Boris Solier

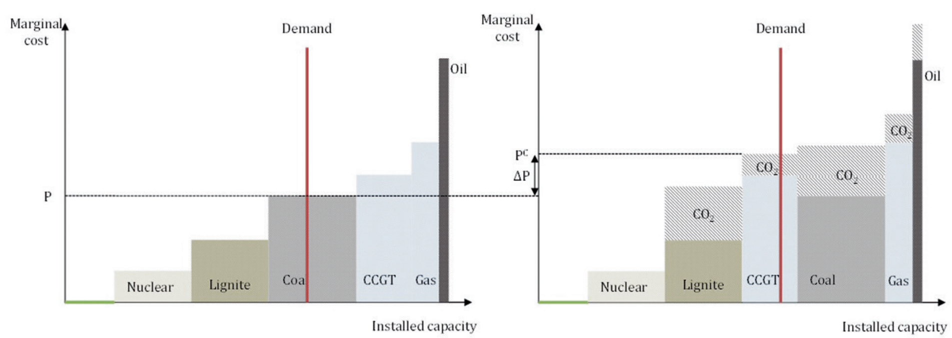
1. Introduction

The establishment of the European Union CO_2 emissions trading scheme (EU ETS) was accompanied by the emergence of a price signal for carbon emissions from electric power generators. The carbon price is an additional cost for CO_2-emitting electricity producers, which therefore include it in their economic calculations (Jouvet and Solier, 2013). According to the theory of permits markets, the carbon price induces operators to reduce emissions whose marginal abatement cost is lower than the carbon price. In the short term, the price of CO_2 can lead to substitutions, in the merit order of the electricity sector, in favour of relatively less emitting fuels. This chapter offers an ex-post evaluation of short-term emissions reductions from electricity generation over the first two periods of operation of the EU ETS (2005-2012). The analysis is conducted on the basis of the development of the Zephyr-Switch simulation model, which consists of a simplified representation of the equilibrium of short-term electricity supply and demand.

2. Determinants of abatement potential by technological substitution

By changing the marginal costs of technologies, the introduction of a carbon price is likely to lead to technological substitutions in terms of electricity production (Solier, 2011). Figure 1 shows the merit order of power generating technologies before (left-hand diagram) and after (right-hand diagram) the introduction of a carbon price. In the absence of a carbon price, for an intermediate level of demand, equilibrium in the sector is achieved by bringing on stream coal-fired plants. The equilibrium price of electricity without a carbon price (p) is therefore equal to the marginal cost of coal-fired plants. With the introduction of a carbon price, the production cost of fossil technologies increases by an amount represented by the shaded area. This amount is equal to the emission factor of the technology concerned, multiplied by the price of carbon. For an equivalent level of demand, the equilibrium of the sector is now attained by the entry into service of CCGT (combined cycle gas turbine) technology, whose marginal cost with a carbon price is lower than that of coal-fired plants. The degree of substitutability between the two technologies is primarily determined by their marginal cost of production, which depends on the relative price of energy as well as the carbon price. In the example, the output of the CCGT plant is wholly substituted for the output from the coal-fired plant, which now lies outside the merit order. Note also that for a higher level of demand, available gas capacity would have been insufficient to completely compensate for the output from coal, and the substitution would consequently have been only partial and the emissions reductions significantly smaller.

◊ Figure 1: Impact of the carbon price on the order of economic precedence



Source: Climate Economics Chair

The potential for substitution between technologies therefore also depends on the level of demand. Indeed, for the substitution to be feasible, it is necessary that production technologies which emit less are available and production capacities which emit more are being used (Ellerman, Convery and de Perthuis, 2010). Consequently, as noted by Bertrand (2012), there is greater substitution potential due to the carbon price for intermediate levels of demand. At the ends of the load curve by contrast, the possibilities of substitution are weak or non-existent.

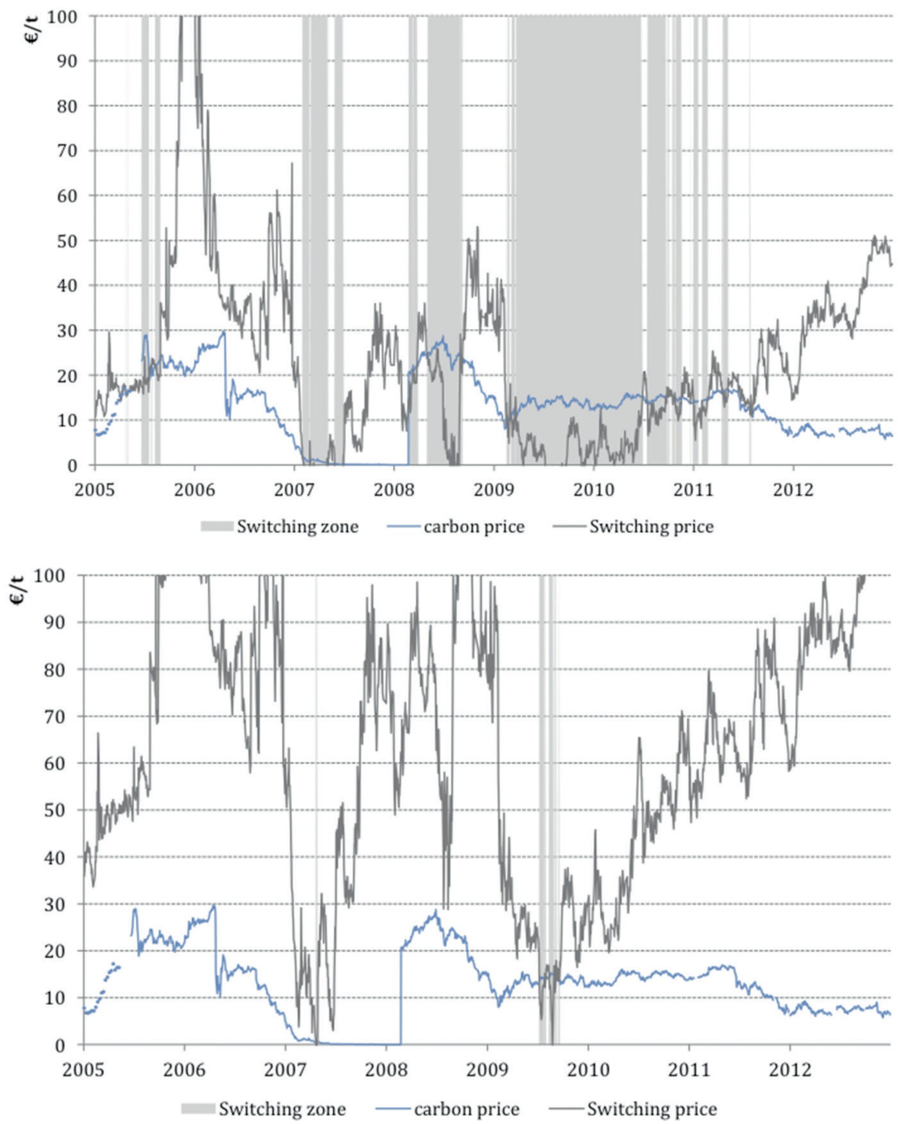
At peak periods, demand for electricity is close to the capacity available. Increased production from less emitting technology is therefore not possible. On the other hand, when demand is low, the probability of using of less emitting production capacity is relatively smaller. If there are no longer any less emitting production plants in operation, then the potential for technological substitution is zero. This is particularly the case for power systems where a significant portion of baseload demand is met by nuclear or hydro.

Similarly, the substitution potential of gas and coal will be lower during periods of the year characterized by strong demand, and vice versa. In Europe, the demand tends to peak during December or January, mainly due to heating and lighting requirements which are relatively greater than the rest of the year. Possibilities for technological substitution are therefore higher in summer than in winter. The impact of the load on the degree of substitutability between technologies therefore varies according to the available capacity of coal and natural gas, as well as the utilization and availability rates of technologies at different periods.

3. History of the abatement potential in Europe over the period 2005-2012

One measure of the potential for substitution between technologies related to the introduction of a carbon price is given by the "switching price" (Bertrand 2012; Delarue et al. 2010). This latter price determines theoretical CO_2 price allowing the marginal costs of production between two technologies to be equalized; it also measures the abatement effort associated with the substitution, in the generation mix, of coal plants by gas plants. The theoretical switching price is determined by the relative prices of gas and coal, as well as by the differences in thermal efficiency and emission factors between the technologies. Comparing the theoretical switching price and the observed carbon price shows, for a given period, the relative profitability of the technologies. When the observed price is higher than the theoretical price, operators are induced to substitute gas for coal in electricity generation. Figure 2 shows the evolution of the theoretical carbon price over the period 2005-2012, calculated from average thermal efficiency of a coal-fired plant, a gas-fired CCGT plant (left-hand figure) and a gas turbine (right-hand figure).

◊ **Figure 2: Theoretical natural coal-to-gas switching price 2005-2012**



Source: Climate Economics Chair, from Point Carbon, Bluenext, ICE and Datastream.
Note: The switching price calculations have been made assuming a thermal efficiency of 35% for coal, 51% for gas-fired CCGT (left-hand figure) and 38% for gas turbine (right-hand figure).

First, it appears that the substitution potential from coal to natural gas is relatively low during this period, when we consider the case of a gas turbine compared to a CCGT plant, taking into account the efficiency differences between the two technologies. Indeed, while the price of carbon allows the daily performance of CCGT to be at least equal to that of coal about 25% of the time over the period 2005-2012, this is the case for only 1% of observations when the reference plant is a gas turbine. Changes in natural gas prices also explain a significant proportion of the fluctuations in the theoretical switching price, because of the greater stability of coal prices. Overall, the periods in which the profitability of the CCGT plant was higher than that of the coal are relatively concentrated.

Mid-2005:

During the introduction of the EU ETS in 2005, operators had forecast an overall short position, i.e. a deficit of quotas, reflected by high levels of carbon prices (Trotignon, 2012). At the same time, the price differential between natural gas and coal remained relatively stable throughout the first half year. The two effects taken together thus increased the profitability of natural gas over coal. From the second half of 2005, the increase in gas prices, concomitant with the increase in oil prices, limited the potential for switching from coal to gas.

Early 2007:

The price of allowances had fallen by early 2007 to a level close to zero. This price drop followed the publication by the European Commission of compliance data for 2005, reporting a position of overall surplus in the market that was likely to extend throughout Phase 1 (Ellerman, Convery and De Perthuis 2010). The decline in the price of carbon was, however, more than offset by lower gas prices, which having increased significantly, then fell in the first half of 2007 to a level below that seen in 2005. Thus CCGT technology became competitive with coal, even for a carbon price level of zero.

Mid-2008:

Similarly to Phase 1, the beginning of the second commitment period of the European market was characterized by expectations that the market would be in a position of overall deficit (Trotignon, 2012). This was mainly due to the decrease of about 10% in the emissions cap in Phase 2 compared to Phase 1. This reduction in the amount of allowances particularly concerned electric power companies, whose allocations were reduced to a greater extent than the other sectors covered. Energy futures prices also fell as from July 2008, due to expectations of reduced activity related to the worsening of the financial crisis. The fall in gas prices, which was more pronounced than the fall in coal prices, gave rise to opportunities for substitution during the summer of 2008.

Early 2009 – Mid-2011:

In a context of relative economic stagnation in Europe, the carbon market was characterized by a stable equilibrium price of around €15 per tonne.

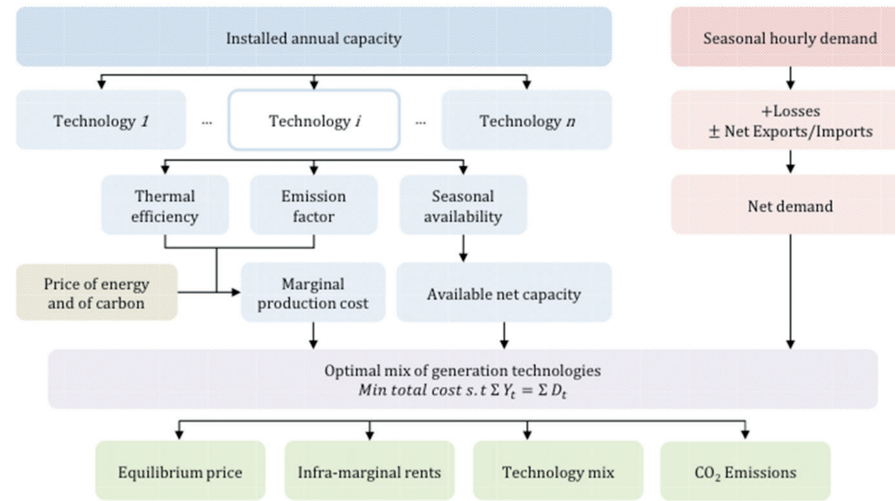
Possibilities for substitution therefore came mainly from lower gas prices, which reached their low point in mid-2009. It then became viable to substitute gas for coal even in the absence of a carbon price. The difference between the price of gas and of coal increased from 2010 as a result in the upturn in global energy demand, which exerted upward pressure on energy prices.

In short, the price of carbon most often proved to be insufficient to ensure the profitability of natural gas industry compared to coal, even when considering the case of a CCGT plant. Moreover, in some periods, the relative prices of energy made natural gas competitive with coal without requiring the use of a carbon price. Indeed, in 2007 and 2009 in particular, the theoretical switching price was less than zero. This meant that the profitability of a CCGT plant was then greater than that of a coal-fired plant, even when the carbon price was zero. Consequently the relative price of energy affects the potential abatement by technology substitution. When the theoretical switching price is negative, the transition from the business-as-usual situation (BAU), i.e. without a carbon price, to the situation with a carbon price does not result in any emissions reduction, since natural gas is already used upstream of coal in the BAU scenario.

Box 1: Representation of the electricity sector using the Zephyr-Switch model

The Zephyr-Switch model is a tool for simulating the short-term equilibrium of the power sector over the period 2005-2012. It is applied to four European countries representing more than half of 2010 installed electricity generating capacity in the EU-27 (Eurelectric, 2012): Germany, France, the United Kingdom and Poland. The annual production capacity of a given country is divided up in the model between 11 representative technologies. Within each technology, installations are considered to be homogeneous. A technology is therefore defined by a thermal conversion yield, a CO_2 emission factor and seasonal availability. The product of the nominal installed capacity and the rate of availability of a technology determine the net power available, the upper limit beyond which the technology cannot produce. The marginal production costs of the technologies are calculated on the basis of thermal efficiency coefficients, emission factors and the price of energy and carbon. For every hour of the year the model determines an optimal mix of generation technologies, taking into account the available net capacity, levels of demand and marginal production costs (Figure 3). Equilibrium in the model is reached when the cumulative production for the period equals total demand. The equilibrium price of electricity is determined endogenously in each period and corresponds to the marginal cost of the marginal technology.

Figure 3: Representation of the Zephyr-Switch model

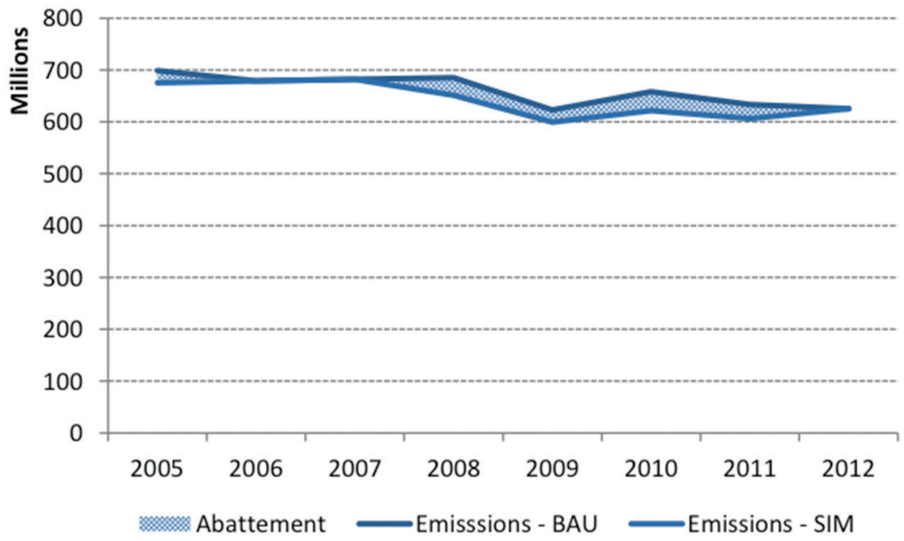


Source: Climate Economics Chair

4. Estimated abatement in phases 1 and 2 of the European market

The model provides an estimate for each period of emissions reductions in the short term induced by the carbon price. Emission reductions are estimated by comparing counterfactual emissions, from the scenario without a carbon price (BAU), to simulated emissions from observed carbon prices (SIM). Figure 4 shows the counterfactual and simulated emissions with a carbon price over the period 2005-2012 for all countries considered. The difference between the two curves, represented by the shaded area, indicates the total amount of abatement.

Figure 4: Counterfactual (BAU) and simulated (SIM) emissions 2005-2012



Source: Climate Economics Chair

It is apparent that for 2006, 2007 and 2012, the estimated emissions are identical to BAU emissions, reflecting the lack of abatement during those years. In early 2006, gas prices were high under the impact of rising oil prices. The supply-demand equilibrium in European gas markets was moreover exacerbated by low temperatures occurring during the winter of 2005-2006, as well as by the Russia-Ukraine “gas crisis” and the related risk of shortages. From April, carbon prices in the European market gradually decreased following the publication of verified emissions for 2005, which revealed a significant surplus of allowances. This decline continued until the end of the first operational period of the European market, since Phase 1 allowances could not be retained for compliance in Phase 2 (inter-period “banking” was not permitted). Thus, in 2007, the carbon price on the spot market was close to zero. The possibility of switching from coal to gas was then more the result of low gas prices than the price of carbon. In other words, gas was already used upstream of coal in electricity generation in the scenario without a carbon price. As in 2006, the lack of abatement in 2012 was due both to low carbon prices and to high natural gas prices. Indeed, since 2010, gas prices in Europe have been heading upward in response to the recovery in global economic growth. Furthermore, from mid-2011 carbon prices fell and at the end of 2012 were less than €10 per tonne. This fall in price followed the announcement by the European Commission of the implementation of the Energy Efficiency Directive, which tends to reduce expected counterfactual emissions independently of the price of carbon, the worsening debt crisis in Europe, and regulatory uncertainties surrounding the CO_2 market (Trotignon, 2012).

Table 1: Counterfactual emissions, simulated emissions and annual abatement

	2005	2006	2007	2008	2009	2010	2011	2012	Phase 1	Phase2
BAU emissions (Mt)	699	679	682	685	623	658	633	625	2,060	3,224
SIM emissions (Mt)	675	679	682	651	599	622	606	625	2,037	3,104
Abatement (Mt)	23	0	0	34	24	36	27	0	23	121
Abatement (%E^{BAU})	3%	0%	0%	5%	4%	5%	4%	0%	1%	4%

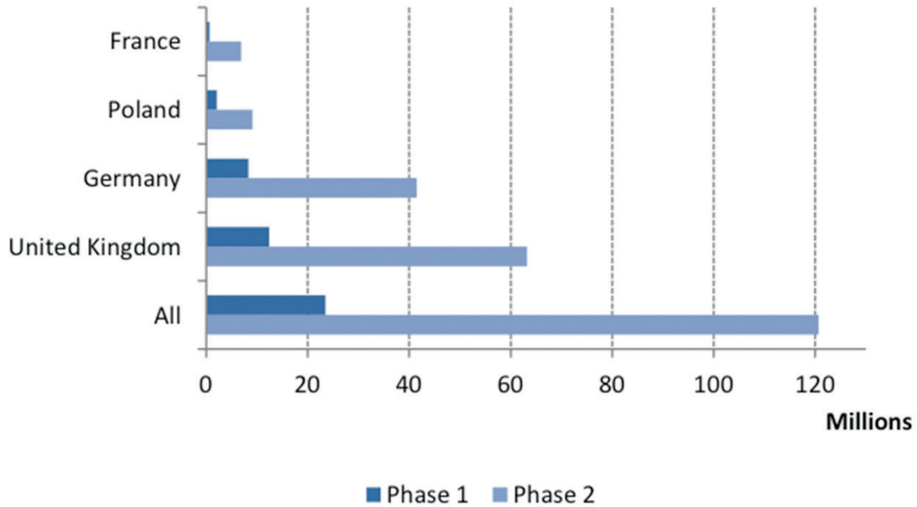
Source: Climate Economics Chair

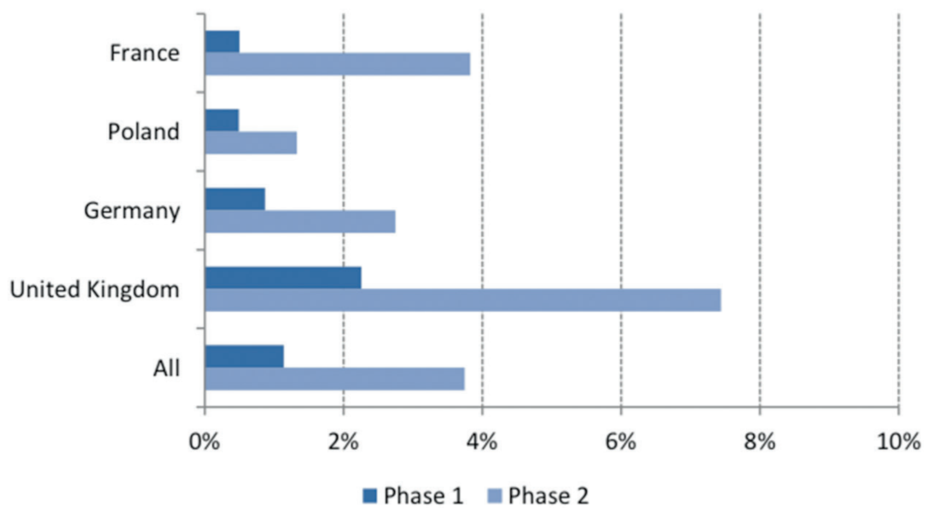
In total, the estimated reductions range from 23 to 36 Mt CO_2 per year, or about 3% to 5% of the corresponding counterfactual emissions (Table 1). 2008 and 2010 reveal the largest total abatement, due to relatively more numerous opportunities for substitution. The reductions are lowest in 2005, when the gas-for-coal substitution was economically feasible only for part of the year, and in 2009 when the theoretical substitution price was negative for a significant proportion of the year, due to low natural gas prices. Overall, emission reductions were proportionally greater in the second phase of the European market, but they still remained relatively low.

5. Geographical distribution of abatement

The characteristics of supply and demand, and in particular the composition of the technology mix, the thermal efficiencies of the installations and hourly demand levels, influence the potential for technology substitution and subsequent emissions reductions. Consequently the estimated reductions differ from one country to another because of differences in the structure of power systems. Figure 5 shows the breakdown between countries of the total absolute (left-hand figure) and relative reductions (as a percentage of counterfactual emissions, right-hand figure) in Phases 1 and 2 of the European market.

Figure 5: Geographical breakdown of absolute and relative abatement in Phases 1 and 2





Source: Climate Economics Chair

Reductions, both absolute and relative, are consistently higher in the United Kingdom and Germany than in France and Poland. As established by Delarue et al. (2010), this discrepancy is explained by the fact that the electricity generation capacities from natural gas are relatively greater in the UK and Germany. In particular, the United Kingdom, most of whose natural gas plants are CCGT, has the highest abatement levels. In Germany, coal-to-CCGT substitutions are more limited than in the United Kingdom because lignite and gas turbines, which are substitutable at relatively high carbon price levels, account respectively for 40% of installed coal capacity and a third of natural gas capacity. By contrast, in France and Poland, the proportion of natural gas in the technology mix is low, and this results in relatively low abatement levels. Moreover, in France, the bulk of production, i.e. about 85% (RTE, 2012), is provided by non-CO_2-emitting plants, which significantly limits the possibilities for substitution. Hence, baseload demand and a proportion of off-peak demand are more often likely to be covered by nuclear and hydro rather than coal. In Poland, on the other hand, coal accounts for 90% of electricity production (Eurelectric, 2012), and relative abatement rates are therefore the lowest of the countries making up the sample group.

6. Conclusion

The carbon price in the European market has encouraged operators to substitute gas for coal in electricity generation. Emissions reductions associated with fuel substitution amount to some 3-5% of the emissions that would have occurred in the absence of a carbon price. The amount of emission reduction differs among countries according to specificities of electricity systems. Overall, emissions reductions were greater in United Kingdom and Germany, which have the largest installed gas-fired capacities in Europe. That said, the end of Phase 2 of the European market has been marked by a lack of abatement in the electricity sector. For the trend of rising gas prices and lower carbon prices observed since mid-2011 has significantly limited the potential for switching from coal to gas in Europe. In the short term, the continuation of this situation is likely to support the price of carbon in Phase 3.

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Chapter 3

Free allocation benchmarks in phase 3 of the EU ETS

Stephen Lecourt

1. Introduction

The European Union Emissions Trading Scheme, the world's largest emissions allowances cap-and-trade market (Ellerman & Buchner, 2007), has undergone a radical change in Phase 3 (2013-20). Allocation methodology has shifted from grandfathering to a combination of auction-based allocation and free allocation now taking place within the framework of Community-wide rules. Broadly speaking, electricity generators are not to be allocated free European Union Allowances except for activities other than the production of electricity; free allocation, based on benchmarking, now applies mainly to non-electricity generators and is transitional. Non-electricity generators will receive a decreasing amount of free allowances throughout the phase, with a target of no free allocation by 2027, as stated in Article 10a(11) of the Consolidated ETS Directive (EC, 2009). Consequently, Phase 3 inaugurates a new market configuration where the value of emission permits is redistributed among market participants and public authorities: allowance auctioning is progressively becoming the allocation standard, and both primary and secondary emission permit markets now coexist.

The shift from free allocation to auctions has been adopted as the main change in allowance allocation. In fact, the allowances to be auctioned in Phase 3 are those that will not be allocated free of charge. Transitional free allocation associated with the move from grandfathering to Community-wide rules therefore merits special attention. This chapter thus focuses on transitional free allocation associated with the move from grandfathering to benchmarking.

2. Two implications of switching to benchmarking

The introduction of benchmarks in Phase 3 of the EU ETS aims at addressing the main two drawbacks of grandfathering: first, the paradox of the largest polluters being treated the same way as the smallest, by now basing free allocation partly on CO_2 emission intensity (the amount of emitted CO_2 emissions per unit of output); second, sectoral distortion involved in National Allocation Plans – that were used during two phases of the EU ETS – by establishing harmonized EU-wide rules for transitional free allocation (EC, 2009). Indeed benchmark-based allocation involves a reduction associated with a redistribution of allocations among installations in the same sector. The extent of this redistribution is further affected by the EU-wide rule that limits the total annual amount of free emission permits to be allocated.

Allocation is reduced and redistributed

Benchmarks have involved a downward momentum in allocation levels, as most installations are less efficient than benchmark values. For those that are more efficient, the increase in allocation levels compared to Phase 2 leads to "allocation redistribution". The analysis of France's National Implementation Measures (NIM) provides a concrete illustration of these two phenomena with regard to manufacturing industries.

At the aggregated sectoral level, manufacturing industries have a fairly homogeneous allocation variation rate, similar to that of the manufacturing sector as a whole – except the pulp and paper industry which has a smaller allocation reduction and oil refining and glass with a larger one. Moreover, most of the manufacturing sector's allocation decline (in EUAs) occurs in three sectors: other non-metallic mineral products, basic metals and oil refining (Table 1).

► Table 1: Sectoral allocation variation from Phase 2 to 2013 (in kEUAs)[3]

	Avg Phase 2 allocation	2013 allocation	Net variation	%
Manufacturing	88,417	75,034	-13,382	-15
Food	4,799[4]	3,965	-834	-17
Pulp and paper	3,942	3,852	-90	-2
Other non-metallic minerals	23,808	20,253	-3,554	-15
Cement	15,372	13,394	-1,978	-13
Lime	3,368	2,967	-401	-12
Glass	3,778	2,865	-912	-24
Basic metals	26,385	23,738	-2,647	-10
Iron and steel	26,156	23,382	-2,774	-11
Oil Refining	16,403	11,262	-5,142	-31

Source: Author's calculation based on France's NIM and CITL data

3 The allocation variation is determined by comparing average Phase 2 allocations with the 2013 allocation level.

4 Figures are rounded.

Allocation redistribution entailed by benchmarks is assessed by focusing on variations at installation level. Although the net variation is negative for the aggregated manufacturing sector as well as the subsectors shown in Table 1, it results in a combination of allocation increases and reductions: the situation for each installation can differ significantly from the overall sectoral picture depending on its location on the CO_2 intensity curve relative to the benchmark value, as illustrated in (Pauer, 2012).

In the case of the French NIM, it can be observed that allocation increases are marginal and that total reductions are thus very close to sectoral net allocation variations (Table 2). This is in line with the way product benchmarks have been defined: a given product benchmark corresponds to the average CO_2 intensity of the 10% best performing installations, for the production of the benchmarked product in question. Consequently, only installations that are more efficient than benchmarks have an increase in their allocation.

► Table 2: Sectoral allocation variation from Phase 2 to 2013 (in kEUAs) decomposition at the installation level

	Number of installations	Total reduction	Total addition	Min	Max	Median	Average
Manufacturing	516	-17,731	4,267	-1,706	439	-7	-26
Food	109	-1,168	334	-193	68	-5	-8
Pulp and paper	91	-1,341	1,250	-310	341	-4	-1
Other non-metallic minerals	149	-3,689	135	-222	21	-12	-24
Cement	30	-1,987	9	-222	9	-49	-66
Lime	20	-450	49	-85	16	-11	-20
Glass	46	-926	6	-92	6	-15	-20
Basic metals	26	-2,826	178	-1,706	21	-12	-101
Iron and steel	24	-2826	51	-1,706	49	12	-116
Oil Refining	13	-5,184	42	-1,273	42	-162	-395

Source: Author's calculation based on France's NIM and CITL data

The pulp and paper industry stands out, as the net reduction of 90 kEUAs from Phase 2 to 2013 masks a similar larger reduction and increased allocation (1,341 kEUAs and 1,250 kEUAs respectively). Although several product benchmarks are used in the pulp and paper industry[5] (involving allocation redistribution based on installations' performances relative to these product benchmarks), the main factor accounting for this remarkable redistribution pattern is the rule change in the allocation for emissions related to heat exchanges, which is concomitant to the introduction of benchmarks in Phase 3. Under this new rule (as part of the transitional Community-wide rules in Phase 3), free allocation is now given to heat producers under specific circumstances only and, as a general rule, allowances are allocated to heat consumers to ensure that the amount they receive is independent from the heat supply structure (EC, 2011c). Therefore high heat consumer industries such as pulp and paper include some installations whose average Phase 2 allocation is several times greater in 2013.

Preliminary NIM amounts can be further reduced by adjustment factors

Harmonizing transitional free allocation rules in Phase 3 requires the amount of allowances allocated free of charge now to be annually capped at EU rather than national level. Preliminary Amounts (PAs) are determined at the installation level based on benchmarks, without consideration of any cap. As such, should their sum exceed the annual maximum amount of allowances allocated free of charge, PAs will be applied with an annual Cross-Sectional Correction Factor (CSCF) to bring their total amount back to the annual cap, which will further accentuate the aggregated allocation reduction observed.

The independence of the definitions of annual maximum amounts and of PAs implies that PAs of all Member States must be known in order to determine the final free allocation. In other words, an installation's allocation final entitlement depends on that of all other installations. As of January 2013, all required NIM have been submitted to the EC and are currently under assessment. The requirement for CSCFs and their potential magnitudes have thus not yet been determined. Annual maximum amounts have not been made public either[6].

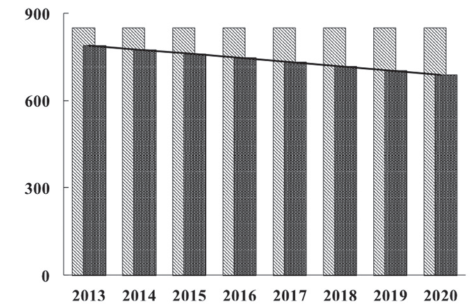
Annual CSCF is determined by comparing the sum of PAs of non-electricity generators of Member States to the corresponding annual maximum amount. Since the sum of PAs is constant and the annual maximum amounts are decreasing the likelihood of the former exceeding the latter increases with time. Three scenarios for CSCFs, affecting the amount of free allowances to be allocated over Phase 3, can thus be elaborated (Figure 1).

5 See all 53 defined benchmarks in Annex I of (EC, 2011a)

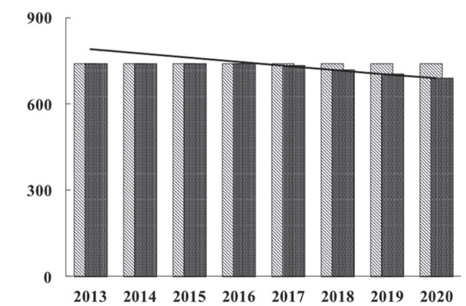
6 See (Lecourt, 2013) for an estimation of the annual maximum amounts of transitional free allocation and of annual CSCFs.

Figure 1: Cross Sectional Correction Factor scenarios over Phase 3

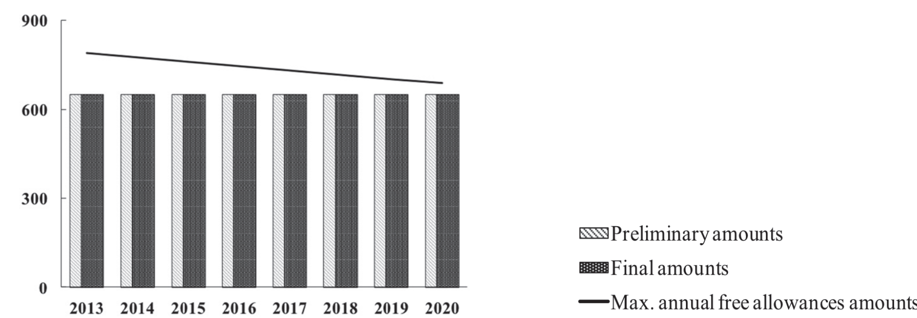
Scenario 1



Scenario 2



Scenario 3



Source: Author calculation based on (EC, 2011a)

The sum of PAs exceeds the annual maximum amount as soon as 2013. An annual CSCF is applied throughout Phase 3. The sum of PAs exceeds the annual maximum amount at a later stage. An annual CSCF applies from this date only. The sum of PAs is below the upper limit throughout Phase 3. No CSCF is applied.

Scenarios 2 and 3 clearly show that annual maximum amounts may possibly not be allocated in their entirety. Should CSCFs be defined and applied from 2013 (as in Scenario 1), it would mean that the overall Phase 3 free allocation cap is independent of benchmarks, i.e. that the current purpose of benchmarks is to redistribute free allowances among market participants, which is consistent with their stated aims in the consolidated EU ETS Directive of "(...) avoid[ing] distortions in the internal market (...)" and "ensur[ing] that allocation takes place in a manner that provides incentives for reductions in greenhouse gas emissions (...)".

3. Two potential flaws of implemented benchmarking

Although benchmarks target installations with higher efficiency, the "historical dimension" that has been criticized in grandfathering will remain in Phase 3 with the use of historical activity levels (HALs) in the determination of PAs. This becomes more obvious in a context of economic downturn. Furthermore, the transitional character of free allocation in Phase 3 may be challenged by the provision for installations deemed at risk of carbon leakage, for which free allocation remains constant over Phase 3.

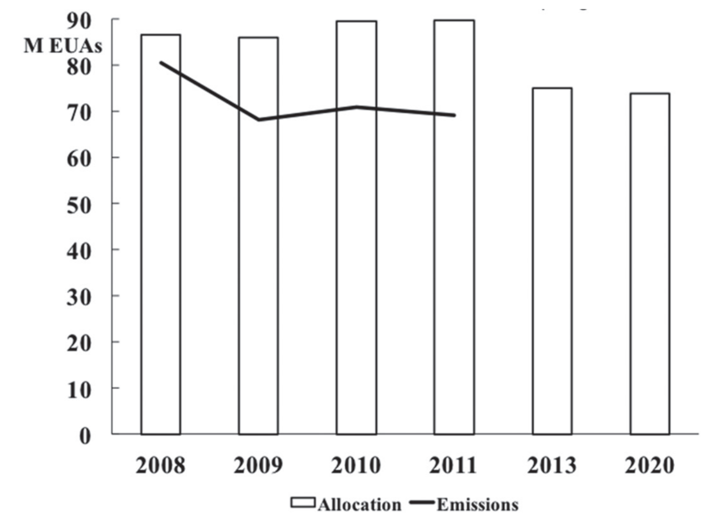
A certain type of grandfathering remains

As mentioned in section 2 of this chapter, the level of PAs, derived from the benchmarking methodology, is *partly* based of CO_2 emissions intensity. Where allocation was directly derived from the historical emissions level under grandfathering, an installation's PA is derived from its HAL[7] multiplied by the benchmark value[8]: the preliminary amount will be proportionate to the installation's output level of a past reference period, as was the case with grandfathering. *Therefore benchmarking perpetuates the practice of grandfathering, but now associated with the production level rather than the emissions level.*

7 HAL is defined as the highest production level median between the 2005-08 and 2009-10 periods.

8 i.e. in the simple and specific case where the installation in question only produces a product for which a product benchmark exists.

Figure 2: Verified CO_2 emissions vs. allocation levels in Phases 2 and 3 for the French manufacturing sector



Source: France's NIM and CITL data

All other things being equal (production levels identical to HALs, physical capital, carbon price feedback, etc.), benchmark-based allocation has led to the expectation that most non-electricity installations (and thus the non-electricity aggregate) will be allocated fewer free allowances than the emissions corresponding to their activity levels (due to most installations having CO_2 intensities above benchmark values). However, the economic recession has strongly affected EU activity levels since 2008, making current levels lower than those from which HALs were defined. *As a consequence, the manufacturing sector will receive in the early years of Phase 3, depending on the economic recovery, a greater share of its emissions in free allowances than if the economic recession had not occurred.* Figure 2 provides an illustration of this for the French manufacturing sector, whose aggregated emissions level is below its 2013 free allocation amount.

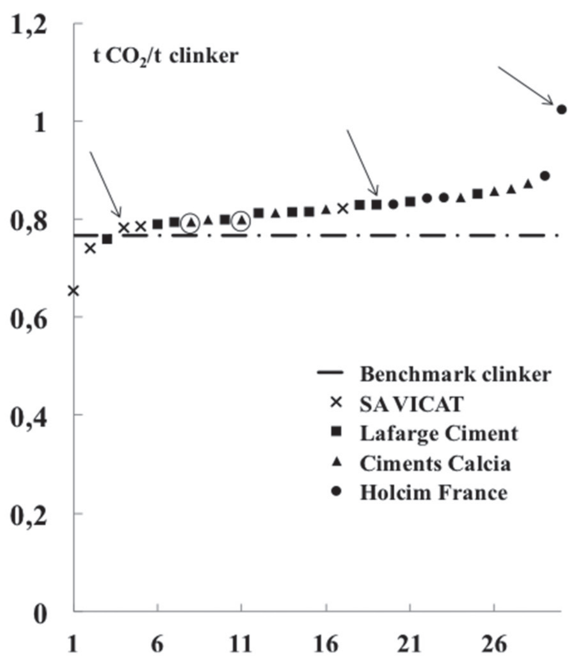
At the installation level, it can even be observed that installations with larger CO_2 emission intensity than benchmarks receive more allowances than their current emission levels, as illustrated in the case of French cement-producing installations (Figure 3). Firstly their CO_2 intensities were determined (Equation 1), so they could be compared to the grey clinker product benchmark value.

$$i_{Clinker} = \frac{Em_{Ref}}{PA} \times BM_{GreyClinker}$$

Where $i^{Clinker}$ is the installation's CO_2 intensity and Em^{Ref} its HAL corresponding to the level of CO_2 emissions[9].

Next, their PAs were compared to their 2011 emission levels. This comparison exercise shows that about two thirds (17 out of 27) of cement-producing installations above the grey clinker benchmark value (except non-circled Ciments Calcia and the three arrowed installations) hold allocation amounts above their 2011 emission levels.

Figure 3: Distribution of EU ETS cement installations by CO_2 intensity



Source: Author calculation based on France's NIM and CITL data

The transitional aspect of Phase 3 free allocation in question

Full auctioning of allowances should be the rule in 2027 (EC, 2011a). In order to reach this objective an annual carbon leakage exposure factor (CLEF) is applied to the manufacturing installations' PAs. CLEF linearly decreases from 0.8 in 2013 to 0.3 in 2020 and should continue to a value of 0 in 2027 (Table 3) in accordance with the Commission Decision on benchmarking (EC, 2011a).

9 These HAL corresponding emissions levels have been defined as the highest of the two emission level medians over the 2005-08 and 2009-10 periods.

Table 3: Factor ensuring the transitional character of free allocation in Phase 3

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
%	80	73	66	59	51	44	37	30	26	21	17	13	9	4	0

Source: Annex VI of (EC, 2011a) up to 2020 inclusive, author's estimation from 2021

However, a provision has been introduced to exempt from the application of the annual CLEF installations belonging to certain sectors and subsectors deemed to be exposed to a significant risk of carbon leakage[10]. Such installations are instead given a CLEF equal to 1 each year of Phase 3, which means that their annual allocation entitlement stays constant and equal to their PA (in the absence of any application of CSCFs).

Therefore the underlying questions are: How will these allocation amounts, not subject to transitional free allocation, be taken care of in 2021? And how will the "carbon leakage exposure" provision be reconciled with the target of no free allocation in 2027? These questions are all the more relevant since, based on the French NIM, most free allocation in the manufacturing sector is related to installations considered at risk of carbon leakage, that is, a large proportion of 2013 free allocation will still be allocated free of charge in 2020 (Table 4). As a result, the total preliminary amount in 2013 decreases by 1.4% in 2020 only, as opposed to the widespread expectation of a 63% decrease in free allocation throughout Phase 3[11]. So far, no indication has been given, either in the EU ETS Directive or the benchmarking Decision, about the outcome of carbon leakage free allocation when Phase 3 ends, or in 2027 where no free allocation is targeted.

Table 4: Allocation to installations at risk of carbon leakage in the French manufacturing sector

Manufacturing sector free allocation	2013 (kEUAs)	2020 (kEUAs)	2013 (%)	2020 (%)
Total	75,034	73,976	100	100
At risk of carbon leakage	73,342	73,342	98	99
Transitional	1,693	635	2	1

Source: Author's calculation based on France's NIM

10 The EC has defined a list of products which are deemed at risk of carbon leakage (EC, 2011b). The current list runs through 2014 included (subject to sector additions). A new carbon leakage list will be defined for the 2015-19 period. Until then, no sector can be removed from the current list. More information on the methodology for drawing up the carbon leakage list is provided at http://ec.europa.eu/clima/policies/ets/leakage/index_en.htm

11 This 63% decrease in free allocation corresponds to the reduction that would have

4. Conclusion

Phase 3 of the EU ETS will start on new allowance allocation grounds, since auction is supposed to become the basic principle for allocation. Nevertheless, transitional free allocation remains for non-electricity generators (most of them in manufacturing industries), and allocation based on benchmarking will replace grandfathering, thus targeting the most efficient installations as opposed to the largest emitters. Two main implications of this shift to benchmarks have been identified: first, free allowances will be redistributed among installations, as benchmark outperforming installations should see their entitlement increase and less efficient installations see the largest declines; second, an installation's final free allocation amounts will depend on those of all the other installations.

Two features of the benchmarks' design were also identified that could call into question the effectiveness of the newly introduced and complex allocation system. First, the continuing use of historical reference levels (now of production rather than emissions) for the determination of the allocation amount, highlighted by the economic recession, suggests that the criticisms (e.g. over-allocation) of grandfathering in the Scheme's first two Phases have only partly been addressed with benchmarks, a situation that contributes to the discussion around *ex ante* versus *ex post* allocation. Second, the provision for installations that are considered exposed to carbon leakage, which consists in keeping their free allocation entitlement constant throughout Phase 3, significantly reduces the transitional character of free allocation. The ways in which these large free amounts, carried over from 2013 to 2020, are dealt with up to 2027, where zero free allocation is targeted, has not yet been addressed in official documents.

Finally, although benchmarks are challenging, as they represent current 2007-08 best practices in Europe, they will still be used until 2020. It may be wondered whether historical business-as-usual CO_2 intensity improvements will not lead to the outperforming of benchmarks before 2020.

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occurred from 2013 to 2020 if the "carbon leakage exposure" provision had not been introduced. In such a case, free allocation would have fallen from 80% of PAs in 2013 to 30% of PAs in 2020, equivalent to a 63% reduction.

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6. Definitions of acronyms and technical terms

Annual maximum amount. Maximum amount of free allowances to be annually allocated. It corresponds to the annual "cap" of free allowances. However, it may not be allocated in its entirety since the annual amount of free allowances that will be allocated is the minimum between the annual maximum amount and the sum of preliminary amounts. The methodology to determine these annual amounts is defined in Article 10a of the consolidated EU ETS Directive.

CLEF (Carbon Leakage Exposure Factor). Annual factor that is applied to preliminary amounts. It ranges from 0.8 in 2013 and linearly decreases to 0.3 in 2020. It is used to make Phase 3 free allocation transitional. This factor is equal to one every year of Phase 3 for preliminary amounts of installations considered at risk of carbon leakage (i.e. free allocation is constant for these in Phase 3).

CSCF (Cross Sectional Correction Factor). Annual factor, applied to preliminary amounts, which ensures that the amount of free allowances to be allocated in a given year is below the maximum amount of the corresponding year.

HAL (Historical Activity Level). Reference that is used, in combination with benchmarks, to determine preliminary amounts. It is defined as the highest activity level median between the periods 2005-08 and 2009-10.

NIM (National Implementation Measures). National document that contains, inter alia, the preliminary amounts of installations participating in Phase 3. This document had to be submitted to the European Commission for assessment.

PA (Preliminary Amount). Amount of free allocation for an installation participating in Phase 3, derived from benchmarks and historical activity levels (HALs). It serves as the basis for an installation's free allocation over Phase 3. It is named preliminary since it may be modified (e.g. application of cross-sectional correction factor, carbon leakage exposure factor) as required by the European Commission, before becoming the final amount.

Chapter 4

Governance of CO2 markets: lessons from the EU ETS

Christian de Perthuis and Raphael Trotignon

1. Introduction

The economic literature differentiates “command and control” policies, in which the public authority sets up standards and rules to directly reduce environmental damage, from policies based on “economic tools” aiming at internalizing the cost of environmental damage. There is a broad consensus among economists in favour of economic tools that aim at protecting the environment in the most efficient way, i.e. by minimizing the total cost of pollution abatement. Despite those recommendations, most of the environmental policies implemented in the real world continue to favour command and control policies.

There are two ways of introducing these economic instruments: price-based regulation and quantity-based regulation. The case of the European Union Emission Trading Scheme (EU ETS) provides the most complete experience to date of carbon pricing through a quantitative tool, a cap-and-trade system. Covering more than 12,000 industrial installations in 30 European countries, responsible for almost half of European CO_2, it came into force in 2005 to facilitate the attainment by European Member States of the targets set by the Kyoto Protocol for the period 2008-12. The rules are set up in the EU ETS directive (see European Parliament and the Council of the EU, 2003). The launch of this instrument and its functioning during the first trading period (2005-07) has been analysed by Ellerman et al. (2010), who view this experience as a major innovation in the field of climate policies, that could inspire the development of other schemes elsewhere in the world.

However, since the publication of this first *ex post* evaluation, the EU ETS has faced new challenges: the unexpected economic recession greatly affected the industries under the cap and contributed to a reduction in their CO_2 emissions; the market was hit in 2008 and 2009 by large-scale frauds that affected its reputation; and the possibility of using offsets reduced the stringency of the cap defined for the second trading period, which ended with a carbon price collapse. At the current price, less than 5 euros per tonne of CO_2, most observers believe that the EU ETS does not provide the right incentives for reducing emissions both in the short and long term. This shortcoming raises the issue of the rules that should govern the market.

Since the end of 2011, the EU ETS has been subject to this debate. In July 2012, the European Commission made a proposal aimed at reducing the supply of allowances in the market between 2013 and 2015 (European Commission, 2012a). In December 2012 the European Commission published a report on the state of the European carbon market, which outlines options for structural reform of the EU ETS (European Commission, 2012b).

This chapter seeks to make a contribution to this debate. Contrary to most views, it does not assume that the current price on the EU ETS is "too low" because of an existing "surplus" of allowances on the market. The EU ETS inherently aims to minimize the cost of reaching a certain predefined emission target. The carbon price has a major role to play in influencing the decisions of economic players both in the short-term management of their existing assets and in the longer term orientation of their investments. The economic efficiency of the policy is thus dependent on the capacity of EU ETS to establish rules that will modify the short-term behaviour of agents as well as their investment decisions, which requires changing their medium to long-term expectations. The main implication of the choice of quantitative instruments is that the price associated with carbon emissions will not be set by the authority but will be revealed through the market. It will reflect the current and anticipated scarcity of emission allowances, so that economic efficiency relies not on a subjective desirable price level but on actors' anticipations of the medium to long-term emission constraint, and particularly how these expectations evolve over time. This consideration leads us to recommend very different measures than the "backloading" or the so-called "structural measures" proposed by the European Commission for reviving the European carbon market.

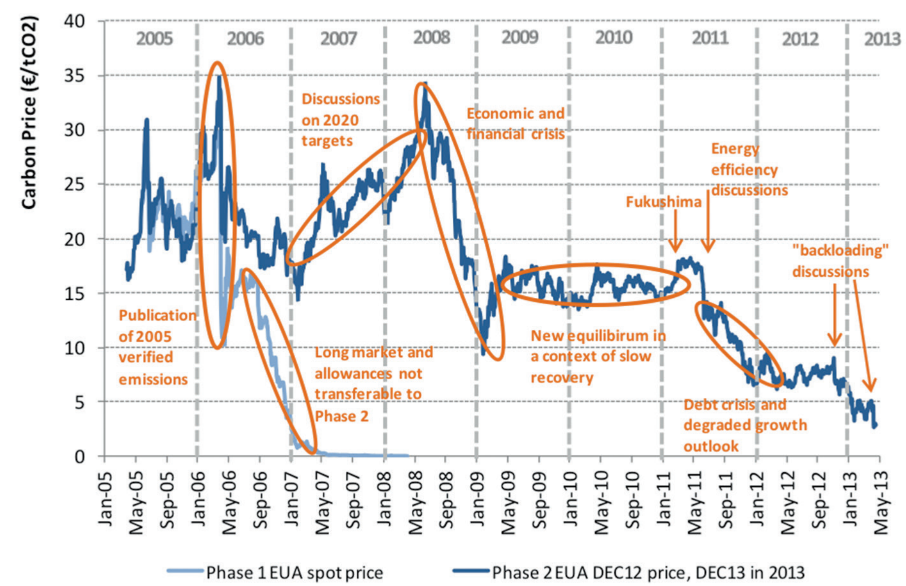
In the first section, we identify the three major causes of the current shortcomings of the EU ETS, and among these distinguish economic influences from the effects of other structural factors. In section 2 we analyse the key role of anticipations in a cap-and-trade system by comparing the past expectations to how the EU ETS has in fact evolved. In section 3 we use our EU ETS simulation model ZEPHYR to examine the options for structural reform made by the European Commission. None of these options appears to completely remedy the previously identified issues. Section 4 tries to build on these lessons and proposes improving the current governance framework by creating an Independent Carbon Market Authority (ICMA), whose mandate would allow participants to establish sound expectations over time. The final section concludes by specifying the general lessons that can be drawn from the EU ETS case.

2. The three causes of current market weaknesses

Most observers (as well as the European Commission in its report on the state of the carbon market) attribute the current weakness of the EU ETS to the economic crisis that markedly affected industrial output and led to a "surplus" of allowances. As we shall see in this section, this observation is incomplete and does not allow the correct lessons to be drawn from the functioning of the market and thus adequate recommendations to be proposed.

There are three main reasons for the current malfunctioning of the market (see the observed EUA price in Figure 2 below). The first is the unforeseen decline in industrial activity since the 2008 crisis, together with future prospects that are perceived as unfavourable. The second is the high use of carbon offsets over a short period of time resulting from the unforeseen evolution of the international Kyoto system in conjunction with the time-flexibility left to participants for using offsets. The third reason concerns the interactions between the allowance system and other energy and climate policies, mainly renewable energy and energy efficiency policies, which can drive EU ETS emissions down independently of the EUA price.

◊ Figure 1: Observed EUA price since 2005



Source: authors and CITL, 2013

The first reason concerns the adverse economic conditions, which strongly influenced changing expectations in the course of Phase 2, both in the short term (production decrease) and the longer term (diminished growth outlook). Between 2008 and 2009, production levels in the sectors covered by the EU ETS fell on average by 10%, with larger decreases in industrial sectors such as cement and steel. But ultimately this influence of economic conditions on the price is desirable. Part of the economic efficiency of a cap-and-trade system comes from this flexibility, which reduces the price if economic conditions deteriorate, with the cap remaining unchanged.

As well as this desirable influence, the system suffered from unwanted weaknesses that arose for structural reasons. The effects on the market for other climate and energy policies (energy efficiency, renewable energy) and the unforeseen use of carbon credits over time, resulted in greatly decreased demand for EUAs in the market in the short term, as well as blurred expectations in the long term.

Weigt et al. (2012) consider the effect of renewable energy support in Germany to be responsible for a reduction of 10% to 16% in the German electricity sector's emissions. Similarly, energy efficiency policies can reduce the demand for electricity generated by sectors covered by the EU ETS, thus entailing emission reductions independently of the carbon price. If these structural weaknesses are not controlled in some way, the process of increasing interaction will automatically lead to the marginalization of the ETS, because the emissions base of the system will be eroded by other policies. The fact that both the environmental and economic effectiveness of cap-and-trade systems can be significantly compromised by interactions with other regulations is crucial, and has been identified by Goulder (2013) as a key element for the implementation of cap-and-trade systems. It is much harder for participants to acquire sound expectations for the future in a situation of uncontrolled policy super-imposition.

As far as the market is concerned, there is only one cap that ultimately matters, namely the total domestic cap plus the allowed offsets over the period. The rules for using offsets in the EU ETS set the amount that could be used over 2008-12 at approximately 1,400 Mt. This limit was then extended to around 1,600 Mt over 2008-20 when the Climate Energy Package was passed (see European Parliament and the Council of the EU, 2009). This provision leaves most participants free to decide the timing at which offsets will be used (the right to use offsets can be banked to later years). Between 2008 and 2009, around 80 million offsets per year were used in the EU ETS (Trotignon, 2012a). But in 2010, the European Commission announced qualitative restrictions on certain offset types that covered most existing offsets, stating that the restriction would apply only from 2013 onward (Hedegaard, 2010). As a result and in anticipation of this future restriction, the use of these offsets surged over the remainder of Phase 2, giving rise to a cumulative amount of around 900 Mt over five years. The price of these widely available offsets dropped to less than €1/t, allowing participants to comply with the ETS constraint at very low cost, because of the unforeseen evolution of the Kyoto trading system. It was initially thought that Europe would not be the only buyer of offsets, but no other large-scale source of demand ever emerged.

The lesson to be drawn is that if the domestic cap remains unaltered but the authorized use of offsets over time is changed, this is strictly equivalent to changing the cap. If the public authority leaves too much flexibility for using offsets, then the anticipations of the future constraint over time can become blurred, and the public authority can lose part of its sovereignty in deciding the reduction effort that will be effective domestically over a given period. In proposals for cap-and-trade programmes outside of Europe, this uncertainty has been accounted for by measures such as conversion rates between offsets and allowances or the price threshold above which more offsets are allowed in the system (an option discussed in RGGI, for example).

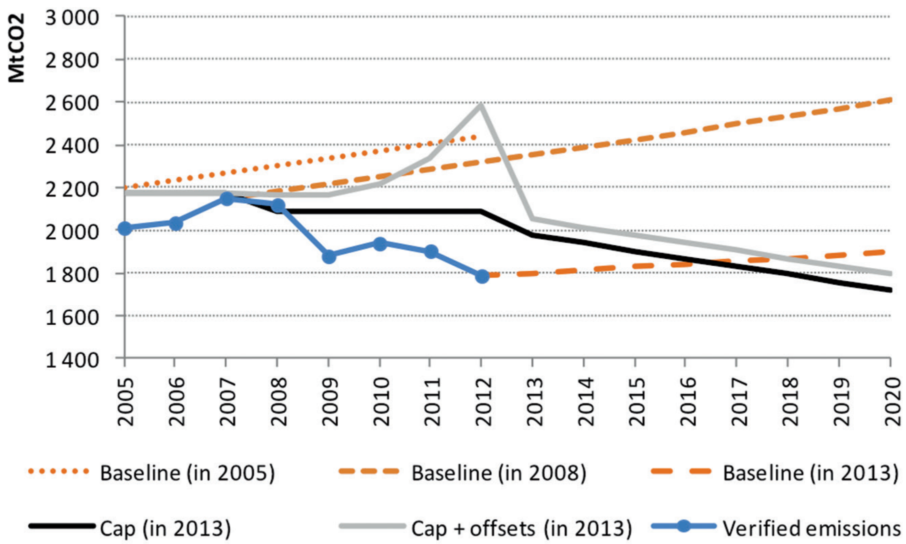
Needless to say, a cap-and-trade system alone cannot do everything, and other targeted policies are probably needed to support specific goals, which will have an impact on EU ETS emissions. Consequently there will be interactions between the EU ETS and other policies, such as European climate energy policies as well as unilateral national policies. The United Kingdom's tax on the electricity sector's emissions is a good example (see United Kingdom HM Revenue and Customs, 2013). If such measures are taken individually by Member States, the economic efficiency of the EU ETS will suffer, because the advantage of having a uniform CO_2 price diminishes when individual countries or sectors "force" a carbon price that is higher than the market price.

The three causes identified in this section can be better understood by looking at how they have impacted participants' expectations over time. This is the subject of the next section.

3. Expectations tend to overestimate the constraint and ignore future uncertainty

In a cap-and-trade system with unlimited banking (where participants can hold unused allowances for later use) the allowance price depends on the current and anticipated scarcity of emission allowances. This perceived constraint associated with the cap can be measured *ex ante* as the difference between business-as-usual emissions of the sectors covered and the allowance cap, over the same period. Figure 1 below shows, for the EU ETS, how those expectations evolved between the beginning of Phase 1 (in 2005), the beginning of Phase 2 (2008) and the beginning of Phase 3 (in 2013). For these calculations, we assume an elasticity of baseline emissions to growth of 0.5, and GDP scenarios of 3%/yr (in 2005 and 2008) and 1.5%/yr in 2013 (from Trotignon, 2012b).

Figure 2: EU ETS ex ante anticipations compared to ex-post observations



Source: authors and CITL, 2013

2005 was the first year of EU ETS, Phase 1 (2005-2007) being a trial period. At that time, very little information was available on the emissions of covered installations, as well on the probable scarcity of allowances, and it was not yet clear whether or not banking into Phase 2 was going to be allowed in some Member States. On the assumption of sustained economic growth and emission levels around the 2005 cap, a degree of EUA scarcity was anticipated.

It eventually turned out that verified emissions for the year 2005 were lower than initially expected, and the market price immediately integrated this new information at the time of their publication in April 2006. The price progressively fell to zero in 2007 as it became clear that the quantity of allowances was sufficient to cover verified emissions over the period, and that banking between Phase 1 and Phase 2 was definitely ruled out.

2008 was marked by the approval of the European Climate Energy Package, a set of directives and regulations aimed at attaining the 2020 objectives (targets for greenhouse gas emissions, renewable energy, and energy efficiency). In particular, the EU ETS directive was extended to 2020 by taking into account the emissions reduction target announced by the European Council, 2007 (European Parliament and the Council of the EU, 2009). A calculation based on sustained economic growth and an equally spread use of offsets over time would have shown a large anticipated deficit of allowances up until 2020. Most price forecasts at the time were counting on a EUA price in 2012 of around €35/tCO_2.

Once again, the expectations were not realized and in 2012 the carbon price fell below €10/tCO_2. The unforeseen financial crisis and the poorer growth outlook were partly responsible this change in expectations, but as we saw in the previous section there were other equally or more important reasons too.

Figure 1 also shows expectations up to 2020 as of the beginning of Phase 3. The possibility of banking unused allowances, amounting to more than 2,000 Mt according to our most recent calculations, appears to call for very little reduction effort up until 2020, in the current low growth context.

The conclusion to be drawn from this analysis is that the anticipations made in 2005 and 2008 turned out to be wrong. We can see a marked tendency for participants and observers to overestimate the constraint *ex ante*. Indeed this is a lesson that is not specific to the EU ETS. It has also characterized the US SO2 trading system, where unanticipated cost savings have been obtained as a result, for example, of the deregulation of railroad rates, allowing for more low-sulphur coal substitution than expected (Schmalensee and Stavins, 2013). In the Regional Greenhouse Gas Initiative, emissions were lower than previously anticipated due to low natural gas prices, prompting a conversion to lower-emitting fuel and, to a lesser extent, energy conservation and the economic downturn. As a result the system was revised with a view on tightening the cap (RGGI, 2013). The same phenomenon also arose in the Kyoto Protocol emission trading system, which turned out to be much less constraining than initially expected.

These historical lessons show that there appears to be a general tendency for any authority implementing an emission trading system to overestimate the constraint *ex ante*. Many structural conditions, such as the implementation of other policies impacting emissions under the EU ETS perimeter, or the timing of the use of offsets, can drastically alter the situation over time. The interesting question thereby arising concerns the capacity of the public authority to establish coherence between the short term and the longer term constraint that will be robust over time, in this context of uncertainty. In the next section we examine whether the solutions on the table today would be able to remedy these identified weaknesses.

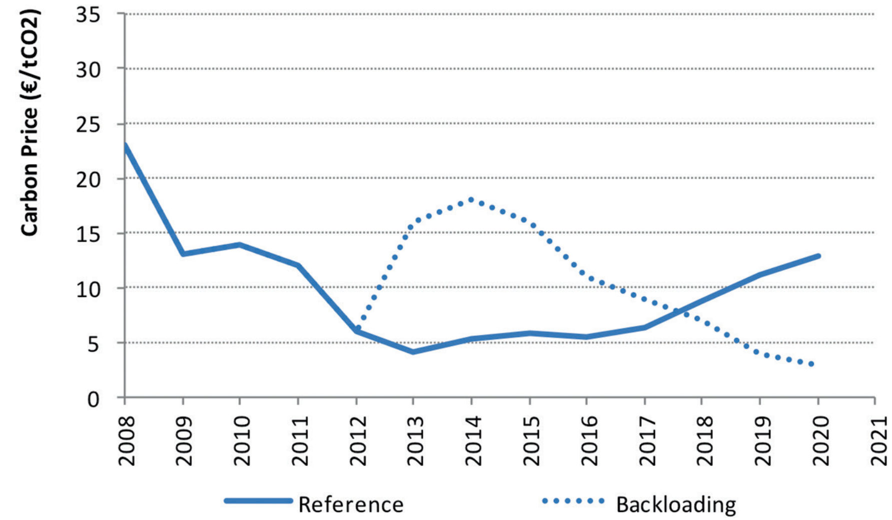
4. Evaluation of the Commission's proposals with the ZEPHYR model

The European Commission has taken two parallel measures to try and remedy current weaknesses. The first is a short-term measure, known as backloading (European Commission, 2012a), which involves delaying the auction of 900Mt taken from the 2013-15 allowance cap and injecting it back into the market through the 2019-20 auctions. In this way the overall cap over Phase 3 will not be changed, but the timing of auctions will shift volumes towards the end of the period. The second measure has been to initiate discussion on the so-called "structural reform" of the EU ETS, following the publication of the Commission's report on the state of the European carbon market (European Commission, 2012b). This report proposes six different options for extending or strengthening the system. We tested the backloading proposal as well as various options from the report using our EU ETS simulation model, ZEPHYR-Flex. The model simulates the compliance behaviour of EU ETS installations in each sector and calculates the annual supply-demand equilibrium up to 2020, based on scenarios for growth, offsets and the future cap (Trotignon, 2012b and De Perthuis and Trotignon, 2012). In the reference scenario, describing the situation prior to any intervention, the annual reduction factor of the cap is set at -1.74% and is assumed to be constant up to 2030 (continuity of the current trajectory), banking is allowed from Phase 3 into Phase 4, and there is a complete use of offset limits up to 2020 and no offsets after 2020. The baseline emission growth is derived from a GDP growth scenario of 2%/yr from 2013 to 2020. In this reference scenario, the resulting EUA price is around €6/tCO_2 in 2015 and €13/tCO_2 in 2020.

"Set aside" or "backloading" does not resolve structural issues

Two extreme cases can be represented. In the first, the change in the timing of auctions is perfectly anticipated by participants. Here there is no change compared to the reference scenario, because the overall cap is unaltered by backloading. In the reverse situation, participants do not anticipate the lower short-term cap, and the price rises abruptly before again falling when volumes are re-injected in the market. Figure 3 below represents an intermediate situation between the two extremes described above. In this scenario, the price rises to €16/tCO_2 in 2015 and falls to €3/tCO_2 in 2019.

Figure 3: Results in the backloading scenario



Source: Climate Economics Chair, ZEPHYR-Flex model

These simulations show that backloading alone does not rectify the market in the medium to long term and leads to even greater confusion in terms of market participants' expectations. The price rise induced by such a short-term measure leads in the medium term to an even lower price than today, as long as the allowances cap remains unchanged.

Changing/extending the reduction target is necessary but not sufficient

Options from the Commission's report were also tested. The two that seem best able to correct the market are options giving more clarity on the longer term constraint: option (a), which consists of raising the 2020 reduction target to 34% and a linear extension of the reduction after 2020; and the combined option (b) + (c), which involves a cancellation of allowances in Phase 3 and a revision of the cap's linear reduction factor in Phase 4, equivalent to a Roadmap trajectory implemented from Phase 3. In both cases, the ZEPHYR model indicates that the price could rise to around €25/tCO_2 in 2020. Only those options which make the allowances cap visible in the longer term seem to be able to remedy the current situation in the market.

Other proposals by the Commission and summary of our results

Table 1 below summarizes our results and comments on the different options.

Table 1: Summary of our analysis of the Commission's proposals

Scenario	Carbon price in 2015	Carbon price in 2020	Comments
Reference	€6/tCO2	€13/tCO2	Current situation (continuity of linear reduction factor in Phase 4)
Backloading	€16/tCO2	€3/tCO2	Perfect expectations: no effect on the price (no change in the Phase 3 cap) Imperfect expectations: effect on the short-term price leading to an even lower price in the medium term
(a): 34% reduction target in 2020 for EU ETS sectors	€17/tCO2	€27/tCO2	Revision of the objective from 2013, in practice impossible Overly ambitious linear trajectory with regard to the 2050 objective Does not allow dynamic management of interactions
(b)+(c): Withdrawal of allowances in Phase 3 and revision of the linear factor in Phase 4 (in line with the Roadmap 2050)	€16/tCO2	€24/tCO2	Appears attractive but requires working on actors' expectations and a complicated political process Does not allow dynamic management of interactions
(d): extension to other sectors	Not tested		Only option proposed that concerns demand for allowances Extends the carbon price to diffuse emissions A good way of reforming the market in theory; probably complicated in practice Does not allow dynamic management of interactions
(e): limiting access to international credits in Phase 4	In all our scenarios: no credit accepted in Phase 4		Use of carbon credits or international allowances in Phase 4 could have a (strong) effect on prices from Phase 3 Difficult to ensure good expectation conditions for actors
(f): price control mechanisms	Not tested		Would allow management of interactions Difficult for the public authority to decide on the "right" carbon price over time Risk of disconnecting the carbon price from market fundamentals in relation to the attainment of the reduction objective at least cost

Source: authors, ZEPHYR model

In the light of the issues discussed in the previous section, none of the routes proposed by the Commission in its consultation paper seems completely satisfactory, because the question of market governance remains a taboo that is not explicitly addressed.

If we stay within the current system of governance, the most appropriate action would be to speed up the adoption by the 27 EU Member States of a credible goal for 2030. Backloading accompanied by an emissions reduction target of 40% in 2030 could raise the price of CO_2 allowances to €16/tCO_2 in 2015 and €24/tCO_2 in 2020. In the current governance framework, such a decision is very difficult to obtain because a lot of time and effort are needed for Member States to agree on the general climate targets and then to negotiate the distribution of effort among the different policy tools and countries.

In the event of the adoption of a clearer long-term reduction target, retaining the current governance would, however, leave a rigid system unable to adapt to shocks which are unpredictable today but are certain to occur between now and 2030. We propose exploring an alternative route to the options currently on the table, in which an independent carbon market authority would be established.

5. The case for an Independent Carbon Market Authority (ICMA)

A cap-and-trade system is fundamentally an instrument of public policy, and consequently will not be revised unless there is strong political involvement, especially in determining its long-term emissions reduction target. The negotiation of a Climate Energy Package for 2030 is currently underway following the publication of the European Commission's Green Paper on a framework for climate and energy policies (European Commission, 2013). A decision on a longer-term reduction target is thus an important prerequisite to the propositions for governance improvements detailed below.

The experience from the eight years of market history previously analysed shows that the current governance framework does not enable participants to develop sound expectations over time. In the long term, the most problematic influences are not those of economic conditions but those induced by structural weaknesses linked to climate-energy policy overlap and to uncontrolled international linking. Dealing with those two uncertainties requires a more flexible intervention framework than the one available today. It would be extremely inefficient for Europe to engage in debates possibly lasting years, as with the backloading negotiations, every time something unexpected happens.

The recovery of the market calls for strong political support at a European level and a commitment to reform its governance, involving the establishment of a predictable and dedicated intervention framework. This mandate could be entrusted to an independent carbon market authority, which would ensure the consistency and credibility of the allowances system in the short to long term through the dynamic management of the supply of allowances. This framework is inspired by the example of monetary policies, with which emission trading has many similarities, as shown by Whitesell (2012). In particular, Whitesell underlines that in both systems the public authority tends to be naturally pressured by short-term market conditions and is less inclined to ensure the credibility of the long-term target over time.

A possible mandate for the Independent Carbon Market Authority (ICMA)

In our proposal, the role of the political authority remains unchanged: namely, to define detailed policy objectives for emissions reduction at a European and national level; and to select the range of public policy instruments for attaining these objectives.

The ICMA's mandate (detailed in Table 2) is to maintain the credibility and political ambition of the policy over time by the dynamic management of allowances supply, from the short term (through the timing of auctions) to the long term (through the revision of EU ETS cap).

In the short term, it would be a matter of being able to adjust the timing of auctions so as to ensure proper functioning and liquidity in the trading market. In the medium and long term, it would be a matter of being able to adjust the allowances cap in order to control interactions with other climate and energy policies and with international carbon credits.

To motivate and justify its actions, the independent authority should implement fair and transparent monitoring of the system (monitoring of transactions, compliance behaviour, low-carbon investment, emission trajectories, effects on competitiveness). It should also report regularly and publicly on its actions to the Council and the European Parliament.

At an institutional level, either the mandate of the ICMA could be assigned to a new agency or the powers of the existing energy markets authority could be extended.

Table 2: Outline of the mandate of the Independent Carbon Market Authority

Function	Associated action
Regular monitoring and transparency of information	Collecting, analysing and sharing information on: Transactions on the ETS market Emission trajectories Compliance behaviour Low-carbon investment Effects on competitiveness Motivating and justifying its decisions.
Liquidity and good functioning of the market in the short term	Primary market: time management of allowances auctions. No need for intervention in the secondary market.
Credibility over time of the medium-to-long-term constraint	The public authority determines the detailed emissions reduction objectives and the policy instruments to achieve these objectives. The independent carbon market authority implements this policy objective in the sectors covered and can dynamically adjust the allowances cap in two cases: To maintain consistency with other climate and energy policy instruments To control interactions with carbon credits and international allowances. No need for a price corridor or cost control reserve.
Reporting and compliance with the mandate	Periodic hearings by the European Parliament and the European Council. Frequent public reporting.

Source: Authors

In practical terms, it may be wondered how such an authority would have reacted to the recent market malfunctioning. In the short term, the question of backloading would no longer arise because of the mandate given by the European Parliament and the Council to the Independent Carbon Market Authority for the dynamic management of auctions. Faced with the three previously identified causes for the fall in the market price, the ICMA would not have made any changes to the cap following the economic recession (in view of the normal and desirable adjustment of the equilibrium price after an economic shock). It would, however, have investigated the impact of changes on the functioning of the international Kyoto credit market and the impact of other Climate and Energy Package directives, with a view to tightening the cap. This tightening would involve returning to the constraint level initially assigned by the public authority to the sectors covered.

Is there a need for a price floor or a price collar?

In our view, the ICMA's means of action should be based on quantitative instruments, and there is no explicit need to introduce a long-term price floor or price collar, as is the case for example in California's cap-and-trade system (California Air Resources Board, 2013).

But the public authority could decide to increase the visibility of the carbon price signal by introducing such price targets. Would doing so solve the problem and make the creation of an ICMA unnecessary?

If the public authority were to introduce a price floor without changing the current governance of the market, there would be a risk of disconnecting the price signal from quantity-based market fundamentals. For example, in the case of a price floor, if the market conditions bring the carbon price to the floor, the imbalance between supply and demand will increase, as the capped entities will be induced to continue abating emissions by an artificial price that does not reflect market conditions. Instead of correcting the initial imbalance, the price floor will exacerbate it and the price signal will be blurred.

If the public authority wants to give a long-term signal with explicit price target trajectories in the medium and long term, the only practical way to do so is to introduce a dynamic supply management of allowances to adapt the quantitative parameters of the market. This requires a change in the way the market is managed today. In other words, our proposal does not require explicit price targets. But if these price targets have to be introduced, the only way to manage the situation would be to establish an ICMA and to add these additional provisions to its mandate.

6. Conclusion

The historical development of cap-and-trade systems reveals a strong tendency to over-estimate the constraint *ex ante*, for fear of high prices, which leads to the implementation of flexibility measures and additional policies aimed at containing the costs associated with the cap-and-trade constraint. What is observed *ex post* is very different from initial expectations, with prices generally much lower than expected. The key point to bear in mind is that the public authority and market participants will never know and perfectly anticipate in advance the future developments that will determine the actual constraint.

It is thus very hard for the public authority to ensure the predictability of the constraint in a context that is inherently very uncertain. This tricky situation calls for a governance framework that can express very clearly the medium to long term targets of the policy, and at the same time has the capacity to react in the short term to unanticipated situations.

One of the ways to reconcile these two requirements is to have the public authority determine the long-term goals and the policy mix to attain them, while entrusting to an independent authority the wherewithal to maintain this constraint over time according to the uncertainties involved. The job of the ICMA is to give credibility and robustness over time to the reduction constraint set by the public authority. There are three pillars for such a framework to be effective: the existence of a clear mandate that determines the independence of the ICMA, the level of expertise of the ICMA, and the reporting and accountability rules of the ICMA.

In the short term, the question of backloading would no longer arise, because of ICMA's mandate on the timing of auctions. In the longer term, the ICMA would also have the mandate of adapting the ETS cap, not in reaction to a change in economic conditions, but when unexpected events such as overlapping policy instruments call for an intervention to maintain the credibility of the scheme so as to attain both the short-term and long-term goals of greenhouse gas emission reductions.

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Part 2

Agriculture, food, forestry and climate change

Forests and agriculture account for 17% and 13% respectively of worldwide GHG emissions. Yet so far they have been only partially included in international climate change mitigation policies. One of the reasons for this situation is the complexity of considering agriculture and forests holistically. For agriculture provides food, energy and landscape environmental services, while forests provide livelihoods, biodiversity conservation, water quality improvements, etc. There is therefore considerable need for applied research in this area, so as to better examine the synergies and trade-offs that may exist between carbon sequestration, GHG emissions reduction, and the other important issues related to agriculture and forests. Various questions arise here, and providing answers to them should lead to constructive new policy recommendations. How should carbon-related forest, agricultural and bioenergy projects be evaluated when so many factors co-exist? How might carbon finance improve and contribute to other environmental and social services? Under what circumstances do agriculture and forests become complementary (agro-forestry) rather than alternatives (agricultural expansion)?

In Part 2, we present two studies concerned respectively with the bioenergy sector and with deforestation:

Chapter 5, *Biomass for power generation in Europe: addressing the potential*, analyses the potential for introducing bioenergy in European power generation. It considers both the potential demand of existing European power-plants and the potential supply provided by agriculture and forests.

Chapter 6, *Forest transition and REDD+ in developing countries: challenges for climate change mitigation*, presents the “forest transition” hypothesis, which describes the long-term change of forest cover in a given country, and analyses the implications of this theory within the REDD+ framework.

Chapter 5

Biomass for power generation in europe: addressing the potential

Vincent Bertrand, Benjamin Dequiedt
and Elodie Le Cadre

1. Introduction

In adopting the 2001 Directive (2001/77/EC) to increase the share of renewable electricity in total electricity consumption, the European Union demonstrated its interest in promoting renewables in Europe. This emphasis was confirmed in 2008, with the Climate and Energy Package, which extends the EU's climate policy beyond 2012. The package includes three "20 targets" to be attained by 2020: reducing greenhouse gas (GHG) emissions by 20% compared to the 1990 level, achieving 20% of renewable energy in total energy consumption, and increasing energy efficiency by 20%. In addition, the EU has also committed itself to reaching 10% of energy from renewable resources in transportation by 2020.[12]

There is a growing interest in using biomass in energy. Biomass is increasingly acknowledged as an important renewable energy source (RES), which can make a very significant contribution to achieve the EU targets. The use of biomass would not only increase the share of RES in the energy balance, but also reduce the carbon footprint, since biomass does not raise CO_2 concentrations in the atmosphere (or very slightly, compared with fossil fuels).[13] Furthermore, as with other RES, a further advantage of biomass is that it reduces energy dependency.

However, there are also a number of concerns about the sustainability of bioenergy, including the potential impacts on food and feed production, changes in land-use, and reduced biodiversity. While, in general,

12 The Climate and Energy Package, which was first discussed in 2008, entered in force in 2009 through adoption of the Directive 2009/28/EC. In the case of biomass, the EU objectives have been further defined in the biofuels Directive (2003/30/EC), and in the Biomass Action Plan of 2005.

13 See ECF et al. (2010) for discussions about actual CO_2 emissions from burning biomass.

such negative externalities cannot be completely eliminated, most of them can be considerably reduced through the use of lignocellulosic biomass. Among the positive effects of lignocellulosic biomass, is the fact that it does not enter into competition with food (or indirectly, through land-use), in contrast to other energy crops such as sugar beet, sugar cane, maize, potatoes, etc. Lignocellulosic biomass can also alleviate concerns about land-use, since a large proportion of those feedstocks come from agricultural and forestry residues. Moreover, any remaining land-use concerns should potentially be addressed through certification schemes similar to those used in the forestry industry (ECF *et al.*, 2010).

Biomass is of particular interest in power generation, since it is not subject to problems of intermittency when used to generate electricity as opposed to other RES. This increases reliability and lowers the cost of managing production, by allowing power producers to dispatch biomass units, as with conventional power-plants. Another very promising feature of biomass in electricity is that it can be used in existing thermal power-plants, which provides great opportunities for increasing the share of renewable electricity in the near-term, with no or little investments. Biomass co-firing in coal plants enables power producers to reduce CO_2, SO_2 and NOx emissions. Regarding CO_2 emissions, co-firing can be considered as the most effective abatement measure in the European Union Emission Trading Scheme (EU ETS), because it substitutes biomass, with zero emissions under the scheme, for coal, which produces the highest CO_2 emissions per MWh of electricity (Al-Mansour and Zuwala, 2010).[14]

The focus of this chapter is on biomass potential in the European power sector. Beginning with an overview of questions related to using biomass in power generation, we next introduce a method that enables us to estimate the potential volumes of biomass that may be used in European power generation, and the associated CO_2 abatements. We also derive the biomass and CO_2 switching prices, which make biomass co-firing profitable in different types of coal plants. Finally, we rely on recent studies to figure out what the potential biomass feedstocks in the EU countries are, and we compare these resources with results of our estimations for the power sector.

2. Key issues and economic considerations in biomass power generation

In this section we present the key issues related to the use of biomass for power generation and the economics of co-firing. The technological options for using biomass in power generation and the pre-treatment of biomass will then be described, followed by a review of the economic advantages and drawbacks of biomass co-firing.

Key issues: Why use biomass in power generation?

Reducing CO_2 emissions and energy dependency

Contrary to fossil fuels, biomass is a renewable *green carbon* resource that can replace non-renewable *black carbons* such as coal, oil and gas. It is considered as a carbon neutral fuel because the CO_2 emissions associated with its combustion were previously fixed in the material as it grew, and will once more be fixed as planted replacement crops grow. However, it is often pointed out that defining biomass fuels as carbon neutral is fundamentally wrong, because it neglects up-stream emissions. The overall CO_2 emissions associated with the use of biomass depend on many factors, such as processing (transport modes and distances), and – in the case of dedicated energy crops – on cultivation, harvesting and possible land-use change effects. Taking into account these indirect emissions can increase the biomass emission factor from zero to about 0.01-0.03 $kgCO_2$/KWh (15 to 38% due to transport), depending on the biomass type (DECC-SAP, 2011). This is still much lower than CO_2 emissions from fossil fuels.[15]

Ancillary benefits from using biomass in energy also include a reduced dependency on imported fossil fuels, and the potential to develop local biofuel supply chains, which can benefit local rural economies. Furthermore, unlike other RES (*e.g.* solar, wind), biomass-based power generation can be made available whenever it is needed, which increases reliability.

Fostering the penetration of RES

To foster the penetration of renewable energy, each EU country different support schemes to promote them.[16] Thus, power producers can take advantage of these economic means to reduce their costs of production and make this production profitable.

On the one hand, there is regulation. The goal is to create incentives that are not compulsory. Thus, electricity suppliers for instance, do not have to include a minimum share of renewable energy in their bids. Similarly, there is no regional or municipal constraint on use or renewable energy production. However, we can have constraints on the technology or the type of biomass used.

14 According with the Directive 2003/87/EC (establishing the EU ETS and related rules) and the Decision 2007/589/EC (establishing guidelines for the monitoring and reporting of greenhouse gas emissions), emissions from burning biomass are exempted from surrendering corresponding allowances. This is equivalent to a zero emission factor applied to biomass.

15 Whereas those indirect emissions are often mentioned for biomass, they are consistently ignored when fossils fuels are concerned. However, CO_2 emissions associated with transport and processing also exist in this case, and can be more substantial than with biomass. For instance, taking into account the overall emissions, the emission factor of hard coal can reach 0.385 $kgCO_2$/KWhp (DECC-SAP, 2011) compared with the 0.339 value provided by IPCC (2006).

16 For an extended literature review of support scheme in France, see Le Cadre et al. (2011).

For example, some countries support biomass only if it is used in CHP-plants and some countries do not support co-firing of biomass with fossils fuels (*e.g.* Netherlands, Germany and France).

On the other hand, we find support-schemes divided into three categories. The first one is the feed-in-tariffs (FIT) where renewable energy production benefits from the purchase-obligation defined by law. Any generation under this mechanism is sold, transported and distributed, except when this production undermines the security of the network. Through this system, the renewable facilities are not dependent on market conditions. Fourteen member states use a FIT as the main support scheme (Austria, Bulgaria, Cyprus, France, Greece, Hungary, Ireland, Latvia, Lithuania, Luxembourg, Portugal, Spain, UK), while four others offer the choice between FIT or Feed-In-Premium (Slovenia, Finland, Germany, Czech Republic).

The second support scheme is the call for tenders, used for higher capacities (*e.g.* in France or Portugal). There is a broad range of conditions concerning plant size, combustion, type of biomass and level of biomass support. Every call for tenders is an opportunity to specify new performance criteria that need to be met. For example, they can highlight security for using heat, which maximizes energy efficiency projects, and biomass supply plans. Calls for tenders for biomass power plant construction thus adjust specifications to technological advances, the maturity of the industry and the biomass sources availability.

The third support scheme is green certificates. The RECS (Renewable Energy Certificate System) is a harmonized European system of traceability and certification of renewable electricity. Six countries have a quota system (Belgium, Italy, Sweden, UK, Romania and Poland). The RECS is administered in each country by a single issuing bank. Currently, this system is the basis for the *green tenders* made by some suppliers of electricity to individual and industrial customers.

In addition to these financial supports, one can also mention: tax credit for sustainable development, eco-zero interest loans, tax exemptions and accelerated or exceptional depreciation. Systems to ensure the production of electricity from renewable sources also cover systems of guarantee of origin, demonstration funds, reduced VAT rates, support for electricity generation from off-grid renewable systems and Energy Performance Plans for farms. In conclusion, a large panel of support schemes has been implemented in Europe to promote RES and the biomass used to produce heat and power. However, progress needs to be made to harmonize them.

Technological options for using biomass in power generation

Current options for generating power from biomass are dedicated biomass power plants, Combined Heat and Power plants (CHP) and biomass co-firing with fossil fuels in large power boilers. These different technologies are presented in what follows.

Combustion in dedicated power plants and cogeneration

The most straightforward way to generate electricity from biomass is to burn it in a power plant that is especially designed for this purpose. In addition to electricity, heat is generated. Biomass is combusted to heat water, generating steam that is conveyed to a turbine to produce electricity. When this heat is used for other purposes (*e.g.* heating), simultaneously with power generation, a CHP-system is created.

Dedicated biomass and CHP plants have to be adapted to the characteristics of fuel, and limitations in the biomass supply. Accordingly, the typical size of these plants is smaller than that of coal plants (1-100 MW, which is about ten times smaller than coal plants), because of the scarce availability of local feedstock and the high transportation costs. The small size strongly increases the investment costs per KW and results in lower conversion efficiency compared with co-firing in coal plants. In Europe, the investment cost of biomass plants varies from USD 3000-5000/KW, depending on the plant technology and size (IEA, 2007). This is about three to ten times more than the investment cost for retrofitting coal plants for co-firing (excluding the indirect co-firing configuration, which is much more expensive). The investment cost can even reach Euros 9000/KW for CHP plants. In this case, the higher investment costs result in higher overall efficiency of the energy conversion chain.

Co-firing in coal-power stations

Co-firing is the simultaneous combustion of biomass and coal in the same coal power station. It is the least expensive option for using biomass in power generation, and is expected to play an important role in the future. A wide variety of biomass can be used, including herbaceous and woody materials, wet and dry agricultural residues and energy crops. Currently, the typical conversion efficiency for a dedicated biomass plant is 25-30% while it is around 36% for conventional coal plants (Ecofys, 2010). Biomass co-firing is expected to decrease the efficiency of coal plants, due to potential sources of efficiency losses associated with biomass (presence of non-preheated air, increased moisture content, etc). However, the impact of a low level of biomass is judged to be modest (IEA-IRENA, 2013) which leads to higher conversion efficiency compared with dedicated biomass plants. Accordingly, biomass co-firing represents a promising way to convert biomass with high electrical efficiency. It offers one of the best short — and medium — term opportunities for reducing GHG emissions from power generation.

There are three basic co-firing options, and all have been demonstrated on an industrial scale (Al-Mansour and Zuwala, 2010):

Direct co-firing:
is the cheapest and simplest co-firing configuration. Biomass and coal are burned in the same boiler, using the same or separate mills and burners. This is by far the most commonly applied configuration as it enables co-firing percentages of up to 3%, without significant investment costs.

Indirect co-firing:
this is a less common option in which a gasifier converts the solid biomass into a fuel gas that can be burned with coal in the same boiler. This approach is more expensive because of the additional equipment required for the gasifier. However, it allows for a greater variety and higher percentages of biomass to be used.

Parallel co-firing:
it is also possible to install a separate biomass boiler that supplies the same steam cycle. As with indirect co-firing, this method allows for high biomass percentages and greater fuel flexibility, but it requires much more investment than simple direct co-firing.

The investment cost for retrofitting a coal plant for co-firing is in the range of USD 430-500/KW for direct co-firing, USD 760-900/KW for parallel co-firing, and USD 3000-4000/KW for indirect co-firing (IEA-IRENA, 2013). It depends on the plant capacity and service (*i.e.* power generation only or CHP), the quality of the biomass to be used, and the type of existing boilers. Apart from indirect co-firing, these costs are always significantly lower than the cost of investing in a dedicated biomass power plant.[17] This is explained by the large pre-existing infrastructures in case of co-firing, and the small size of dedicated biomass power plants.

Co-firing is also associated with constraints that limit utilization of biomass in coal plants. They include modification of combustion behavior, possible reduction in conversion efficiency, deposit formation, corrosion and resulting changes in equipment life-time related to the quality of the biomass. Nevertheless, a significant part of those difficulties can be overcome through different pre-treatments that make it possible to improve biomass quality, while increasing the quantity of biomass that can be included in coal plants. The quantity of biomass that can be co-fired in coal plants also depends on the co-firing configuration. Although direct co-firing is the cheapest option, it causes more severe problems for coal plants. Hence, the co-firing percentage is typically lower with direct co-firing compared with other options.[18]

17 Investment costs for indirect co-firing are about ten times higher than for direct co-firing. However, this configuration allows for the use of cheaper waste fuels with impurities, which can strongly decrease operating costs related fuel consumption.

Pre-treatment of raw biomass

Most of the constraints related to co-firing originate from fuel properties. Raw biomass fuels usually have high moisture content and chemical composition that reduce the conversion efficiency of coal plants, and generate potential problems of corrosion. Various pre-treatments can be applied to raw biomass in order to avoid or reduce these problems. Pre-treatment can also lower the costs of handling, storage and transportation of biomass. Furthermore, pre-treatment can create new opportunities for long distance trades. Finally, pre-treatment could reduce the need to invest in complex and expensive co-firing technologies.[19]

Several options exist, which correspond to more or less sophisticated solutions. Common basic pre-treatments include drying, chipping and grinding. There are also more advanced options that produce biomass fuels with higher quality. These pre-treatments include pelletisation, torrefaction and pyrolysis. Pelletisation is a process that densifies fine biomass particles into compact and low-moisture capsules by applying pressure and heat. Torrefaction and pyrolysis are thermo-chemical pre-treatments that consist of biomass heating (at, respectively, low and high temperatures) in the absence of oxygen. Torrefaction produces a solid uniform product with very low moisture content and high energy density. Torrefied biomass contains around 70-90% of the initial weight and 80-90% of the original energy content (Uslu *et al.*, 2008). Pyrolysis produces gas, liquid (bio-oil) and solid (char).

The cost of pre-treatment can significantly vary from one option to another, but it is usually high.[20] However, it can be compensated by better operability of fuel (*e.g.* handling, storage and transportation), reduced co-firing constraints and higher conversion efficiency of coal plants. Some recent studies point out that the cost of pre-treatment can reach more than 50% in case of torrefied wood pellets (KEMA, 2012; IEA-Bioenergy, 2012). However, when taking into account the benefits of pre-treatment on the whole supply chain, up to the point of combustion, torrefied wood pellets yield better economic performances than simple wood pellets (IEA-Bioenergy, 2012).[21]

18 The constraints associated with co-firing also depend on the boiler technology of coal plants. In general, limitations to co-firing are less stringent with fluidized bed than with fixed bed or pulverized coal boilers. Thus, in general, fluidized bed boilers can substitute higher levels of coal with biomass than fixed bed or pulverized coal boilers (Maciejewska et al., 2006; Leckner, 2007; IEA-IRENA, 2013).

19 For a wide overview of biomass pre-treatments and economic issues related to co-firing, see Maciejewska et al. (2006) and Le Cadre (2012).

20 See Maciejewska et al. (2006) for cost estimations of different pre-treatment options.

21 Uslu et al. (2008) evaluate torrefaction, pyrolysis and pelletisation in terms of their

The economic advantages and drawbacks of co-firing

A higher fuel cost than coal

Power plant operating costs are, in general, higher for biomass than for coal, due to the higher delivered cost. Even when the biomass is nominally free at the point of production, for instance in the case of some dry agricultural residues, the costs associated with collection, transportation, preparation, and on-site handling can increase the cost per unit of input to the boiler to a point where it rivals, and often exceeds, the cost of coal.

Comparison with other RES

When compared to alternative RES, biomass co-firing is normally significantly cheaper, and has the advantage that it can be implemented relatively quickly (Al-Mansour and Zuwala, 2010). Hartmann and Kaltschmitt (1999) show that in comparison to wind, hydro and photovoltaics (PV), the use of biomass is very promising in terms of non-renewable energy consumption (MWhp/MWhe), CO_2 and SO_2 emission-equivalents per MWhe. Moreover, the fact that most RES cannot be dispatched when required, as they strongly depend on weather conditions, prevents them from constituting a reliable base-load solution. Contrary to PV and wind power, the technologies based on biomass are not subject to problems of generation intermittency. Despite their short setup periods and zero fuel requirements, PV and wind often suffer from resource unavailability. In this respect, biomass has a great advantage compared with other RES, and it can be used as a buffering capacity when wind or PV are not available. Moreover, the resource can be stored and used during peak hours.

Supply security and fuel flexibility

There is currently no large European or national biomass market, which creates uncertainty with respect to supply and price. However, biomass co-firing holds the advantage of uncertain biomass supplies not jeopardizing the fuel supply for power plant owners, who can manage a temporary loss on the biomass supply side (or short-term biomass price volatility) by increasing the share of coal in the fuel mix (Hansson et al., 2009). Biomass as a fuel provides a hedge against price increases and supply shortages of coal. Thus it can be viewed as an opportunity fuel, used only when the price is favorable.

energy and economic performances on the whole biomass-to-energy supply chain for power generation and biofuel production. Results indicate that torrefaction is more advantageous than pelletisation, while pyrolysis has drawbacks in terms of energy and economic efficiency when compared to other pre-treatments. When torrefaction is combined with pelletisation, this results in the optimal supply chain from an energy and economic perspective.

Reducing the cost of GHG emissions and other pollutions

Apart from direct savings in fuel cost, other financial benefits can be expected. Indeed, co-firing can reduce the net SOx, NOx and heavy metal emissions and the plant could claim the applicable pollution-reduction incentives offered by government agencies. Replacing coal by biomass in an existing boiler will also reduce CO_2 emission. Moreover, the use of biomass to displace fossil fuel can be eligible for special tax credits from many governments.

3. Biomass in the current European power generation: potential demand, associated abatement, and cost estimates

In this section we propose a simple and original method, that enables us to estimate the potential biomass demand, and associated CO_2 abatements from using biomass in the European power sector. The quantities obtained represent technical potentials, which do not necessarily coincide with results given by economic optimization. Our aim is to figure out the volumes that are technically attainable, regardless of economic decisions. By contrast, our estimations of the co-firing cost, and associated biomass and CO_2 breakeven prices, reflect economic conditions that make biomass co-firing in different types of coal plants profitable.

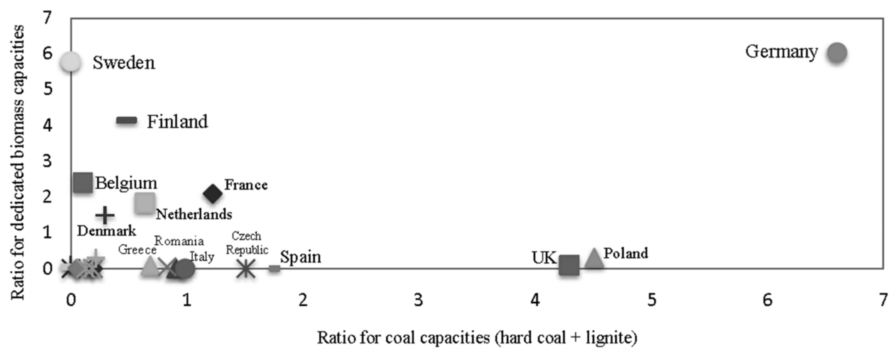
Potential biomass demand and associated CO_2 abatements

Overview of coal and dedicated biomass capacities in the European power mix

In order to get first intuitions about biomass potential in the European power sector, we begin with a short overview of coal and dedicated biomass capacities in Europe. This is summarized in Fig. 1, which represents ratios between the capacities of each country and the EU average capacity for coal and dedicated biomass power plants in 2011. Thus, for a given type of power plant (coal or dedicated biomass), a ratio higher than one means that the country has more installed capacities than the EU average (and *vice versa*).[22]

22 For instance, the ratio for coal capacities in Germany corresponds to the German coal capacities divided by the EU average of coal capacities.

Figure 1: Installed capacities for coal (hard coal + lignite) and dedicated biomass power plants in the EU countries.



Source: Data provided by ENTSO-E (www.entsoe.eu)
Values are ratios between capacities of each country and the EU average capacity.

Fig. 1 enables us to distinguish between countries with many dedicated biomass and few coal plants (Sweden and Finland), many coal and few dedicated biomass plants (Poland and the UK), and both many coal and dedicated biomass plants (Germany).

Estimation method for potential demand and associated abatements

The method consists in determining the amount of primary energy associated with observed production of power plants. This enables us to deduce how much biomass can be used in power generation. In the case of coal plants, one can derive the volumes of biomass entering the boiler, given a percentage of biomass in the biomass-coal blend. We call this the incorporation rate. Finally, once quantities of coal and biomass associated with electricity production are known, we estimate the resulting CO_2 emissions of coal plants by applying primary energy emission factors. Emissions are derived with and without co-firing, which allows us to compute abatements. Basically, the method encompasses three steps (see Box 1).

Box 1: Three-step method

Step 1: Estimating the quantity of primary energy associated with observed production

$Q_c^i = \frac{Y_c}{n_c^i}$ is the quantity of primary energy (MWhp) in coal plants of type c, with c = {Hard-Coal (HC), Lignite (L)} and i = {co-firing (cf), no co-firing (nocf)}. Y_c represents production of coal plants c (MWhelec), and n_c^i is the efficiency rate of coal plants c under i cycle (MWhelec/MWhp). In the same way, we compute the quantity of primary energy entering in dedicated biomass power plants. We model the efficiency rate of coal plants under co-firing using the following equation:

$n_c^{cf} = n_c^{nocf} - P_b\, inc_{c,b}$, where subscript b denotes the type of biomass. P_b is a coefficient measuring losses in the efficiency rate of coal plants under co-firing, and $inc_{c,b}$ represents the incorporation rate of biomass b in coal plants c.

Step 2: Estimating the quantity of biomass entering in the boiler, in case of co-firing

Under co-firing, $Q_c^{cf} = Q_{c,c}^{cf} + Q_{c,b}^{cf}$, where $Q_{c,c}^{cf}$ and $Q_{c,b}^{cf}$ are, respectively, the quantity of coal and the quantity of biomass in the blend. $Q_{c,b}^{cf} = inc_{c,b} \times Q_c^{cf}$ and $Q_{c,c}^{cf} = (1 - inc_{c,b}) \times Q_c^{cf}$.

Step 3: Estimating CO_2 emissions and associated abatement

$E_c^i = e_c\, Q_{c,c}^i$ represents CO_2 emissions of coal plants c under i cycle (tCO_2), where e_c is the primary energy emission factor (tCO_2/MWhp). In case of co-firing, $Q_c^{nocf} = Q_{c,c}^{nocf}$. We get co-firing abatements as follows: $A_c = E_c^{nocf} - E_c^{cf}$.

In order to figure out a range of values in which we can situate the potential biomass demand and the CO_2 abatements, we consider two extreme cases, reflecting minimal and maximal values. Thus, we get a lower (min case) and a higher (max case) range (Tab. 1).

Table 1: Lower and higher range for potential biomass demand and CO_2 abatements.

Cases to estimate	Biomass type	Incorporation rate	Losses coefficient
Min case (lower range)	Low quality = Raw biomass (RAW)	5%	P_{RAW} 0.05
Max case (higher range)	High quality = Torrefied pellets (ToP)	50%	P_{TOP} 0

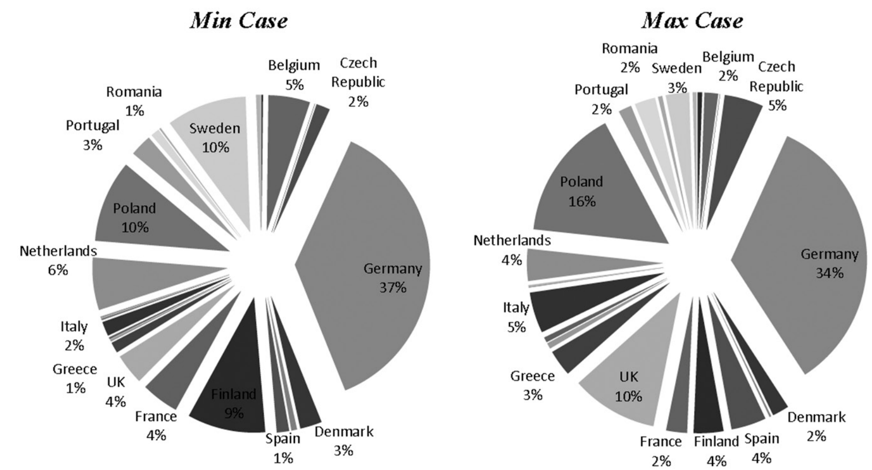
Regarding incorporation rates and losses coefficients, the values in Tab. 1 reflect differences induced by variations in the quality of biomass. Indeed, the higher the quality of biomass, the higher the incorporation rate is. This translates into higher incorporation rates for ToP than for RAW. Thus, we assume incorporation rates of 5 and 50%, reflecting the *Min case* and the *Max case*, respectively.[23] Losses on the coal plants efficiency rates also depends on the type of biomass. Hence, the value of the losses coefficient increases when the biomass quality decreases. As a limit case, we assume a zero loss coefficient for ToP.

The way we model n_c^{cf} enables us to represent the effect of different incorporation rates on the efficiency losses, for a given losses coefficient (Box 1). According with Ecofys (2010), we assume a linear relationship between the efficiency losses and the incorporation rate. This is not a very strong assumption, because this only affects estimations in the *Min case* ($P_{TOP}=0$ in the *Max case*), in which the efficiency losses are to be small because of the 5% incorporation rate. Indeed, several studies on co-firing have reported very few efficiency losses (or even none) for incorporation rates of about 5-10% (Baxter, 2005; Ecofys, 2010; IEA-IRENA, 2013). Hence, using this setting, we get higher efficiency losses for higher losses coefficients, and, for a given losses coefficient, higher efficiency losses when the incorporation rate increases. As an illustration, let us assume a co-firing situation with the following values: $n_c^{nocf}=0.38$, $P_b=0.05$, and $inc_{c,b}=0.05$. In this case we get $n_c^{cf}=0.378$, which corresponds to a loss in conversion efficiency of 0.66%. Baxter (2005) indicates that, if all the efficiency losses associated with co-firing were allocated to only the biomass fraction of energy input, they would represent a 0-10% loss in conversion efficiency. In our case, assuming $P_b=0.05$, the loss in conversion efficiency spans from 0.66% ($inc_{c,b}=0.05$) to 6.58% ($inc_{c,b}=0.5$).

Estimation results for potential demand and associated abatements

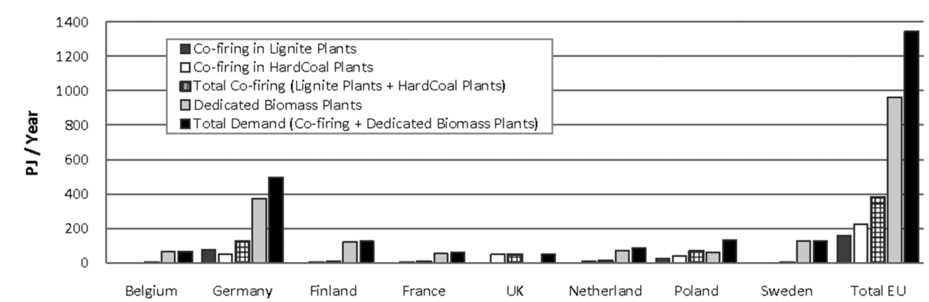
Before turning to results, we first present data. We use 2011 yearly power production data of hard coal, lignite and dedicated biomass power plants in the EU-27. Data are provided by ENTSO-E, the European Network of Transmission System Operators for Electricity. We assume efficiency rates of 30, 34, and 38%, for dedicated biomass, lignite, and hard coal power plants, respectively.[24] The CO_2 emission factors for primary energy (tCO_2/MWhp) are provided by IPCC (2006): 0.357 for lignite, 0.339 for hard coal, and zero for biomass.

Figure 2: The EU countries' shares in the total EU potential biomass demand from the power sector (co-firing + dedicated biomass plants)



Source: Data provided by ENTSO-E (www.entsoe.eu)

Figure 3: Potential biomass demand (per country and type of power plant) in the min case.



Source: Data provided by ENTSO-E (www.entsoe.eu)

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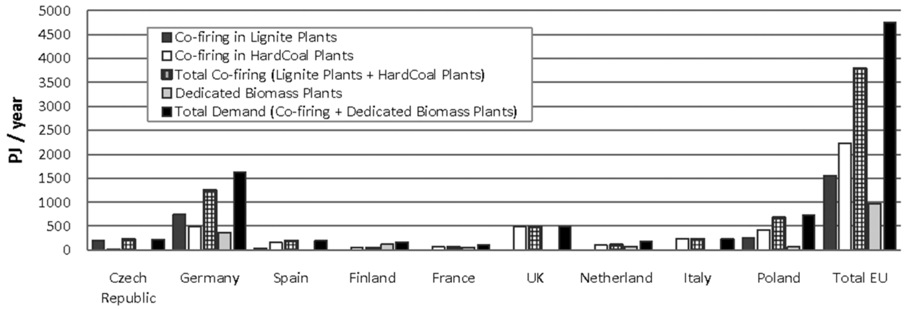
23 Co-firing is feasible with incorporation rates of 20%, and sometimes almost 50%. With pre-treatments, incorporation rates can reach more than 50%. However, in practice, actual incorporation rates rarely exceed 10% (IEA-IRENA, 2013).

24 We consider both hard coal and lignite plants. Indeed, the co-firing potential of hard coal and lignite plants is broadly the same. Slight differences exist in some cases, because hard coal plants generally require high-quality biomass, while lignite plants can more easily burn biomass with high moisture content. See ECF et al. (2010).

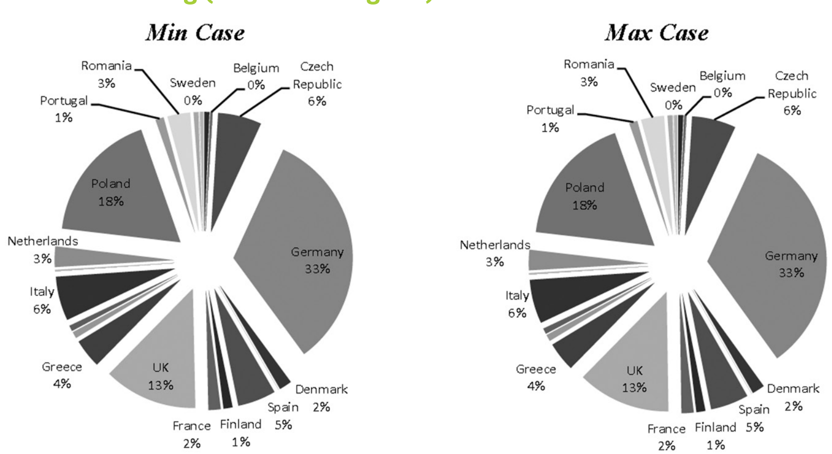
◊ **Figure 4: Potential biomass demand (per country and type of power plant) in the max case.**



Source: Data provided by ENTSO-E (www.entsoe.eu)

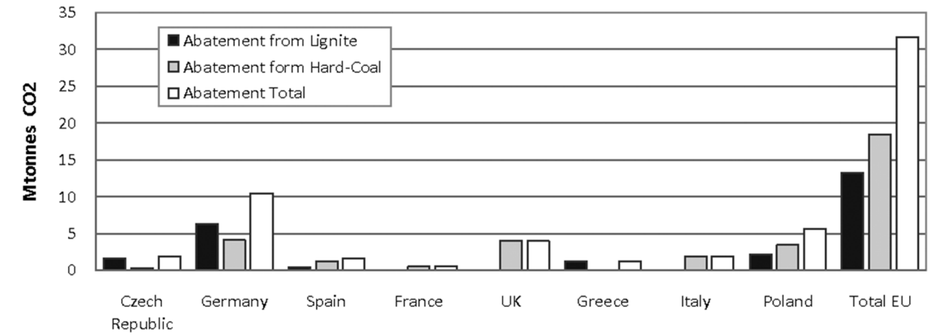
Results indicate that the EU potential demand ranges from 1344 to 4739 PJ a year (381 to 3787 for co-firing alone). In all cases, Germany has the highest potential demand with 498 to 1618 PJ (125 to 1243, co-firing alone). For instance, this is much higher than that of Poland, the second biggest demand potential with 132 to 738 PJ (68 to 675, co-firing alone). Moving from the min to the max case, we observe a change in distribution of quantities among countries. The demand share from coal plants increases, while that of dedicated biomass plants decreases (Fig. 3 and 4). Hence, the share of countries with many coal-fired plants and few dedicated biomass plants in their power mix increases (*e.g.* Poland and the UK, see Fig. 1 and 2). On the other hand, countries with many dedicated biomass plants and few coal plants represent a smaller share of the whole EU demand (*e.g.* Finland and Sweden, see Fig. 1 and 2). In between, the share of Germany is high and stable in all cases. This is because there are both many coal and dedicated biomass plants there.

◊ **Figure 5: EU countries' shares in the total EU abatement potential from co-firing (hard coal + lignite).**



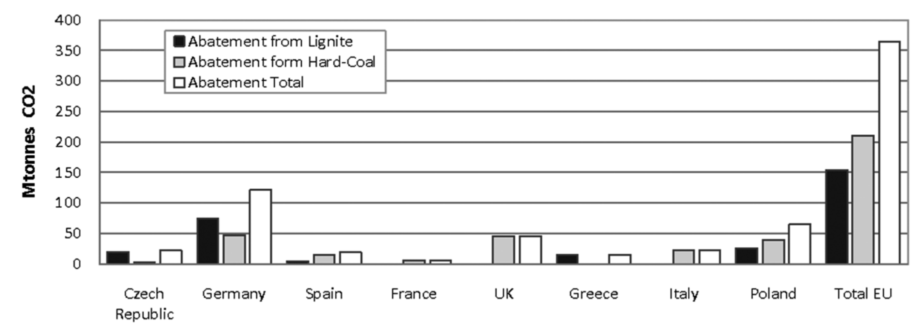
Source: Data provided by ENTSO-E (www.entsoe.eu)

◊ **Figure 6: Estimated CO_2 abatements (per country and type of power plant) in the min case.**



Source: Data provided by ENTSO-E (www.entsoe.eu)

◊ **Figure 7: Estimated CO_2 abatements (per country and type of power plant) in the max case.**



Source: Data provided by ENTSO-E (www.entsoe.eu)

Regarding CO_2 abatements, results indicate that the total EU potential ranges from 31.6 to 364.6 Mt a year.[25] Here again, Germany has the highest share with 10.4 to 120.8 Mt. Poland and the UK also have a great potential, due to the importance of coal-based electricity in these countries. As opposed to what we observe with biomass quantities, there is no change in the geographical distribution of abatements when we move from the min to the max case (Fig. 5). Indeed, the contribution of each type of coal plant to abatements is not modified when the incorporation rate increases (Fig. 6 and 7), whereas we observe a reduced share for the potential demand of dedicated biomass power plants (Fig. 3 and 4). When the incorporation rate increases, this translates into the same percentage of increase in every coal

25 This corresponds to between 0.7 and 7.7% of the EU GHG emissions in 2010, which accounted for 4721 $MtCO_2e$ (EEA, 2012). In comparison, coal-to-gas fuel switching, which is often considered as one of the main abatement option in the EU ETS, offers a maximal potential of about 150 $MtCO_2$ a year (Delarue et al., 2012).

plant, whatever the country and the type of coal. Hence, only the abatement volumes are increased, and the distribution is not modified.

Cost of electricity under co-firing and switching prices: Which carbon and biomass prices make co-firing profitable?

Switching prices and co-firing: Economic background

The usual matter of switching prices in the European power sector is to describe the power producers' ability to substitute (cleaner) gas-fired plants for (dirtier) coal-fired plants in power generation, thereby reducing CO_2 emissions. This phenomenon is known as *fuel switching*, and has generated a wide literature including both empirical and theoretical works (*e.g.* Sijm *et al.*, 2005; Kanen, 2006; Delarue and D'haeseleer, 2007; Delarue *et al.*, 2008; Carmona *et al.*, 2009; Bertrand, 2010; Delarue *et al.*, 2010; Bertrand, 2012; Lujan et al., 2012).[26] The basic idea is that with a high enough CO_2 price, coal plants switch places with gas plants in the merit order.[27] Without a CO_2 price, coal plants are usually brought on line first, because of their lower fuel cost. Gas plants are used next, during shorter periods, when demand for power is higher. However, with a high enough CO_2 price, gas plants may be preferable to coal plants, due to their lower carbon intensity, and thus it may be cheaper to switch between coal and gas plants. If such switching occurs, CO_2 emissions are reduced because coal plants are brought on line for shorter periods. In this case, the CO_2 price that makes fuel switching profitable is known as the *fuel switching price*. It is computed by equalizing the marginal cost of coal and gas power plants, including the cost of CO_2. This allows deriving the breakeven points, which express how advantageous fuel switching is at a certain point in time, given the fuel and CO_2 prices.

The method we present here enables us to compute switching prices which highlight economic conditions that make the biomass co-firing in coal plants profitable.[28] More precisely, they correspond to prices that make coal plants equally attractive under co-firing or classical conditions (*i.e.* when coal is the only input). Equalizing expressions of marginal costs of electricity with and without co-firing, we derive values for which power producers are indifferent between co-firing and classical cycle. These values are breakeven points for co-firing. We call them, *carbon switching price* and *biomass switching price*.

26 See Bertrand (2011) for a literature review.

27 The merit order is the ranking of all power plants of a given park by marginal cost of electricity production. Technologies are stacked in order of increasing marginal cost, so that power producers add ever more expensive plants to production as demand increases.

28 For a French estimation of coal-to-biomass switching price, see Le Cadre (2012).

Estimation method for switching prices

The first step consists in determining expressions of the marginal cost of electricity, with and without co-firing. The switching prices can then be derived using these expressions. We do not include the whole method in this chapter. We only give brief indications about factors that influence the marginal cost of electricity under co-firing.[29] In short, it depends on the coal and biomass types. Primarily because coal and biomass prices are not unique. Indeed, the price of lignite is not the same as the price of hard coal. Likewise, the price of biomass varies from one quality to another. Second, the coal and biomass types determine the losses coefficient and the incorporation rate, which, in turn, influence the co-firing cost. That is, the higher the losses coefficient is, the higher the loss in conversion efficiency is. This increases the cost of co-firing. Furthermore, modifying the incorporation rate affects losses in conversion efficiency and CO_2 emissions per MWh of co-fired electricity.[30]

Equalizing the marginal costs of electricity with and without co-firing, we get:

$$EUA^{sw}_{c,b} = \frac{q^{cf}_{c,b} B_b - (h^{nocf}_c - q^{c,f}_{c,c}) C_c}{e_c^{\,nocf} - e^{c,f}_C}$$

and
$$B^{sw}_c = \frac{c_c (h^{nocf}_c - q^{cf}_{c,c}) + EUA(e^{nocf}_c - e^{c,f}_c)}{q^{c,f}_{c,b}} \qquad (1)$$

where $EUA^{sw}_{r,b}$ is the *carbon switching price* (Euros/tCO_2) associated with using biomass *b* in coal plants *c*, and B^{sw}_c is the *biomass switching price* (Euros/MWhp) associated with using biomass in coal plants c. $h^{cf}_c = 1/n^{cf}_c$ is the heating rate (MWhp/MWhelec) of coal plants c under co-firing (where n^{cf}_c is given in Box 1). It corresponds to the quantity of primary energy (MWhp) in the biomass-coal blend, which allows power producers to generate one MWh of electricity under co-firing. Hence, once h^{cf}_c and $inc_{c,b}$ are known, one can compute the quantities of coal and biomass needed to generate one MWh of co-fired electricity as follows: $q^{cf}_{c,b} = inc_{c,b} \times h^{cf}_c$ and $q^{cf}_{c,c}$, $q^{cf}_c = (1 - inc_{c,b}) \times h^{cf}_c$. $q^{cf}_{c,b}$ ($q^{cf}_{c,c}$, respectively) denotes the quantity of biomass b (quantity of coal c, respectively) entering in the biomass-coal blend (h^{cf}_c) allowing to generate one MWh of co-fired electricity in

29 More details are available from the authors upon request. One can also refer to Bertrand (2013).

30 Whereas the effect of modifying the losses coefficient is straightforward, it is difficult to disentangle in case of the incorporation rate. In fact, modifying the incorporation rate induces two opposite effects for the co-firing cost, and the net effect is undetermined. See Bertrand (2013).

coal plants of type c (*i.e.* $h_c^{cf}=q_{c,c}^{cf}+q_{c,b}^{cf}$). Finally, e_c^{cf} and e_c^{nocf} are emission factors of coal plants c (tCO_2/MWhelec), with and without co-firing, respectively.[31]

$EUA_{c,b}^{sw}$ is calculated given the prices of biomass b (B_b, Euros/MWhp) and coal c (C_c, Euros/MWhp). It corresponds to the increased fuel cost from co-firing which enables power producers to abate one tonne of CO_2.[32] Accordingly, co-firing is cheaper than using coal plants in classical cycle if the additional fuel cost associated with co-firing is smaller than the cost of increased CO_2 emissions in the case of classical cycle. In other words, switching to co-firing will (will not, respectively) occur if $EUA_{c,b}^{sw} < EUA$ ($EUA_{c,b}^{sw} > EUA$, respectively), where EUA denotes the EU ETS carbon price. Hence, $EUA_{c,b}^{sw}$ reflects the CO_2 price from which it becomes profitable to include biomass b in coal plants c.

B_c^{sw} is calculated given the prices of coal c (C_c, Euros/MWhp) and of CO_2 (EUA, Euros/tCO_2). It corresponds to the benefit associated with including one MWhp of biomass in coal plants of type c. This arises from reduced costs of coal consumption and of CO_2 emissions. Hence, B_c^{sw} can be considered as the benefit of one MWhp of biomass entering in coal plants c, whereas B_b is the cost. Therefore, including biomass b in coal plants c is a profitable (not profitable, respectively) option as long as $B_b < B_c^{sw}$ ($B_b > B_c^{sw}$ respectively). Hence, B_c^{sw} reflects the biomass price beyond which including biomass in coal plants of type c is no longer profitable.

Estimation results for switching prices

In order to compute the biomass and carbon switching prices, we use price data for lignite, hard coal and different types of biomass. Values and references are summarized in Tab. 2. Regarding, efficiency rates of coal plants and emission factors for primary energy, we assume the same values as in section 2.1.

Table 2: Fuel prices (Euro/MWhp) as delivered to power plants.

Fuel	Prices – Euros/MWhp (as delivered to power plants)	Sources
Lignite	16.8	www.kohlenstatistik.de
Hard Coal	11.3	www.kohlenstatistik.de
Torrefied Pellets (ToP)	30 – 31.7	ECF et al. (2010), KEMA (2012)
Wood Pellets (WP)	25 – 31	ECF et al. (2010), Argus (2011), KEMA (2012)
Wood Chips (WC)	13.4 – 27	ECF et al. (2010), Argus (2011)
Agricultural Residues (AR)	13 – 16	ECF et al. (2010)

31 Note that in equation we use to compute e_c^{cf} ($e_c^{cf} = e_c x q_{c,c}^{cf}$, e_c where is defined as in Box 1), the CO_2 emissions arise from the coal fraction of energy input only. This reflects the zero emission rate applied to biomass in the EU ETS.

32 As opposed to fuel switching with coal and gas plants, co-firing does not necessarily entail changes in the dispatch of power plants. Thus, the constraints associated with co-firing are less stringent, which tends to decrease the cost of managing power generation.

In all our estimations, we assume an incorporation rate of 10%, which corresponds to the rate most encountered in practice. Furthermore, we split the different biomass types of Tab. 2 into two categories: Pre-Treatment (PT), and No Pre-Treatment (NOPT). While we consider ToP and WP as high quality pre-treatments lying in the PT category, we include WC in NOPT. We choose this division because WC exhibits energy contents that are quite similar to the ones of raw wood (Maciejewska et al., 2006; Acharya *et al.*, 2012). This enables us to apply a higher losses coefficient to the NOPT category, reflecting the lower quality of this biomass type (Tab. 3).

Table 3: Estimated carbon switching prices (using price data from Tab. 2) as given by equation (1).

$EUA_{c,b}^{sw}$	Pre-Treatment ($\rho_{PT} = 0$)		No Pre-Treatment ($\rho_{NOPT} = 0{,}05$)	
	Low biomass price	High biomass price	Low biomass price	High biomass price
$EUA_{L,ToP}^{sw}$	36.88	41.64	(51.36)a	(53.66)a
$EUA_{HC,ToP}^{sw}$	55.11	60.12	(68.51)a	(70.89)a
$EUA_{L,WP}^{sw}$	22.88	39.68	(34.35)a	(54.65)a
$EUA_{HC,WP}^{sw}$	40.38	58.06	(51.54)a	(71.90)a
$EUA_{L,WC}^{sw}$	(-9.60)a	(28.48)a	-3.13	41.51
$EUA_{HC,WC}^{sw}$	(6.19)a	(46.27)a	12.17	58.33
$EUA_{L,AR}^{sw}$	(-10.44)a	(-2.32)a	-4.44	5.40
$EUA_{HC,AR}^{sw}$	(5.01)a	(13.85)a	10.81	21.00

a: Values associated with losses coefficients which do not reflect the quality of the considered biomass type.

So far we have defined the carbon switching price as the increased fuel cost of co-firing, which enables power producers to abate one tonne of CO_2.

More precisely, two effects have to be considered when switching to co-firing. On the one hand, the fuel cost of biomass increases (since no biomass was used before). On the other hand, the cost of coal consumption decreases. Thus, defining the carbon switching price as an increased fuel cost is equivalent to considering that the effect of biomass is greater than that of coal. It is worthwhile mentioning these two effects to interpret the results of Tab. 3.

Results of Tab. 3 show that the carbon switching price associated with using biomass in lignite plants is always cheaper than that of hard coal plants, whatever the situation we consider. This is because, in the price data we use, the lignite price is higher than the price of hard coal. Thus, each time a MWhp of biomass is included in a coal plants, it comes with a higher avoided cost for coal consumption in the case of lignite. This translates into a lower carbon switching price in lignite plants compared to hard coal. Accordingly, one can conclude that switching to co-firing is cheaper in lignite plants, and it can be profitable with lower CO_2 prices. In addition, Tab. 3 shows that the carbon switching price associated with using non pre-treated biomass (WC and AR) is cheaper than that of pre-treated biomass (ToP and WP). Indeed, in the price data we use, pre-treated biomass is so expensive that it is associated with a higher carbon switching price than non pre-treated biomass, even taking into account the lower losses coefficient of pre-treated biomass.[33] Note that an exception comes from the carbon switching prices associated with the high WC price, which are higher than those associated with the high WP price. In this case, the price difference of biomass is so small that it produces a weaker effect on the carbon switching price than the difference of losses coefficients.

Interestingly, we also observe in Tab. 3 that the carbon switching price of lignite plants turns out to be negative in several cases, meaning that switching to co-firing is a profitable option even for a zero CO_2 price. The negative carbon switching prices arise from circumstances in which the considered biomass type is so cheap that, combined with the high lignite price, this translates into situations where the additional cost of biomass is lower than the coal cost saving. Hence, power producers can make money by switching to co-firing, even neglecting the CO_2 cost saving.

33 Results of Tab. 3 indicate that the carbon switching price is an increasing function of the losses coefficient. That is, the higher the losses coefficient is, the higher the loss in conversion efficiency is. This increases the additional fuel cost needed to abate one tonne of CO_2 under co-firing, and thus the carbon switching price. However, the effect of modifying the incorporation rate is more difficult to disentangle. Actually, this induces two opposite effects for the co-firing cost, and the net effect is undetermined. See Bertrand (2013).

Table 4: Estimated biomass switching prices (using price data from Tab. 2) as given by equation (1). Subscripts PT and NOPT only reflect different values of losses coefficient (as given in Tab. 3).

$B^{SW}_{c,b}$	Carbon price				
	Euros 5/tCO_2	Euros 10/tCO_2	Euros 20/tCO_2	Euros 50/tCO_2	Euros 100/tCO_2
$B^{SW}_{L,NOPT}$	15.88	17.40	20.45	34.68	52.54
$B^{SW}_{HC,NOPT}$	11.29	12.76	15.71	28.55	45.23
$B^{SW}_{L,PT}$	18.61	20.40	23.97	29.58	44.81
$B^{SW}_{HC,PT}$	13.00	14.69	18.09	24.54	39.28

Similarly to the carbon switching price, results of Tab. 4 indicate that co-firing is cheaper in lignite plants. Indeed, we observe that the biomass switching price has higher values in the case of co-firing in lignite plants. This reflects the higher benefits associated with including one MWhp of biomass in lignite plants, due to greater coal cost savings with a higher lignite price. Accordingly, the zone in which biomass prices are compatible with a profitable co-firing is larger with lignite plants than with hard coal. For instance, in the case of non pre-treated biomass with a Euros 5 CO_2 price, results indicate that co-firing in lignite plants is a profitable option as long as the biomass price is not more than Euros 18.61. The same breakeven value is Euros 13 with hard coal plants. Assuming a biomass price of Euros 15 per MWhp, it would be profitable switching to co-firing in lignite plants, but not in hard coal plants.

We also observe in Tab. 4 that the biomass switching price always has a higher value when reflecting pre-treatment. This is explained by the lower losses coefficient we use in this case. This translates into lower losses in conversion efficiency, and thus lower cost for co-fired electricity. Hence, co-firing produces better outcomes in this case, which appears in the higher biomass switching prices.

Finally, the results of Tab. 4 illustrate that co-firing can remain profitable with a very high biomass price, if the carbon price is high enough. For instance, assuming a Euros 50 CO_2 price, co-firing would be profitable in lignite plants with a biomass price of about Euros 25-35 per MWhp (about Euros 40-50 per MWhp with a Euros 100 CO_2 price), depending on the situation. Hence, the carbon price can be an important driver of co-firing, which can make the switching profitable even with a high biomass price.

4. Matching European biomass supply with potential demand from the power sector: uncertainties and competition for biomass resources

This section focuses on matching biomass supply with potential biomass demand estimations of previous section. We rely on literature to figure out what the potential biomass feedstocks in the EU countries are. Comparing potential supply and demand, we want to shed light on how the biomass market may be impacted by biomass demand in the power sector. Results indicate that potential demand may be high compared with supply, which may induce conflicts with other biomass usages.

In order to carry out a relevant comparison between potential supply and demand, we focus on papers covering the same geographical area as in section 3. We identify three main references that provide an extensive overview of potential biomass supply for energy production in the EU-27: Ericsson and Nilsson (2006), Renew (2006) and Panoutsou et al. (2009).[34] These studies use basically the same classification for biomass feedstocks, which facilitates comparisons. Accordingly, we split lignocellulosic biomass into four groups as follows:

Agricultural residues.

These products include a wide range of plant material produced along with the main product of the crop. Cereal straw, fruit tree prunings, corn stems, cobs, etc, are some examples of agricultural residues that can be used for energy purposes.

Forestry Wood.

This category includes wood fuel and residues from logging and forest thinning (branches, sawdust, stumps and roots, etc).

Wood industry by-products.

These residues are produced mainly in forest-related industries like sawmills and paper. This includes materials like sawdust, husks, kernels or black liquor.

Energy crops.

Woody or herbaceous crops that are grown specifically for their fuel value. This includes short rotation (*e.g.* willow, poplar, eucalyptus) and perennial crops (*e.g.* miscanthus, switchgrass, reed canary grass).

34 These papers are based on a large number of studies using data from country level reports and European statistics. This provides us with a wide overview of the potential biomass supply in the EU countries.

Figure 8: Potential biomass supply assessment in EU-27.

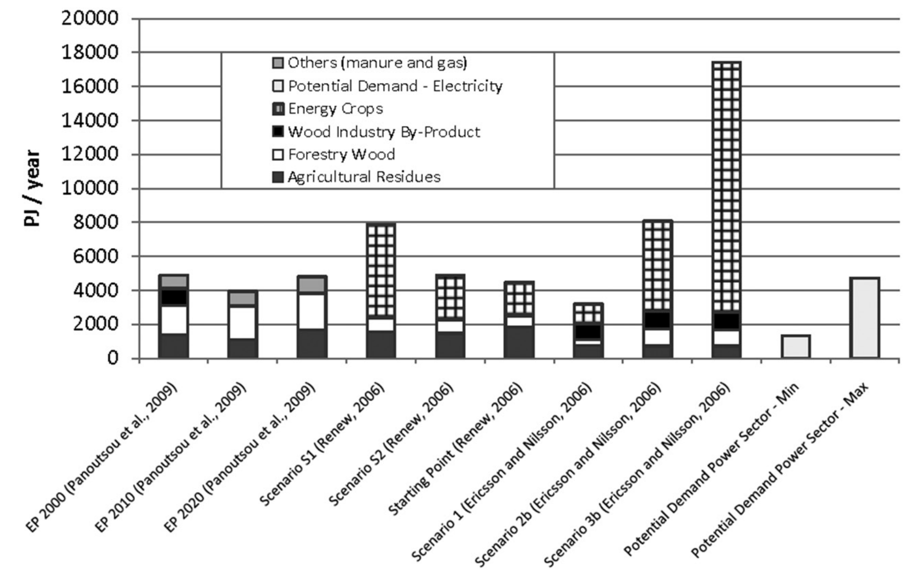


Fig. 8 indicates that there may be strong differences in potential supply estimates from one study to another. There may also be significant differences in the same study, when considering different scenarios.[35] This induces strong uncertainties about the actual biomass potential. This strong discrepancy in estimates is explained by the heterogeneity of biomass. Moreover, biomass production can be heavily dependent on the region where it is produced. Hence, different hypotheses about land availability, agronomic or weather conditions can substantially impact the results.

The main uncertainty is about the development of energy crops. Potential detrimental effects related to changes in land-use or reduced biodiversity may constitute barriers to their development.[36] The evolution of yields is also an important unknown parameter. Even though yields have increased in Europe during the last decades, we cannot be sure that this rise will continue with the same rate in the future. Renew (2006) anticipates an increase in yields from 10 to 30% by 2020 in their intensive production scenario, and from 7 to 20% in another scenario in which agricultural practices are less intensive. The share of energy crops also differs from one scenario to another.

35 Renew (2006) consider projected estimates for 2020 with high (S1) and low (S2) biomass production. Starting Point reflects the biomass potential for the years 2000-2004. In Ericsson and Nilsson (2006), scenarios 1, 2 and 3 refer to periods 2015-2025, 2025-2045, and beyond 2045, respectively. The letters in the scenario names indicate low (a) and high (b) biomass supply. Panoutsou et al. (2009) provide estimates for the biomass supply in 2000, 2010 and 2020.

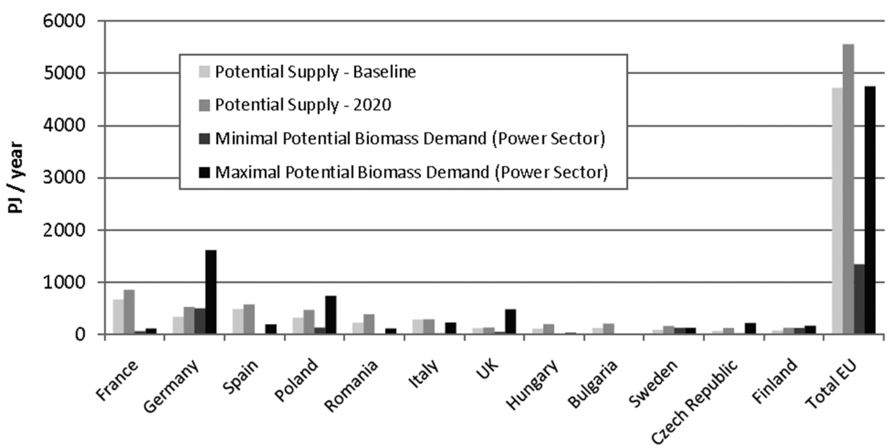
36 See Ben Fradj (2013) for an economic analysis of potential effects induced by changes in land-uses due to development of energy crops in France.

Results also depend on hypotheses about availability factors for energy purposes of forestry, wood industry and agricultural residues. Even though the same availability factors are assumed in general for all the European countries, the value can differ from one study to another. For example, Panoutsou et al. (2009) retain a uniform availability factor of 30% for agricultural residues in all the European countries. Ericsson and Nilsson (2006) and Renew (2006) distinguish the availability factor of maize (25%) and other cereals (22%).

The heterogeneity of hypotheses induces significant differences in the share of each biomass source in the overall biomass supply (Fig. 8). Globally, literature indicates that energy crops offer the most important potential source of biomass supply, with 1150 to 14000 PJ a year. The following category can be forestry, wood industry or agricultural residues, depending on the scenario and other hypotheses.

Despite great uncertainties in the supply side, when comparing the EU biomass supply estimates from literature with potential biomass demand from the power sector, we observe that demand may be quite high compared with supply and sometimes higher (Fig. 8 and 9).[37] This may induce potential tensions in the biomass market.

Figure 9: Comparison between potential biomass supply and demand in the ten EU countries with the highest potential supply.



Actually, our results indicate that the EU27 potential demand could cover between 8% (min potential demand with the Ericsson and Nilsson (2006) Scenario 3b) and 148% (max potential demand with the Ericsson and Nilsson (2006) Scenario 1) of the biomass production in Europe. This may significantly increase biomass prices. As pointed out in the previous section, a high enough carbon price can make co-firing profitable even with very high biomass prices. Hence, high biomass prices can be affordable in the power sector, whereas this can constitute barriers for other competing biomass usages.

When comparing situations of different EU countries, Fig. 9 indicates that there are great differences in the balance between potential demand and supply. While some countries have a heavily positive balance (*e.g.* France, Spain), meaning that they can produce more than the potential demand from inland power generation, others countries have a significantly negative balance (*e.g.* Germany, the UK). Hence, one may conclude that a lot of trading opportunities could exist between the EU countries. For instance, France would export a substantial part of its biomass resources to Germany. While, in general, feedstock costs are relatively low in the case of biomass, additional costs related to logistics and transportation may be much more significant (Hamelinck et al., 2005). However, as pointed out in the first section of this chapter, several pre-treatments can be applied to raw materials in order to densify biomass and save transport and handling costs. This would facilitate biomass trading among European countries and beyond.

5. Conclusion

Biomass is increasingly acknowledged as an efficient way to develop RES in Europe. Using biomass in energy makes it possible to reduce CO_2 emissions and other pollutions, as well as energy dependency. This also creates opportunities for developing rural economies. Furthermore, unlike other RES such as wind or solar, biomass is not subject to problems of intermittency when used to generate electricity, which increases reliability and lowers the cost of managing power generation.

Biomass is of particular interest in electricity, where there are great opportunities to substitute fossil fuels with no or little investments, through biomass co-firing in coal power stations. Co-firing has numerous technical and economic advantages, which explain why it is often considered the easiest, most efficient, and least expensive option for developing biomass in power generation. These advantages include high conversion efficiency, fuel flexibility, low investment costs, etc. Co-firing can also generate constraints for coal plants, which may limit the utilization of biomass. Most of these limitations are related to biomass quality. However, they can be considerably reduced through various pre-treatments that can be applied to raw biomass in order to improve the quality.

Co-firing is expected to play an important role in developing biomass in power generation. The biomass quantities that are technically attainable in the power sector are expected to be quite substantial, because of the great

37 In Fig. 9, the Baseline Supply Potential refers to the average of values provided in the Renew (2006) Starting Point and in the Panoutsou et al. (2009) EP 2000. The 2020 Supply Potential is the average of values in the Renew (2006) S1 and S2, the Ericsson and Nilsson (2006) scenario 1, and the Panoutsou et al. (2009) EP 2020.

co-firing potential with the high share of coal in the European power mix. This appears in our estimations, which show a high potential biomass demand in the European power sector, with up to 80% of the overall potential demand that may come from co-firing. Co-firing can also produce high volumes of CO_2 abatements, which may account for more than two times the potential abatements from the coal-to-gas fuel switching.

Comparing our estimations for potential demand from the power sector with the potential supply of biomass in Europe, we see that using biomass in power generation may generate tensions in the biomass market if a high share of potential biomass demand turns out to be economically profitable. Our economic analysis regarding biomass and CO_2 breakeven prices highlights economic conditions that make co-firing profitable. We show that co-firing profitability depends on the quality of biomass and on the type of coal plants involved. In some cases, considering biomass prices that reflect the current market conditions, we find that co-firing can be profitable with a zero or very low carbon price. Interestingly, we also derive from our framework that a profitable co-firing remains possible with very high biomass prices, when the carbon price is high enough. Hence, the carbon price appears as an important driver of co-firing. Determining the interest for switching to co-firing, the carbon price determines the biomass demand from power producers and potential tensions in the biomass market. A high enough carbon price can induce a strong biomass demand in the power sector (and in other carbon dependant sectors), even with a substantial increase in biomass prices compared with their current levels. However, as biomass stocks are limited, such a situation would result in potential conflicts between different biomass usages.

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Chapter 6

Forest transition and REDD+ in developing countries: challenges for climate change mitigation

Gabriela Simonet and Julien Wolfersberger

1. Introduction

Deforestation in developing countries is responsible for considerable ecological damage, including flooding and soil erosion. In addition, deforestation is among the main factors contributing to global greenhouse gas (GHG) emissions, accounting for approximately 10% of these emissions (Werf et al., 2009).

According to the Forest Transition (FT) theory, net deforestation in a given country ends up to halt once reached a threshold of development. This theory (Mather, 1992) is based on observation of developed countries, such as France or the USA, which have implemented a permanent transition in their deforestation, from positive to negative rates. In the global context of climate change, implementing such a transition is now a major challenge for developing economies. The end of net deforestation in a country reduces emissions from the forestry sector and helps preserve biodiversity, water quality and other ecosystem services.

The REDD+ mechanism, which aims at Reducing Emissions from Deforestation and Degradation, may be a good way of achieving these transitions in developing countries. Indeed, the central idea of REDD+ is to help reduce the rate of deforestation by providing financial compensation to the countries concerned, possibly leading to earlier transitions.

To achieve this, some adjustments need to be made since REDD+ does not currently take into account the heterogeneity between countries, especially in terms of development. Clearly, different stages of development/deforestation call for different policies. For them to be effective, it is then necessary to implement programmes suited to the macroeconomic characteristics of each country.

In this chapter, we tackle the issue of FT in countries involved in the REDD+ mechanism. For this purpose, REDD+ is discussed in light of the different development stages within the FT framework. In addition, by distinguishing primary and secondary forests, we attempt to provide an accurate picture of the transitions' benefits on climate change and biodiversity. Our work offers insights for the design of public policies.

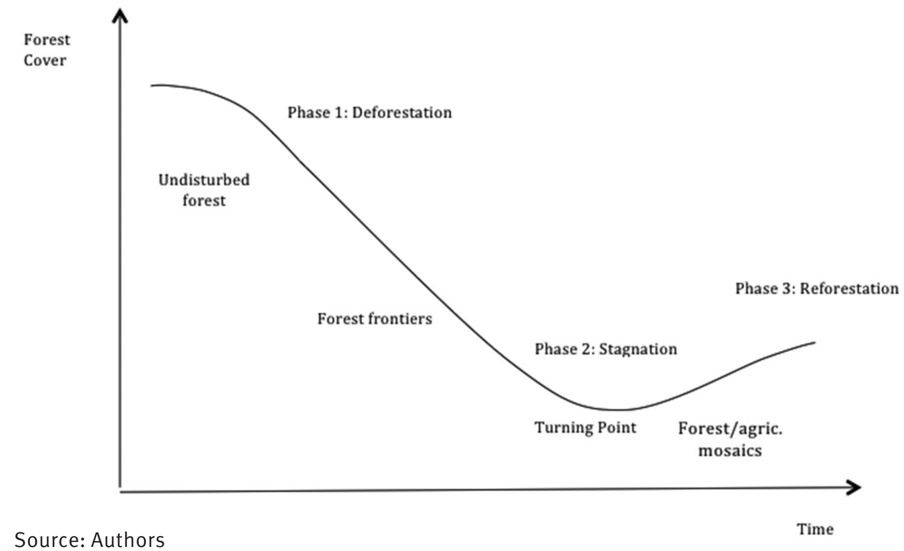
In the following section, we present the FT theory and suggest an extension of this theory by integrating the type of forest (i.e. natural old-growth forest or plantations). Section 3 introduces the REDD+ mechanism and discusses the potential improvements in its efficiency when taking into account the development stages. In section 4, we highlight the impact of REDD+ on future transitions when separately considering primary and secondary forests. We conclude in section 5.

2. Forest transition theory, REDD+ and deforestation

Development and deforestation: the Forest Transition hypothesis

Land use constantly changes throughout a country's development. In the early stages, the main trade-off is between agriculture and forest. On the basis of empirical observation, Mather (1992) developed the Forest Transition (FT) hypothesis, describing the evolution of the forest cover in a given country over time. Based on the French case, Mather argues that a country's forest cover undergoes various major phases: first deforestation, then stagnation, and finally reforestation. These phases correspond to different forest contexts/stages, as presented in Figure 1. Prior to deforestation, we refer to *undisturbed forest*. The *frontier areas* stage comes next, during which land and forests can be exploited. Finally the *forest-agriculture mosaic* stage occurs, in which forests have both high financial and environmental values (Chomitz et al., 2007). The moment of minimum forest cover is termed the *turning point*.

Figure 1: Forest Transition



Source: Authors

Initially, most of the land is forested (the undisturbed forest stage), with little variation in land use. The country is in a pre-development stage, with developing infrastructure roads and rent from agriculture and forest.

With the development of infrastructure and the control of all the land, the growing population migrates to previously inaccessible areas, for rent seeking in forest and agriculture. Agriculture-based development takes place, providing income, food and energy. The marginal value associated with agriculture becomes higher than that of forest and the land-use trade-off favours land conversion. An abundant supply of labour and the low cost of access to land ensure high agricultural rents. This is the major phase of deforestation, at the end of which GDP per capita and the capital stock significantly increase. Subsequently there is greater investment made in new and more profitable sectors, particularly industry, and the pressure on forests slowly decreases. The country concerned is approaching the turning point.

The gross deforestation rate finally turns sustainably from positive to zero or negative. Different paths may account for this switch. In the *economic development* path (Rudel et al., 2005), new non-rural jobs, with higher wages, emerge from the development of the economy. Farmers leave their land for new jobs, leading to a rural exodus and urbanisation, with some of the abandoned land reverting to forest. Furthermore, *forest scarcity* (Rudel et al., 2005) causes the price of wood to rise and may result in environmental problems such as flooding and desertification. The marginal value of forestland becomes higher than that of agriculture. Some tree planting programmes take place on previously less productive agricultural land, although natural forest harvesting may continue.

In addition to *economic development* and *forest scarcity*, more recent pathways have been identified in studies to explain the occurrence of the turning point (Lambin and Meyfroidt, 2010). *Globalization* can help reaching a transition, with the adoption of economic reforms leading to the growth of non-agricultural sectors, including tourism, and the emergence of environmental concerns. For instance, in Costa Rica, the creation of protected areas speeded up the arrival of the turning point. Another pathway involves social and political will. For example in Bhutan, the forest cover is not legally permitted to fall below 60% of total area. As a result, the country underwent a turning point several years ago, and a high level of forest cover remains in place.

Because it describes the entire evolution of the forest cover, the FT theory is an effective tool for studying deforestation issues, especially in the long term (Delacote, Garcia and Wolfersberger, 2013). A challenge now is to introduce new features to this theory. To better correspond to empirical facts, instead of focussing on gross forest cover, FT should be viewed as the transition between two dynamics – deforestation of natural old-growth forest and reforestation through planted forest. Clearly, since natural and planted forests do not provide the same environmental benefits, there are various consequences to this shift.

Forest Transition: towards a more complete theory

Replacing a hectare of primary forest by a hectare of secondary forest is not without consequences. The two types of forests have different characteristics, particularly in terms of timber harvesting and the impact on climate and biodiversity.

The way timber is harvested in tropical forests is determined by economic incentives. In this context, primary and secondary forests are harvested differently. Selective logging occurs in natural old-growth forest. Around the frontiers, industry or smallholders harvest high-value species, which allows them to raise capital and reinvest it in agricultural activities (Asner et al., 2009). This is how selective logging may ultimately lead to complete deforestation of some areas of primary forest. On the other hand, planted forests are associated with commercial and/or environmental objectives. Depending on global rents and price variations, plantation harvesting can become more profitable than agriculture or old-growth forests, leading to large-scale plantations. This takes place either on previous croplands or directly leads to old-growth forest clearance, such as in Chile with commercial pines.

Regarding climate impact, the question of whether more carbon is sequestered in old or young forests is still controversial, to the extent that a website is dedicated to the issue[38]. Luyssaert et al. (2008) highlight the fact that "old-growth forests accumulate carbon for centuries and contain large quantities of it" so it would take a long time before a newly planted forest stores the same amount of carbon. However, primary old forests capture new carbon at a very slow or zero rate (an idea contradicted by Luyssaert et al., 2008). Planted forests may hold a smaller amount of carbon, but their sequestration performance is larger. If the new forest is planted after having harvested old growth forests, the result of the intervention in terms of climate change mitigation might not be positive before a very long time, but in case of afforestation of a degraded land or ecosystem restoration, the results are better. Montagnini and Nair (2004) compare three options for climate change mitigation: carbon Sequestration (afforestation, reforestation, restoration of degraded lands, agroforestry), carbon conservation (preserving carbon in biomass and soil in existing forests, improved logging techniques, fire protection), and carbon substitution (increased use of bio-fuels, introduction of bio-energy plantations). They conclude that carbon conservation has been regarded as the most effective method of rapidly mitigating climate change, whereas carbon sequestration takes place over a long period of time. In this last category, agroforesty systems are particularly interesting as they link forestry and agricultural production and can thus, under certain conditions, conciliate environmental and development issues (Simonet and Wolfersberger, 2013).

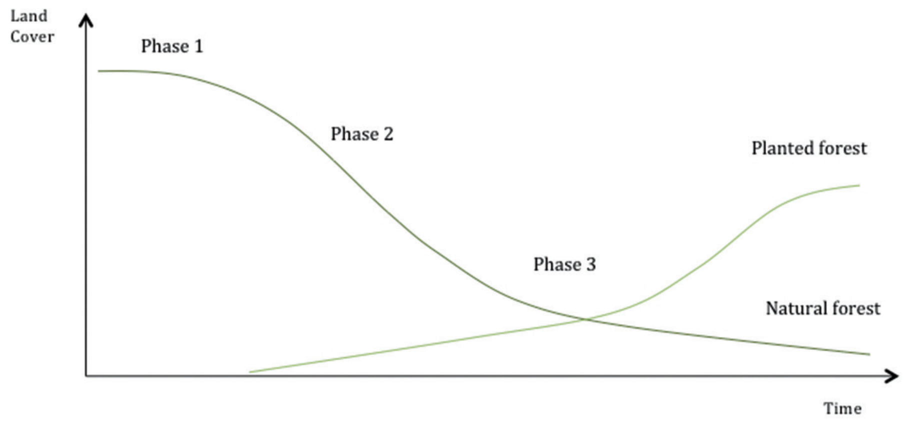
Regarding carbon dioxide emission, it is therefore more efficient in the short and mid terms to conserve old forests than to plant new ones, while this statement may be reversed in the long run, if planted forests are sustainably managed.

Concerning biodiversity, it is well known that natural world forests host most of the planet's total biodiversity. According to Burley (2002), tropical forests are home to 50% of the known vertebrates and 60% of plant species. Reforestation does not necessarily lead to a loss of biodiversity. For example, ecosystem restoration on degraded land improves biodiversity. Conversely, the substitution of primary forests by secondary ones will have a negative impact on biodiversity, particularly in the case of monocultural plantations.

Figure 2 represents the FT as the transition between two dynamics of forest cover. The turning point occurs when the two curves intersect.

38 See http://oldvsyounggrowthforestasoffset.weebly.com/index.html

Figure 2: FT hypothesis as the transition between two dynamics



Source: Authors

This distinction between primary and secondary forests provides new insights for global research. As seen above, primary forests have a higher environmental value, at least regarding climate and biodiversity issues.

It is then relevant to integrate the distinction within the FT theory. Analyses may be more accurate and lead to new results since the substitution between the two types of forest is not perfect. Section 3 provides insights of the innovative results that can be found by integrating the two dynamics in the FT theory.

Deforestation issues have been regularly discussed in the past couple of decades. In the mid 80's, Integrated Conservation and Development Projects (ICDP) were introduced with the aim of reconciling biodiversity and rural development issues at stake in protected areas. With the signature of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, the question of climate change was brought to the forefront of international debates. This created a renewed interest for tropical forests, with a new focus on their carbon stock. In this context, the next session analyses the potential of the two dynamics highlighted above for climate change mitigation.

The two dynamics of forests: two levers to combat climate change

Since the 90's, the interest for forests in developing countries has been reinforced by the new focus of the international sphere on climate change.

The significant role of tropical deforestation in the global emissions of greenhouse gases (GHG) provided an additional argument to support forest conservation. Emissions from deforestation were first estimated at around 17.4% of the global anthropogenic or 22.7% of the global emissions of carbon dioxide (CO_2) (IPCC, 2007). These figures were then revised downward to around 10% of global GHG emissions or 12% of global CO_2 emissions (Werf, 2009), but the potential of avoiding emissions by conserving tropical forests remains remarkable.

However, the role of forests in climate change mitigation is not limited to deforestation that could be avoided. Indeed, Pan et al (2011) stressed the important carbon sink capacity of forests. They reveal that around 14.8 tons of CO_2-equivalent (tCO_2e) has been sequestered yearly by global forests over the 1990-2007 period thanks to the natural growth of forests and the regrowth of secondary forests after deforestation. More than 10tCO_2e of this was achieved in tropical forests, the remaining being in boreal and temperate forests. Such figures reveal that the activities of afforestation and reforestation could capture a large stock of carbon dioxide.

Finally, forests in developing countries offer two levers to fight against climate change: avoiding the emissions from deforestation and enhancing sequestration though reforestation.

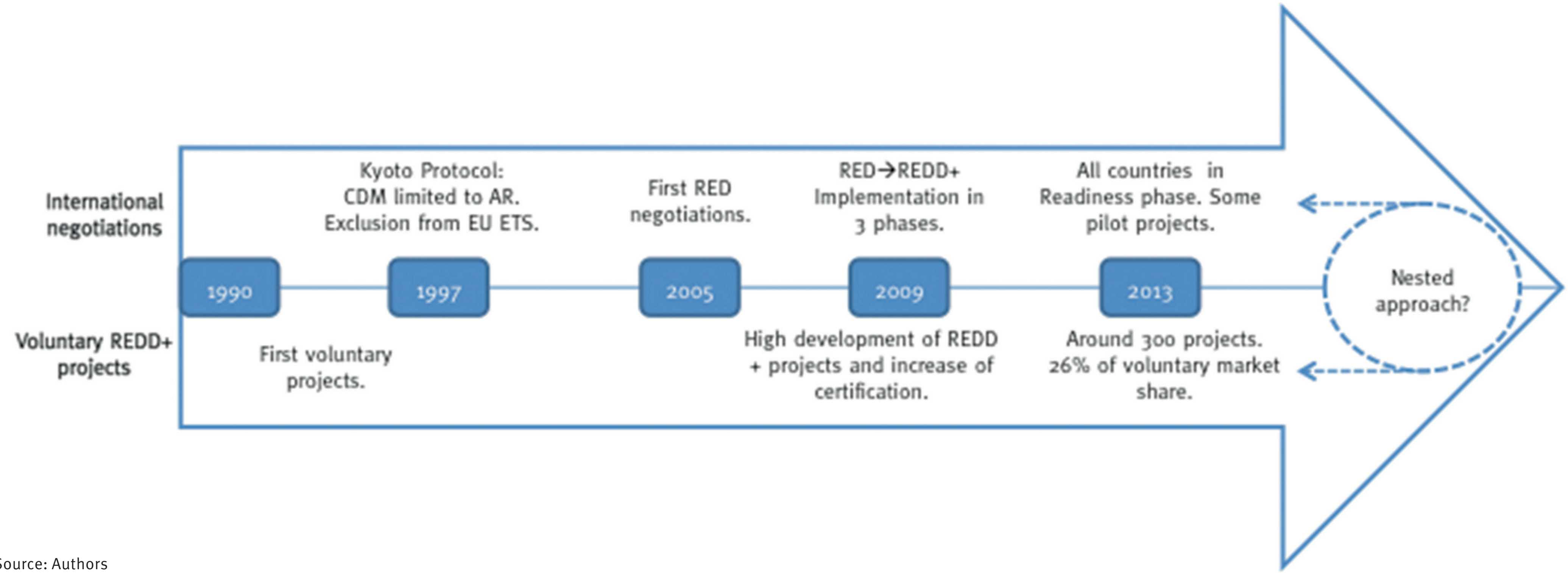
How were these two levers taken into account during the global negotiations against climate change?

The integration of forestry in climate change negotiations began slowly and remains quite limited. Forests in developing countries were integrated into the Kyoto Protocol only through the Clean Development Mechanism (CDM). Projects of Afforestation/Reforestation (AR) were the only forestry projects allowed in the CDM, deforestation projects being excluded notably because of the complexity of taking into account leakage. Forestry CDM was very unsuccessful due to the complexity of the methodologies and the lack of attractiveness of the temporary credits created specifically for forestry CDM. Finally, the decision of the European Union to exclude forestry offsets from its Emissions Trading System (EU ETS) contributed to the low development of AR CDM. According to UNEP-Risoe, there were 71 A/R CDM projects registered in June 2013, representing 0.8% of the total CDM projects in the pipeline.

In 2005, while discussions about deforestation issues had been set aside until then, Costa Rica and Papua New Guinea suggested the creation of a new mechanism that would pay developing countries for their effort to Reduce Emissions from Deforestation. The RED mechanism was born. To alleviate the problem of leakage, it was suggested that emissions could be accounted for at a national level, the issue of international leakage being still unresolved.

Then RED became REDD and REDD+, encompassing a wider variety of activities, including averted degradation, carbon stock conservation and enhancement. In 2009, it was agreed that the mechanism would progress through three phases, starting with capacity-building, before moving to demonstration

Figure 3: REDD+, a two-speed, two-scale mechanism



Source: Authors

activities and then full implementation and performance-based payments. At present, all countries are still in the first phase, also called the "*Readiness phase*", meaning that neither implementation nor payment will have been realized yet.

However, as shown in Figure 3, while official REDD+ negotiations and their application at a national scale are stalling (because key questions like the financing of the third phase remain unsolved), numerous "REDD+ projects" are blossoming in developing countries.

These projects are mainly initiated by the private sector, which saw in REDD+ an opportunity to have a new source of funding for forestry projects. Though some pilot projects concerted with governments, most of them are not integrated in a national strategy. They consist of projects with a stated goal of reducing GHG emissions through averted deforestation/degradation (RED projects) or afforestation/reforestation (AR projects). A minority of projects of Improved Forest Management (IFM) have also developed. REDD+ projects monitor and report their emission reductions and some project developers certify the process with labels like the Verified Carbon Standard (VCS). They expect to deliver carbon credits that might be sold in the voluntary carbon market, where forestry credits are particularly successful. In 2012, forestry projects generated 26% (or 19.3 $MtCO_2e$) of the volume of offsets transacted on the voluntary market (Peters-Stanley and Yin, 2013): 12% from AR projects, 9% from REDD projects and 5% from IFM projects.

REDD+ appears to be a two-speed mechanism, with a duplication of the scale of realization between the local and the national. This duplicity might be problematic when countries move to the second and third phases of the mechanism. A nested-approach is under consideration to reconcile local and national approaches, with accounting problems to be resolved.

Conservation and reforestation are both integrated in REDD+ as a double lever to fight climate change and increase forest cover. Among the countries involved in REDD+ negotiations or hosting REDD+ projects, trends might emerge between a conservation strategy and a reforestation strategy. The next section identifies these trends and analyses them within the FT theory framework.

3. Different REDD+ strategies for different phases

Policies depend on the country's position on the FT curve

REDD+ negotiations involve more than forty countries. Countries can be separated into three main groups depending on their position on the FT curve. This position has several implications regarding REDD+, as summarized in Table 1.

First, as pointed out by Angelsen and Rudel (2013), "*matching REDD+ Policies to FT stages*" is of particular interest. Developing countries have different patterns of *demand* depending on their position on the curve between the phases 1, 2 and 3. As a consequence, REDD+ *supply* must be adapted in order to achieve the best environmental deal.

Then, the different positions on the FT curve led countries to adopt different points of view during REDD+ negotiations. A first point of contrast was the scope of activities that should be included in REDD+. Indeed, REDD+ was initially limited to "Reducing the Emissions from Deforestation" (RED). The addition of the second "D" and of the "plus" led to the integration of forest degradation, forest management, carbon stock conservation and enhancement. An expansion to REDD++ is even under discussion and would include the carbon held in agricultural soils. However, the broadening of the mechanism did not receive the support of all countries, as explained further on.

Another main point of dissent, still under discussion, is the choice of the method for the calculation of the baseline scenario. This point is particularly strategic as it conditions the performances measured and thus the payments that each country will receive. Three main positions are being discussed: an historical approach, a projected approach and a stock approach. We now present in table 1 the different profiles of country on FT. Using the recommendations of Angelsen and Rudel (2013), we discuss the REDD+ strategies of countries when taking into account the two types of forest. We add examples of countries and their positions in REDD+ negotiations.

Table 1: The position of countries on REDD+ depending on FT stage

Position on FT curve	Phase 1	Phase 2	Phase 3
Profile	High forest cover, low deforestation rate.	High and medium forest cover, high deforestation rate.	Low forest cover, low deforestation rate.
Countries	Cameroon, Democratic Republic of Congo, Guyana (no projects).	Brazil, Indonesia, Mexico, Peru.	China, India, Uruguay.
Position in REDD + negotiations	REDD with projected emissions.	RED to REDD+ with historic emissions.	REDD+ focus on carbon stock.
REDD+ strategy and policy	Protection of natural old-growth forest — Develop institutions	Protection of natural old-growth forest and implementation of plantations — Reduce extensive agricultural rent	Implementation of plantations — Increase forest rents

Source: Authors

Stage 1 – Undisturbed forest:

This group contains countries with high forest cover and low deforestation rate, such as Cameroon, Colombia, Congo (Democratic Republic) or Guyana. Economic development, directly taken from the forests, hasn't started yet and the GDP per capita is still low[39]. For these countries, it is necessary to establish property rights that will frame access to rents[40]. REDD+ policy should consist of primary forest protection (i.e. RED actions) as the proportion of natural old-growth forest that could be preserved is still important.

Regarding REDD+ negotiations, countries of the first group defended the limitation of the mechanism to REDD as they are generally affected by forest degradation but rarely concerned by reforestation. Highlighting their low deforestation rates and their right to development, they struggle against a historical approach and promote the use of a projected baseline. A projected

39 Exceptions can be found when other natural resources are available, such as oil or mining.
40 In developing countries, road construction often triggers deforestation (Angelsen, 2007). Public policies should then focus on framing this, with well-defined property rights, a national forestry code, etc.

baseline has been adopted by Guyana in a bilateral agreement with Norway, allowing Guyana to maintain its deforestation at current levels.[41]

Stage 2 – Frontier areas:

This group includes countries such as Brazil or Indonesia; with a high deforestation rate and a relatively high forest cover remaining. Their growth is strongly built on forest clearing. Harvested lands are used for agricultural production, cattle ranching, oil palm plantation, etc. Industrial wood or forest products are exported. The first priority of this stage is to reduce the rent from extensive agriculture. It is necessary to implement targeted policies aiming at intensifying production. The second priority is to develop property rights and promote forces that stabilize forest cover, such as plantations. As a consequence, both RED and AR projects may be efficient.

Due to their high deforestation rates, most of group 2 countries claimed the restriction of REDD+ to RED in order to limit the number of countries that would benefit from the mechanism. This was the position of Brazil for example. Countries of this group support a historical approach instead of a projected one. Indeed, their effort to reduce deforestation and reach their objectives would be lower as their deforestation rates are particularly high and expected to naturally decrease with the development of the country.

Stage 3 – Forest-agriculture mosaics:

This group encompasses countries with low forest cover remaining and low deforestation rates, such as China or India. They are characterized by better property rights, more developed non-agricultural sectors and they participate in the global market. During this phase, REDD+ programmes are focused on tree planting and extensive plantations policies. One direct environmental benefit is to fix issues from previous deforestation, such as floods or desertification. Also, secondary forests may become sustainably managed and supply both industrial and energy producing wood.

Because of their low or negative deforestation rates and increasing reforestation rates, group 3 countries defended the expansion of RED to REDD+, China and India leading the way. A further expansion to REDD++ would benefit countries with low deforestation and reforestation, but with highly degraded agricultural soils, like Kenya or Sudan.

Countries belonging to group 3 defend a stock approach that would account for the variation of carbon stocks in national forests and would be the most eligible for taking into account their re(af)forestation or plantation policies.

41 For more details on this agreement see http://www.regjeringen.no/en/dep/md/Selected-topics/climate/the-government-of-norways-international-/guyana-norwaypartnership.html?id=592318

The position of countries on REDD+ negotiations is clearly influenced by their position on the FT curve and their national REDD+ policies should be adapted to their stage of FT. In phase 1, primary forest dynamics should be favoured, with the development of RED projects. In phase 3, AR projects on secondary forest dynamics are more appropriate. Finally, phase 2 countries should focus on both RED and AR programmes.

As REDD+ activities are currently developed on a local scale, the next section compares the type of projects developed in each country and their location on the FT curve.

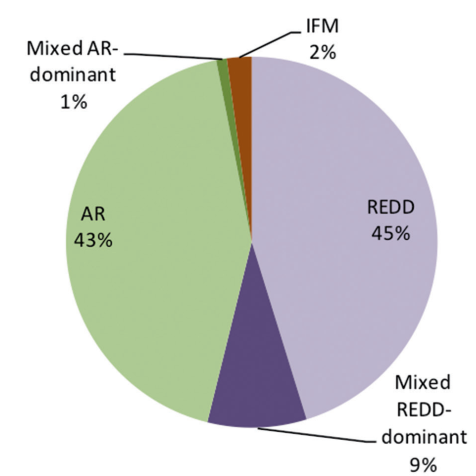
Empirical facts on RED and AR projects

To compensate for the lack of information that can be used to analyse REDD+ projects, a new database of REDD+ projects is being implemented jointly by the Climate Economics Chair and the CIRAD[42]. The database gathers information on general aspects of the projects, as well as carbon and socio-economic variables. This work is based on project certification reports (VCS and CCBA mainly) and on the data available on project developers' websites and other websites[43].

According to this database, more than 300 projects could be identified in 2013, located in 45 countries. Their location is illustrated in Figure 5.

As shown in Figure 4, 54% are REDD projects (including 9% of mixed projects whose dominant activity is conservation), 44% are A/R projects (including agroforestry, plantation and ecosystem restoration) and the remaining 2% are IFM projects.

Figure 4: Global repartition of REDD+ projects by type

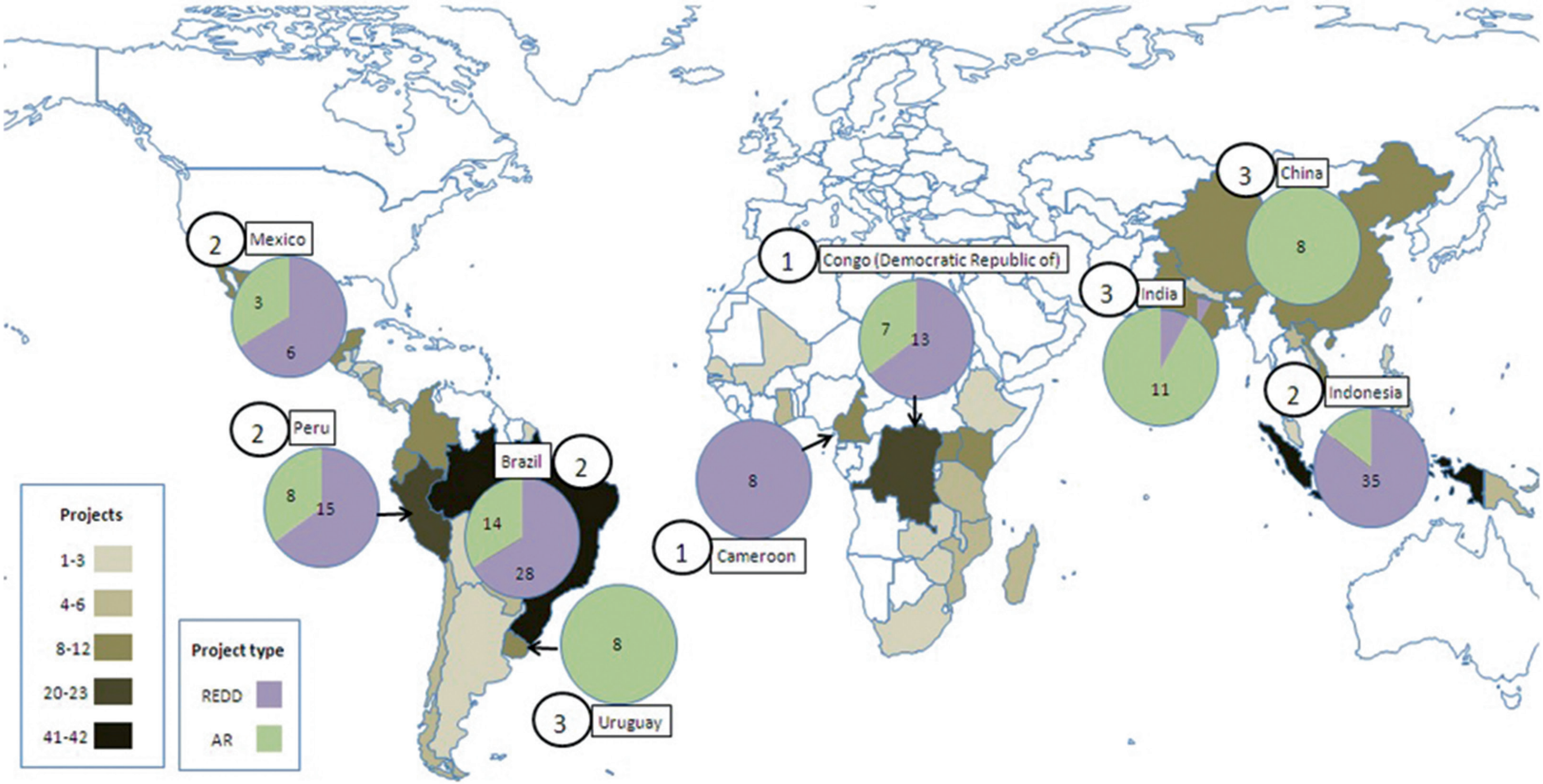


Source: Authors

42 Centre de Coopération Internationale en Recherche Agronomique pour le Développement.

43 The main ones are Ecosystem Market place Forest Carbon Portal, The REDD desk

◊ **Figure 5: Location of REDD+ projects and repartition by type for key countries**



Source: Authors

As shown in Figure 5, focusing on the countries gathering the most important number of projects, we can see that there is a link between the dominant type of REDD+ projects developed and their stage in the FT.

Countries belonging to group 1 (as defined in section 2.A) show a clear trend towards REDD projects. Countries of group 3 present mainly or exclusively AR projects. Finally, countries situated in the second stage of FT present a mix of AR and RED projects, but with a significant dominance of REDD projects. These findings corroborate our hypothesis that there is a link between the location of a country on the FT curve and its trend in terms of REDD+ projects development.

AR and RED projects have very different profiles and thus different impacts. Thanks to a preliminary analysis[44] of the CEC-Cirad database, we can see that REDD projects cover on average a much larger area and have a significantly higher potential in terms of emission reductions. The mean size of AR projects is around 3,700 ha whereas it reaches 630,000 ha for RED projects. In terms of climate benefits, AR projects are expected to capture on average 20,000 tCO_2e annually and 740,000 tCO_2e throughout the life of the project. As regards RED projects, the previsions are around 552,000 tCO_2e annually and reach 32,566,435 tCO_2e for the life of the project. These figures are consistent with Berne (2012) who analyzed REDD+ projects certified by the VCS and showed that RED projects deliver on average 26 times more VCUs (Voluntary Carbon Units) per year than AR projects and 4 times more VCUs per hectare per year. RED projects are thus more efficient in terms of climate change mitigation.

Moreover, it appears that REDD projects are generally conservation projects, with a high focus on biodiversity. One third of the REDD projects were found to cover all or part of a protected area, which is not the case for AR projects. Even though AR projects can provide many social co-benefits in terms of job creation and alternative revenues, it clearly appears that REDD projects have a higher potential for biodiversity conservation.

Projects of conservation and reforestation deliver different benefits, notably in terms of climate mitigation and biodiversity. This highlights the lack of substitutability between primary and secondary forests. Depending on how we value these environmental benefits, we can wonder whether the two REDD+ policies (conservation and reforestation) should be considered to be equivalent. In the next section, we explore the effect of promoting either of the above strategies on the "quality" of the forest transition.

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and the REDD+ database of the Institute for Global Environmental Strategies (IGES).

44 As of June 2013, project data from 6 countries (Indonesia, Vietnam, Brazil, Peru, Madagascar, and DRC) has been fully completed. The first analysis includes 121 projects.

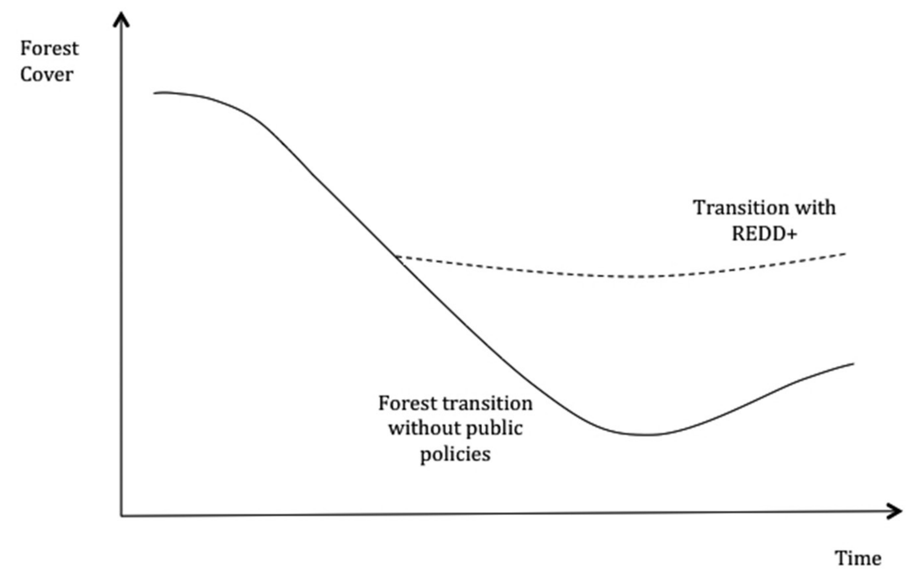
4. How REDD+ policies can lead to different forest transitions

As mentioned before, so far, the FT framework has not taken into account the distinction between primary and secondary forests, although several environmental implications are expected. These implications must be considered during REDD+ implementation.

Double dynamic and REDD+ implementation: what can we learn?

Figure 6 shows the effect of REDD+ on the FT curve, as usually presented in the literature. When REDD+ starts, the FT curve is modified. Authors conclude that more forest area is preserved during the transition.

Figure 6: A common representation of the effect of REDD+ on FT

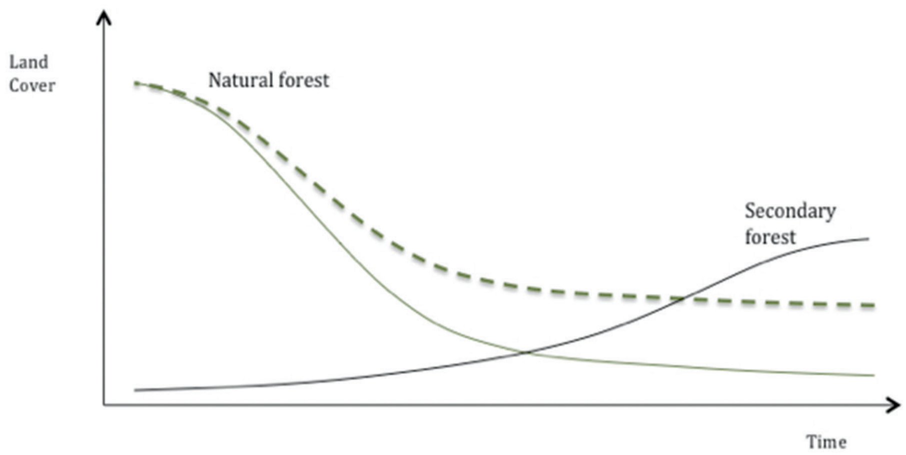


Source: Authors

This representation does not distinguish between the types of forest. However, ecological benefits may be significantly different. In the first section, we highlighted the climate and ecological benefits of natural forests compared to plantations.

When considering the two dynamics, we can show that REDD+ will have a different effect on FT depending on which of the dynamics (conservation or reforestation) is emphasized. Figure 7 illustrates the application of RED programmes on the natural forest dynamic.

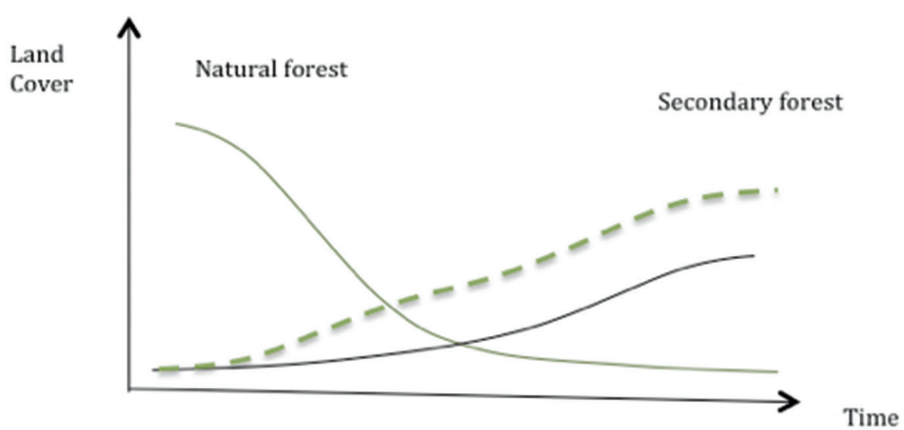
Figure 7: RED programmes on primary forest dynamics



Source: Authors

We can see that the turning point occurs (1) with more forest cover and (2) later in time. Favouring the natural forest dynamic with public policies (i.e. RED programmes) delays the turnaround in the deforestation rate. However, at the turning point, the amount of primary forest is more important. Then, during the development, more biodiversity is conserved and less carbon released in to the atmosphere. We now examine the case of AR programmes on secondary forest dynamics (Figure 8).

Figure 8: AR programmes on secondary forest dynamics



Source: Authors

In this case, the turning point occurs: (1) with more forest cover (2) earlier in time. We assume that the gain of total forest cover is the same between figure 4 and 5. It allows us to drop the hypothetical quantity effect, and focus on the quality of transitions. Favouring the second dynamic leads to an earlier turning point. However, due to less primary forest conserved, the level of biodiversity and the effect on carbon emissions reduction is lower than in figure 4. As a consequence, we observe that the second case of transition is ecologically less valuable than the first, where natural forests are targeted.

Consequences for REDD+ negotiations: towards a new valuation?

As it is still possible to preserve a significant share of natural forest, countries in phases 1 and 2 must be targeted by RED projects. On the contrary, countries in phase 3 already experienced a turning point and are mainly concerned by AR projects. Regarding economic development, it is assumed that the more advanced a country is on the FT curve, the higher its development is. These observations have implications for REDD+ payments. Even though the primary aim of REDD+ is to participate in the fight against climate change, it is believed that forest preservation cannot be addressed only from the perspective of emissions mitigation. REDD+ is now presented as a mechanism that aims at reconciling climate, biodiversity and development issues. The recognition of the multiple objectives of REDD+ was formalized by the establishment of environmental and social safeguards in the Cancun Agreement (2010)[45] (Simonet et al. 2012). In this paper, we mainly focused on the environmental aspects of REDD+. However, our reasoning must include development as countries are in different development stages with uneven dependence on forests for further development. Countries in early stages of development clearly claim that REDD+ should be a "tool for development", such as Cameroon in its Readiness Preparation Proposal (RPP)[46]. A last argument showing that REDD+ is closely linked to development is that development assistance is currently the main source of funding for REDD+, raising the question of the conditionality of the aid.

If we decide to take into account economic and ecological issues at stake with REDD+ and not only carbon, then financial compensations should differ between RED and AR strategies.

In this regard, phase 1 countries should receive the highest levels of compensation. They are still undeveloped and have the most important ecological value (i.e. the highest potential for natural forest preservation). With adapted public

45 http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf#page=2
46 See p 1 of RPP:
http://www.forestcarbonpartnership.org/sites/forestcarbonpartnership.org/files/Documents/PDF/Aug2012/Cameroon draft R-PP — August 6, 2012.pdf

policies, they are more likely to experience a transition such as described in Figure 4.

Phase 2 countries are close to phase 1 countries, as they still have a non-negligible share of natural forest to preserve. However, as they have already implemented sustainable economic growth and lost substantial amounts of primary forest, payments should be less important than for phase 1 countries. For instance, Brazil boosted its economic growth by harvesting the Amazon forest, but still has a significant amount of primary forest to preserve.

Finally, phase 3 countries are logically the ones where payments should be the lowest. They are developed, have observed a turning point, and a low stock of natural forest remains. For instance, in China, the GDP per capita is high and plantation programmes have been initiated since the 1980s. Local tree-planting projects were first implemented, and finally took a large-scale dimension at the end of the 1990s, with the "*Sloping Land Conversion Program*" (Mather, 2007). Likewise, the Indian government introduced a new forest policy in 1988. The pursued objective was to get one third of the total land under forest, in order to reach environmental stability and meet fuel wood demand (Lambin and Meyfroidt, 2011). This proves a certain level of development, which has often been obtained by previous old-forest harvesting.

This raises the issue of evaluation in REDD+, which is a performance-based mechanism. Until now, performance has only been considered in terms of CO_2 emission reductions. In this paper, we argue that other elements should be taken into account in the calculation of performance.

The first reason is that carbon emission reductions in the forestry sectors are particularly difficult to measure and monitor, due to complex issues such as non-permanence, leakage and baseline scenario. These barriers lead to an expensive and uncertain monitoring of emission reductions, which slow down considerably the development of the REDD+ mechanism. Several cases of dubious accounting at project scale have been denounced, weakening the credibility of REDD+. Lowering the weight of carbon accounting in REDD+ payment might thus avoid such problems.

If the role of REDD+ as a mechanism to protecting biodiversity and to participate in a country's development is recognized, payments should be indexed on more elements than emission reductions. Karsenty (2012) recommends the definition of performance criteria that include proxies for all measurable activities contributing to reducing deforestation and not only the emission reductions themselves. The possibility of taking into account governance indicators such as the one created by UN-REDD[47] could notably be discussed. Considering the non-substitutability of primary and secondary forests, we suggest that biodiversity and development aspects should also be taken into account. Simple indicators must be found in order not to result in a more complex process.

To summarize, REDD+ payments should be indexed on two main features: (1) the potential environmental benefits of the transition and (2) the development stage of the given country.

5. Conclusion

In this chapter, we discussed the positive effect of REDD+ on future forest transitions in developing countries. An important contribution of our analysis is that we distinguished natural old-growth forests from plantations in the global FT framework and then provided more accurate results in terms of environmental benefits.

We first saw that in order to efficiently influence the FT in a country, REDD+ policies should take into account its macroeconomic background. For phase 1 countries, it is important to control the main factors that usually trigger massive deforestation (e.g. development of infrastructures, entrance into global markets, etc.) of primary forest. The priority for phase 2 countries is to limit extensive agricultural production and preserve the remaining natural forest. As phase 3 countries have already reached a turning point, plantation programs generally become the most common strategy.

We then show that the choice of the REDD+ strategy (conservation or afforestation) for countries in phases 1 and 2 has an impact on their future forest transition. When conservation projects are applied to primary forest, the FT may occur later in time but with more environmental benefits. Indeed, more biodiversity and ecosystem services are conserved since more natural old-growth forest is preserved. Also, less carbon is released into the atmosphere. On the contrary, favouring the dynamic of reforestation leads to faster transitions but with fewer environmental benefits.

As a conclusion, REDD+ may be an adequate tool for speeding up forest transitions if it takes into account the entire ensemble of features of countries, both environmental and economic. In addition, depending on REDD+ policies, different transitions may emerge, with greater or lesser environmental benefits. The success and the pace of these public policies now obviously depend on the willingness of countries to reverse the trend and the ability of public decision-makers to question the effectiveness of their policy.

47 http://www.un-redd.org/NewsCentre/Support_to_Effective_Governance/tabid/5543/Default.aspx

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Part 3

Mobility in a Low Carbon Society

In 2010 intra-European freight transport amounted to 3,831 billion tonne-kilometres. It grew by 1.5% annually in the period 1995-2010 and, after a downturn in 2008 due to the economic crisis, by 5.3% from 2009 to 2010. To introduce the appropriate signals for limiting externalities related to freight transport, a toolkit containing a large number of instruments is available for public policy makers. But the practical application of these tools is difficult because of the inter-relatedness of the underlying issues and because of the multimodal and multi-level nature of the transport industry. One of the messages that emerges from the analyses in Part 3 is the need to consider the effects of environmental policies pertaining to the transport sector through a "systemic" approach regarding urban constraints. The second message is that only those actors able to anticipate and innovate will be in a position to turn regulatory constraints into real opportunities, thereby participating in the design of future regulatory systems.

Two chapters address this question of the practical and efficient implementation (and coordination) of regulatory tools for transport.

Chapter 7, *Specific challenges of the transport sector for implementing carbon regulation*, addresses the complexity of transport systems, which is dependent on multiple objectives, externalities, sectors, levels and players and is subject to inertia. Despite this complexity, the chapter focuses on key factors likely to influence behaviour in the medium and longer term and examines the relevant issues when implementing economic tools for carbon regulation in road transport.

Chapter 8, *Low-carbon policies for road transportation in Europe*, proposes a classification of policy tools based on the form of action taken by the instrument (e.g. whether it is binding or non-binding). This leads on to the differentiation of regulatory constraints, price incentives, collaborative tools and information policy and an assessment of their potential impact on the demand and supply sides.

Chapter 7

Specific challenges of the transport sector for implementing carbon regulation

Maxime Le Roy, Bénédicte Meurisse
and Claire Papaix

1. Introduction

The human and economic development of a world whose population is rapidly rising cannot occur without increasing the mobility of people and goods.

Yet rapidly increasing traffic and a high dependency on fossil fuels have made transport a crucial issue with regard to action to combat climate change. Indeed climate action regarding the transport sector is particularly challenging. In 2009 the sector accounted for 30% of total CO_2 emissions in the European Union and 38% in France (EC, 2012a), and levels have increased relentlessly since 1990 (by 26% between 1990 and 2007; EEA, 2011), whereas CO_2 emissions in other industrial sectors have decreased (by 15%) over the same period.

In its publication "A roadmap for moving to a competitive low-carbon economy in 2050", the European Commission has set the objective of reducing transport GHG emissions by 2030 to 20% below their 2008 level, and has called for a 60% cut by 2050 compared to the 1990 level. The European Commission has also pledged, in its White Paper of 2011, to halve the use of conventionally fuelled cars in urban transport by 2030 and to phase them out in cities by 2050. Similarly in France, the French Climate Plan launched in 2009 adopts the objective set in the Grenelle 1 Act to cut transport GHG emissions by 20% by 2020, i.e. to return to 1990 levels within this period.

To change people's travelling practices, which at the very least are constrained by their travel requirements, and thus reduce CO_2 emissions from transport, economic theory offers public policy-makers a number of levers and tools. But these instruments remain extremely theoretical. When applied to problems of mobility in the real world they have neither the same effectiveness nor the same relevance as the theoretical models predict.

The transport system is distinctive because of its complexity. It has multiple objectives, multiple externalities, multiple sectors, multiple levels and multiple players (Section 1). This complexity is augmented by the inertia characterizing the sector (Section 2). Nevertheless, some key factors are likely to influence behaviours in the medium and longer term (Section 3). In addition, since road transport accounted for 72% of the sector's CO_2 the EU-27 in 2009, and 79% in France (EC, 2012a), we choose to focus in this chapter solely on road transportation and more specifically on passenger cars, which in France, for example accounted for 57.4% of road emissions in 2010 (CCTN, 2011). We will show which issues are relevant when implementing economics tools for carbon regulation in road transport.

2. An integrated approach to the complexity of the transport system

Multi-objective public policy instruments

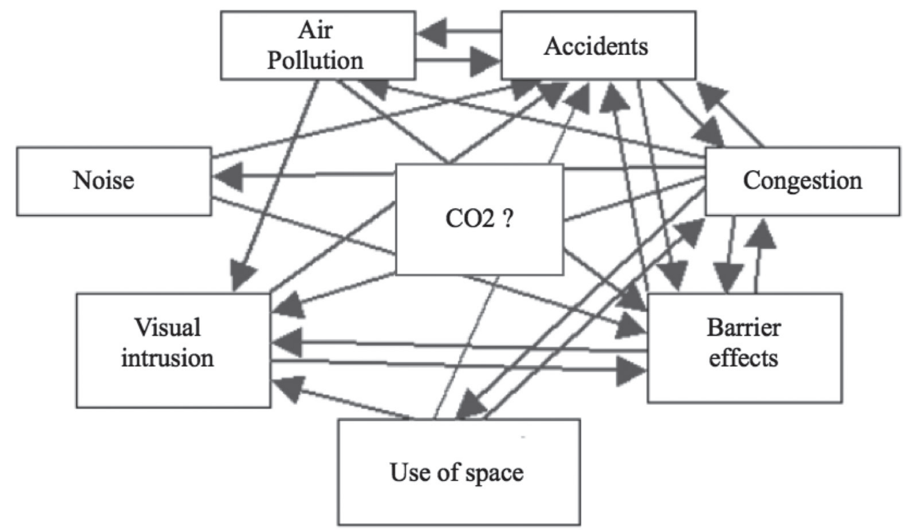
Several instruments can serve the same objective (see the overview in Chapter 8 of the policy toolbox for low-carbon road mobility in the European Union). Indeed the impacts of the various instruments cannot be separated. In other words, the effects of different policy measures are not cumulative and all these policies thus have to be addressed simultaneously. But multiple objectives – such as fighting against congested roads (where one in four heavy goods vehicles still runs empty in the EU (EC, 2012b)), increasing road safety (while maintaining attractive working conditions for transport professionals), reducing air and noise pollution and the carbon footprint of road transport (without hampering people's purchasing power) and moving the system towards cost-effective options, especially with regard to urban and intermodal transport solutions as alternatives to road haulage – can be also pursued at the same time by a single instrument. This possibility runs counter to the economic theory that states that in order to ensure the effectiveness of a public policy in an optimal situation a separate regulatory instrument must be associated with each objective.

That a single instrument can address several objectives at once is partly due to the fact that transport, particularly in densely populated areas, brings into play a series of externalities, both positive and negative. Figure 1 illustrates the interactions (self-augmenting or self-reducing effects) among the negative externalities of urban mobility. It will be seen that on this scale all the externalities are interrelated, so that it is impossible to target only one of them. Among the external benefits of transport systems, which are harder to measure than negative factors, the most often cited are: economies of agglomeration (i.e. gains in competitiveness and effects on innovation and employment which come from the development of transport networks enabling businesses to be located near to each other), and the redesignation of buildings or the "Mohring effect", that is to say the increased returns on public transport investment. Furthermore, investing in public transport

gives the local authority concerned specific assets for endogenous growth, which are especially useful in a situation of heightened territorial rivalry.

In connection with what has been said about the different ways of coordinating the instruments and objectives of public policy, combining so-called "bottom-up" tools can affect users' travel behaviour over time (changing the time of travel, the number of passengers, the equipment, the mode, etc.) and in space (relocation, etc.) and thus ultimately alter all the externalities of the urban mobility system (congestion, problems of road safety, respiratory disease and death, noise, etc.) and in particular the level of CO_2 emissions.

◊ **Figure 1: Interactions between the negative externalities of urban mobility**



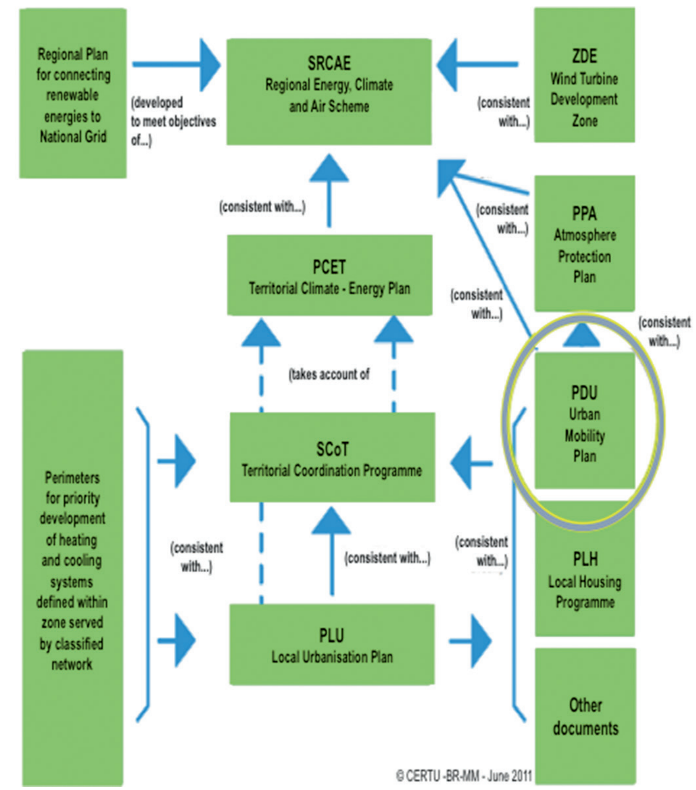
Source: Héran, F. (2011), "Pour une approche systémique des nuisances liées aux transports en milieu urbain", AFITL pp. 83-112.

Taking into account this system of interactions between the negative externalities generated by urban mobility (see Figure 1) and investigating the benefits in terms of reducing CO_2 emissions, which could be created by activating the standard levers of urban transport policies, are of particular interest to local policy makers. Given that the externalities of mobility systems are correlated, the fact one instrument (a carbon tax, for instance) can simultaneously address more than one of these external costs (CO_2 *plus* congestion *plus* air pollution, etc.) serves transport decision-makers, especially in the case of an underestimated "climate friendly" transport project. Climate gains are, for instance, evaluated at over 30 times less than congestion improvements following a decrease in passenger-km on the road (in 2012, they represented, for example, at 2009 rates, 0.45 euro cents (2009 rates) per passenger-km reduced in high density areas, while the corresponding congestion value was 16.6 euro cents per passenger-km reduced (see Table 1 below)). Thus once again, acting on behalf of the climate in terms of urban mobility and taking into account simultaneously all the effects produced by the action reinforces its social benefits, whereas if the action had been considered in isolation it would have been of no interest to the policy maker.

Interdependent policies by sector

In the current situation of marked urban growth in the regions, transport policies are not alone in looking for existing benefits at the local level. Housing, shops, offices, universities, etc. all want to cohabit in city centres. More generally, the interdependence of public transport policies and those in other sectors creates a major challenge for public policy makers. Local authorities are required to take into account all the market mechanisms and government decisions which can affect transport supply and demand. In other words, they have to coordinate their transport policies with urban development policies, housing policies and economic development policies (see Figure 2). In France, policy-making areas have been less compartmentalised since the passing of the Chevènement law in 1999 and the creation of Urban Transport Authorities (AOTU).

Figure 2: Local authority coordination of transport organisation and urban planning



Source: CERTU (2011), "Schéma régional du climat, de l'air et de l'énergie (SRCAE): articles 68, 69 and 70 of Grenelle 2 legislation" Fiche n°1 Décryptage Grenelle.

A multi-level decision-making process

Apart from the necessary coordination of public policies by sector, transport policies also need to be coordinated mutually. Indeed, one of the major issues for public policies on transport comes from the governance models, since the uncertain vertical and horizontal (see, for example the case of Low Emission Zones in chapter 8) coordination by the public authorities hinders the implementation of economic and environmental policies and responses from private players in the transport system. However, new tools (Agenda 21, climate plans, etc.) are beginning to bring together experimental actions.

A transport system with multiple stakeholders

There are a large number of players at the various levels – urban, interurban and national – of mobility management. They may be local authorities – municipalities and groups of municipalities, *départements* and regions

– or public bodies and establishments. In France, as Figure 2 above shows, within a given geographic area (for example, the reach of the Urban Mobility Plan (*PDU*), known as *PTU*) there are numerous public stakeholders with different fields of responsibility.

They may also be (increasingly diversified) private actors. For example, new Information and Communication Technologies allow personal mobility to be measured, providing a possible response to the problem of stowaways, which for transport is a major economic issue.

Furthermore, while public players on the one hand and private players on the other are ever more numerous, the two are increasingly linked through Public-Private Partnerships (PPPs), i.e. Public Service Delegation contracts (motorway concessions in France are a good illustration) and partnership agreements to provide mobility services and thus share their resources and skills as well as the associated risks.

Economic and social impacts: an intelligent economic calculation

Since the passing of the domestic transport framework legislation (LOTI) in December 1982, the theoretical socio-economic profitability of major projects has to be evaluated and the results published before authorisation for the project is given. To implement this cost-benefit analysis, reference values are commonly used by decision-makers. The main interest of these values lies in allowing a comparison between different public policy projects, but they are not exempt from criticism: being based on a high number of factors (e.g. dense urban, sparse urban or rural, for location), the reference values tend ultimately to reflect political choices. Table 1 gives an overview of such values (*valeurs Boiteux II*) in 2012 expressed as euro cents (2009 rates) per passenger-kilometre applying to the appraisal of French transport projects.

► Table 1: Evaluation of the external costs of passenger transport (France, 2012. Euro cents at 2009 rates per passenger-kilometre)

	Dense urban	Sparse urban	Rural
Environment	2.24	1.17	0.74
CO_2	0.45	0.45	0.29
Local air pollution	1.15	0.62	0.44
Noise	0.64	0.1	0.01
Lack of safety	4.75	1.83	1.14
Congestion	16.6	2	1.19
Infrastructure use	0.57	0.57	0.37
Total	24.2	5.6	3.4

Source: CGDD (2012), "Étude sur les externalités des transports — Le mode routier". Service de l'Économie, de l'Évaluation et de l'Intégration du Développement Durable, Sous-direction Mobilité et Aménagement. June 2012.

Such major transport projects can be grouped under the heading of "transport services" and classified in descending order of materiality: traffic, access and parking infrastructure, vehicles (except when operating), different consumables (energy), and driving, guidance and flow management services.

Following the introduction of a new transport service or its modification, the welfare (labelled profit) of the service provider and also of the user of the service (labelled utility) varies. In theory, *a priori* public economic calculation should precisely take into account these variations or "producer and consumer surplus".

In practice, however, to be integrated into the evaluation, these variations in producer and consumer surplus have to be modelled and simulated. It should be noted that among all the elements that make up the producer surplus on the one hand (changes in traffic volumes, operating costs, etc.) and the consumer surplus on the other (travelling time, comfort, environmental effects, etc.) very few are actually taken into consideration in economic calculation. For instance, the knock-on effects of transport services on economic activity, residential prices, the reorganisation of daily domestic consumer and corporate consumer activities, etc. are often omitted in *ex-ante* and/or *ex-post* surplus appraisals.

We have recently come to realize that there is a toolkit available to public policy-makers for regulating the transport system so as to produce less CO_2 and more generally limit its impact on the environment. But the practical application of the tools in the sector is made difficult by its extreme complexity, as we have seen above. This complexity is reinforced by the many examples of inertia found in the sector.

3. Inertia in the transport system

The transport system is characterized by various types of inertia.

Inertia in the decision-making process

The characteristics of the transport policies presented above imply that public decision-making is generally slow. Conflicts of interest, for example, are all the greater because of the large number of associated sectors (energy, housing, etc.) and players concerned. As well as the difficulty of reaching a political consensus between decision-makers, there is also the challenge of sharing information openly. In large urban administrations, information is often shared between players of different status and may therefore be incomplete. Moreover, in the area of environmental policies, the difficulty of obtaining the data needed to carry out prior economic evaluations (quantifying CO_2 emissions, for example) further slows down the process.

Inertia due to infrastructure

Transport infrastructures that are highly structuring for many activities such as production, distribution, social activities, etc. are non-redeployable assets. This means, on the one hand, that a portion of the project's construction costs cannot be recovered, whereas the revenue flow created by the project is uncertain and, on the other, that transport infrastructures have a long lifespan (between half a century and a century for major motorways). On top of the factors of sunk costs and longevity there are also the costs of maintenance due to the wear and tear that come with use over time. In addition, the proportion of the collateral costs is bound to increase with the higher temperatures and precipitation levels induced by climate change.

For these reasons, studies take a relatively long time to implement, especially as it is increasingly difficult to get agreement on the route of a railway or motorway. Moreover, the complexity of the work involves a construction period of several years. As a consequence, between 10 and 15 years are needed for the study and construction of a transport infrastructure (Didier and Prudhomme, 2007), a consideration to be borne in mind when creating an infrastructure project, for example in response to the challenge of global warming. Furthermore, the National Transport Infrastructure Plan (SNIT) emphasizes that "State policy must give priority to making optimum use of existing networks before envisaging their extension", especially in that taken alone an infrastructure policy has a marginal impact that is offset in the long term by the creation of newly generated traffic.

Inertia due to technology

Technological solutions are an important lever for reducing the environmental impacts of transport. But designing new low-carbon mobility solutions is also a long process. For example, the development time for a car is estimated at between 18 and 30 months, while the car remains in production for between 5 and 8 years (Fournier, 2011). Consequently, for mobility solutions that will appear on the market before 2020, the die is already cast – one of the factors making the task of the motor manufacturer complex. It is also important to note that one technological innovation can delay the arrival on the market of another, something that can readily be understood from the example of conventional and electric vehicles. This runs counter to the economic intuition that the introduction of new technologies accelerates the development of established technologies, both by introducing a spirit of technological competition and by offering new combinative possibilities.

Secondly, mature markets (or "replacement markets") such as Western Europe (only 1.1% growth rate in 2011 for passenger cars) or Japan do not offer many penetration opportunities for innovation, except through annual car replacement, whose rate remains low (6% in 2010 and scarcely more in 2011). However, windows of opportunity are opening fast in developing countries, where the markets are not yet saturated and are growing rapidly (with a growth rate of almost 3% for the Chinese market in 2011 and over 5% for other Asia-Oceania countries). Moreover, increasing vehicle life expectancy and possession duration (which rose from 4.5 years to more than 5 between 2000 and 2011) has given rise to new business models allowing certain components (batteries, for example) to be replaced during the lifetime of the vehicle (Data from CCFA, 2012).

Inertia due to mobility behaviour

In the area of mobility, flexibility for behavioural change is low because transport weighs heavily in the domestic budget[48] and transport is a necessity (Fournier, 2011). Transport is often a "derived demand", i.e. it is generally not requested for its own sake but is very largely associated with the consumption of other goods (Crozet, 2012). And changes in mobility behaviour are marked by structural trends among users, which account for the slowness of the process. In France, the key determinants of transport demand are age[49], gender[50], employed/unemployed status[51], revenue and place of residence (CGDD, 2010).

Despite these different types of inertia, it is nevertheless possible to identify a number of key factors likely to influence travel behaviour in the medium and longer term.

48 Total spending on transport amounted to 11.8% of effective household consumption in 2007 (INSEE, 2007)

49 In 2008, the number of daily journeys per person initially increases until the age of 30 (with the exception of the 11-15 age group), remains stable until 45 and declines steadily thereafter.

50 In 2008, the majority of private car drivers were men. Women use public transport and walk more often than men (with respective proportions of the public transport mode being 15% for women and 10% for men, and of the walking mode, 10% for women and 8% for men).

51 In 2008, people in active employment were more mobile than the unemployed, with 16% more journeys and 42% more mileage.

4. Factors influencing behavioural change in the short and medium term

Shifting world geopolitics

A whole series of external and random events can change the context in which policy instruments are effective: for example, an economic crisis, a change in energy prices due to geopolitical events or technological progress, a natural disaster, etc.

Sudden shocks may lead to temporary behavioural change. For example, the decline in vehicle purchases in France of over 300,000 vehicles between 2007 (5.57 million sold) and 2009 (CCFA, 2012) can partly be explained by the economic downturn (note that used vehicle registrations are less sensitive to the economic situation than new vehicle registrations).

The economic situation may also result in long-term changes. The upward trend in fuel prices in France since the early 1980s (from €0.52/L in 1980 to €1.51L in 2011 for petrol and, similarly but to a lesser extent, from €0.37/L in 1980 to €1.34/L in 2011 for diesel, CCFA, 2012), which has been much steeper since 2003, by continuously raising the cost of passenger car use, may discourage consumption in the long term.

These notions of elasticity of transport demand to fuel price were developed by Goodwin (1992), who showed that price elasticity in fuel consumption was low but increased over time, from -0.27 in the short term to -0.71 in the long term. The same applies to fuel price elasticity of mileage demand, which rises from -0.16 in the short term to -0.33 in the long term. However, such a decline in fuel consumption following a rise in car use costs should be treated with caution, since psychological factors (namely the "rebound effect" as illustrated in the box below) may distort it.

In short, external shocks that modify individual travel practices in the long term may reduce the effectiveness of existing or proposed economic instruments. Taking the examples already mentioned, an emission standard for new vehicles will concern a smaller number of vehicles if the proportion of used vehicles increases. And an increase in oil prices certainly has an effect, even if small, on fuel consumption and levels of travel, and can in certain cases make the adoption of new economic instruments more costly.

The socio-economic balance of the climate policies studied thus greatly depends on the initial assumptions (e.g.an oil price change, the discovery of new reserves such as shale gas, the use of gas in the transport sector, etc.).

Shifting demographics

As mentioned above, travel behaviour is largely determined by economic factors. It is also influenced by demographic factors and consequently, when the structure of the population changes (age, type of household, socio-professional group, etc.), mobility behaviour on a national level will also change. If we consider, for example, the ageing of the population, currently a feature of developed countries[52], a parallel may be drawn with the tendency for travel to level off because of the smaller proportion of young people, even if this factor does not explain the full extent of the phenomenon. Another feature of developed countries is the growing number of single households and of single-parent families and couples without children[53]. It is also forecast that by 2030 the number of driving license holders in France will have stopped growing.

The life cycle of a product or service (in this case, travel) can be interpreted as coinciding with three different explanatory factors: age (the product or service is associated with a particular age group), era (the product or service reaches all age groups and disappears as quickly as it appears) and generation (an effect characteristic of a group of people born in a given period and whose behaviour stays the same throughout their lives). To the extent that car use benefits from a positive generation effect, according to these definitions the ageing of the population should not significantly affect the demand for cars. Overall mobility demand, though, is likely to be more affected.

Shifting mobility demand

Although travelling is part of the contemporary lifestyle, and markedly more so than in the past, consumers today are less and less inclined to bear the costs of mobility. It may be a question of external costs such as problems of road safety, congestion, noise or atmospheric pollution. Indeed safety is an important issue, with high user expectations (see the objective of the European Commission to halve the number of fatal road accidents by 2020, embodied in the Transport White Paper of 2011).

The question of travel time is also a major issue, since it is still seen as time lost. The aim is to restore value to the journey. Furthermore, high-speed travel increases the range and diversity of accessible activities, which explains a preference for speed in accordance with the economy of variety (Crozet, 2012). With regard to the demand for passenger cars, costs borne by the individual such as the cost of ownership, the cost of maintenance, the cost of parking and the cost of fuel are rising, which accounts for the following tendencies:

— car-sharing will increase, so as to share the costs between several passengers, though doing entails accepting a lack of privacy;

52 In France, the BIPE report forecasts an increase in the number of households over 45, of recently retired people and people over 75. The proportion of the population aged over 60 rose from 23.5% in 1982 to 26.0% in 1994 and 30.6% in 2008.

53 In France, between 2010 and 2020 the number of single households will increase by 2.5 million and single-parent families and couples without children by 260,000 (BIPE).

— younger generations are more interested in the car as a service rather than as an object (see “Service economy” in the “Shifting mobility supply” section below).

Ultimately, the customer value – the way manufacturers evaluate and quantify demand – will bridge shifts in mobility demand and in mobility supply, and will largely contribute to the dynamics of change. For instance, the customer CO_2 value, or the average willingness of the customer to pay for a reduction in CO_2 by a given unit, is a key strategic tool for the manufacturers, enabling them to determine from prospective scenarios how accessible the innovative technological solutions arriving on the market will be to the consumer.

Shifting mobility supply

Changing provision of mobility solutions depends on infrastructure capacity, quantitative and qualitative changes in the vehicle fleet, and on a reshaping of the structure of the mobility system.

In terms of infrastructure, investment on a European scale has mainly concerned motorways. By way of illustration, in 2000 in France, transport infrastructure investment amounted to 1.4% of GDP, with 0.9% spent on roads, 0.25% on rail and 0.25% on urban transport (Crozet, 2012). But to cope with the anticipated increase in traffic in 2050, though the proportion of GDP will not need to increase, the allocation among roads, rail and urban transport must change in favour to rail transport.

Market conditions favour the arrival of new technologies and the level of activity of the sector in question. With regard to the vehicle fleet, the development of the car market offering enables consumers to choose among premium, traditional, low-cost, urban, integrated mobility, rental and sustainable development products. Cars in particular have benefited from numerous innovations in terms of combustion engines, weight reduction, etc. and will continue to evolve in the future. However, by improving fuel efficiency and thus decreasing the unit cost of travel, these new or optimized technological trends may also create distorting effects and mitigate the expected fall in fuel consumption following a rise in fuel prices (as explained in Box 1 below).

Box 1: The rebound effect

Improving fuel efficiency through the adoption of new technologies usually interacts with the effects of fuel price increases, that is, it leads to greater car use (a negative side-effect) and thus hinders the reduction of CO_2 emissions from road transportation initially induced by decreasing fuel consumption. Such technological improvements cannot be expected to result in proportional cuts in CO_2 emissions in road transport, since efficiency improvements are highly correlated with other factors such as mileage and fuel demand. An initial reduction in consumption resulting from an improvement in energy efficiency will also lead to an effective decrease in the per kilometre price of transportation. As a result, car use may increase, partially offsetting the impact of the efficiency gain in fuel use. This phenomenon is referred to in the literature as the “rebound effect”: a gain in energy efficiency may not necessarily lead to a decrease in CO_2 emissions. Efficiency improvements induce both direct and indirect rebound effects that can offset potential energy savings, hence CO_2 emissions reduction. Direct effects such as an increase in the number of vehicles, average mileage or fuel demand directly counterbalance the gains resulting from technological improvements.

It is particularly difficult to quantify the size of the rebound effects, and they are generally estimated using elasticity methods. An illustration is given in a 2011 study by Emmanuel Kemel et al., based on panel data from 1999-2007. Several elasticities to fuel prices are estimated. The positive fuel efficiency elasticities (respectively 0.05 and 0.57 for the short and long term) show that significant efficiency improvements have been made by the industry. The corresponding mileage elasticities in the short and long term (-0.26 and -0.45) are negative, but still lower than the fuel demand elasticities (-0.32 and -0.76 respectively). These results show that, in response to energy savings made through gains in energy efficiency, household mileage is less sensitive to an increase in fuel prices.

Indirect effects such as substitution or income effects may also be induced: real income increases in response to decreasing energy costs. Consequently, demand for other goods increases, including fuel consumption.

In short, rebound effects may reduce the potential emission gains resulting from improvements in energy efficiency. Public policies have a part to play in tackling these adverse effects. For instance, in response to an increase by 20% in energy efficiency, Brännlund et al. (2007) find that it is necessary to “increase the CO_2 tax by 36% to achieve the same level of CO_2 emissions as before the increase in energy efficiency”.

Motor manufacturers should not forget that these innovations will have to function alongside older vehicles, and need to accept the idea that they will not be the only transport players. Whereas the car was once *the* symbol of mobility, it has now become just one among others.

With regard to structural changes in the mobility system, new transport services are starting to appear. Although the shift in demand trends remains slow, due to the strong inertia characteristics mentioned above, consumption behaviour is constantly changing. The notion of *service economy* emerged in the 2000s: the basic idea is to sell the function provided by the item rather than the item itself; the customer uses the good but the supplier remains its owner. Companies are thereby able to reduce overall costs over the product's life cycle by including recovery and maintenance costs in their strategies. By adding the "use value" of the product in the benefits resulting of its use rather than in its possession, a service economy aims to clearly separate value creation from material and energy flows.

This approach very much calls into question our concept of property: people are still largely attached to owning their car. However, since the mobility budget accounts for a substantial proportion of household expenditures, the savings generated by a service economy make transport a particularly fertile field for its experimentation and implementation.

On the demand side, natural societal trends arise, like for instance an increase in the willingness to use less polluting transport, or a still marginal but growing disinterest in possessing one's own vehicle. These trends are highly correlated with "fashion effects" conveyed and reinforced by the media.

On the supply side, industrial actors themselves will play a triggering role, by diversifying their service offering and developing vehicle variants and models adapted for use in car-sharing networks. Such systems already exist. Autolib' and Zipcar are good examples of successful implementation, and major car rental companies have developed their services, as well as manufacturers themselves (Daimler's car2go, BMW's Drivenow, etc.). Opportunities also arise in the freight sector, and equipment suppliers are coming up with similar schemes. For instance the "Michelin Fleet Solution", launched in 2002 by the tyre manufacturer Michelin, involves charging customers (mainly freight companies) proportionally to their intensity of use (price per kilometre) of the tyres. The customer no longer owns the tyres, but benefits from the know-how and experience of the manufacturer through regular and contractual maintenance services, resulting in a longer operational lifetime for tyres and savings in fuel consumption and use of raw materials.

This involvement of manufacturers, rental companies, suppliers and other upstream actors is a strong incentive and a powerful lever to change demand behaviour and favour a service economy in transportation.

From a producer or supplier standpoint, a crucial feature in the shift towards a more service-oriented economy is the ability to identify the precise need satisfied from a user standpoint when consuming a good, so as to provide alternative ways of ensuring equal or even greater satisfaction. One difficulty lies in the estimation of such a qualitative characteristic. There are also other obstacles: the necessary high levels of IT connection and partnerships between manufacturers, intermediate buyers and public authorities; strong lobbying from manufacturers; and the substantial investment needed to develop suitable infrastructure.

5. Conclusion

Transport system has multiple objectives and multiple external impacts, and is multi-sector and multi-level. It is further complicated by the various types of inertia inherent in the system.

Despite the great complexity of the issues around sustainable mobility and the different types of inertia, some key structural factors are likely to influence mobility behaviour over the longer term and have to be taken into account by the authorities responsible for the transport system if they are to apply the regulatory tools offered by economics.

Progress in mobility which takes into account the issue of climate change cannot be achieved without the involvement of all the stakeholders, particularly private enterprise. Only those players who anticipate correctly, who make the right decisions and who launch the appropriate innovations will be able to turn regulatory constraints into real opportunities. They will unquestionably be proactive, that is to say, be able to design and create the regulatory systems of the future.

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Chapter 8

Low-carbon policies for road transportation in Europe

Pierre-Franck Edwige, Bénédicte Meurisse and Claire Papaix

1. Introduction

Since roads account for 72% of CO_2 emissions from transport in the EU-27, and 79% in France in 2009 (EC, 2012a), we choose to focus in this report solely on the levers for reducing emissions from road mobility systems. Climate action with regard to road transport is particularly challenging and this is one of the reasons why we mainly concentrate on carbon emissions related to transport rather than more broadly addressing air pollution when dealing with the environmental impacts of the sector. In fact, even though many cities are still struggling to meet EU legislation on concentration limits, observed trends in air pollutants have been downward since 1990 (NOx were reduced between 1990 and 2009 by 25%, PM2.5 by 27%, SOx by 37%, CO by 75% and NMVOCs by 77% (EEA, 2012)) despite the great expansion of activity. In addition, to consider measures to combat air pollutants (e.g. EURO standards) at the same time as CO_2 emissions regulating tools would make the analysis of economic instruments more complex, since the former can counteract the efficiency of the latter (as in the case of particulate filters).

The broad range of policy instruments dealing with road transport's greenhouse gas (GHG) emissions in France and in the European Union (EU) can be relevantly classified in various ways. We have chosen here a classification of tools based on the form of action taken by the instrument (e.g. whether it is binding or non-binding) as follows: 1. regulatory constraints (see "Command-and-control levers"), 2. Price incentives (see "Economic instruments"), 3. collaborative tools, and 4. informative policy. Each category in the decision-maker toolbox can then act either on the demand side or on the supply side for stakeholders in the low-carbon mobility system.

But when it comes to the methods for achieving low-carbon transportation, most transport GHG emissions are not directly covered by "first best" economic instruments, such as fossil fuel carbon taxation. Indeed, "taxing cars or kilometres rather than the fuel is an indirect and imperfect way of taxing GHG emissions as these depend on how the car is used" (OECD, 2011). Some exceptions exist, however, and a number of carbon tax schemes have been introduced in Finland (1990), Norway and Sweden (1991), Denmark (1992) and more recently Ireland (2010) (Elbeze and de Perthuis, 2011). In this report we therefore offer a French and European review of such "first best" and "second best" policy tools for rolling out low-carbon mobility systems.

At this stage, it is noteworthy that binding instruments – i.e. pricing levers (less true for road tolling and parking pricing (VTPI, 2013)) and command and control tools – may, in certain cases, be more costly for the society and less meaningful with regard to climate than non-binding/qualitative policies. Bamberg et al. (2011) refer to "soft measures", namely "the voluntary change measures, the psychological and behavioural strategies, the mobility management tools (…), workplace or school travel plans, personalized travel planning, etc.) and the marketing policies (e.g. mass advertising campaigns for public transport, travel awareness campaigns to deter from car use, etc.)". Moreover, a stated preferences survey carried out by Xenias and Whitmarsh (2013) in the UK revealed a strong preference for this range of policy tools (reduction in transport demand through qualitative measures) stemming from both expert and non-expert samples of the population. This said, we explore in this chapter the efficiency of binding instruments as a first-best way to combat climate change in transport and in particular to change road mobility patterns. For the sake of brevity, "soft measures" such as collaborative initiatives (e.g. public procurement on the demand side and Public Private Partnership on the supply side) and communication and diffusion policies (multimodal information, labelling, etc. on the demand side and CO_2 reporting, eco-driving training, etc. on the supply side) are not examined here.

We will therefore identify some of the commanding heights available to French and European policy-makers for implementing the low-carbon mobility pathway. To do so, we first explore command and control levers (Section 1) and second economic instruments (Section 2).

2. Command and control levers

Demand side

Speed limits

Because vehicles on average use less fuel per kilometre at lower speeds, tightening speed limits can reduce transport CO_2 emissions. For example, a CE Delft pilot study has estimated a 30% reduction in CO_2 emissions on highways (in the longer term) if the speed limit is reduced from 130km/h (110km/h in wet weather) to 80km/h (Otten and van Essen, 2010).

Low Emission Zones

Low Emission Zones (LEZs) are areas or roads where the most polluting vehicles are restricted (i.e. banned from or charged for entering the zone). LEZs aim at reducing pollutant emissions by forcing drivers to: a) buy a lower emission vehicle; b) retrofit (incorporating pollution abatement equipment such as a diesel particulate filter, a cleaner engine, etc.); c) check for exemptions or d) change their route.

In 2012 there were 182 LEZs in the EU, mostly concentrated in Italy and Germany for topographical (size of the streets) and/or political reasons. Euro classes, motorization types and maximum vehicle weight allowed/forbidden in the regulated zone vary according to the country and even between cities within a given country (ADEME, 2009).

First introduced in the 2010 Grenelle 2 Act, LEZs are currently encountering opposition in France. The French urban areas that are eligible (municipalities of more than 100,000 inhabitants with an Urban Transportation Plan (PDU)) consider the scheme to be too stringent and somewhat unfair for owners of high-polluting cars. However, given the average level of particle concentration in French cities in recent years, the penalty imposed by the European Court of Justice could amount to about €100M by 2016 (Journal de l'Environnement, 2012).

High-occupancy vehicle lanes

One way of reducing congestion (and consequently CO_2 emissions) is to limit the number of cars on the road. Although people increasingly tend to drive alone, high-occupancy vehicle (HOV) lanes are intended to encourage drivers to share vehicles (carpooling) or to take public transport (buses).

HOV lanes benefit both motorists and the whole community by making journey times faster, reducing travel costs (since car-poolers can share the outlay), increasing the use of taxis and airport shuttles, encouraging the purchase of electric vehicles (EVs are sometimes authorized to used HOV lanes) and reducing GHG emissions.

In the EU, road priority access for HOVs are generally limited to reserved lanes for buses, although in Norway electric cars are also allowed to use bus lanes.

Parking policies

Drivers looking for a parking place account for about a third of car traffic in towns and are responsible for a fifth of CO_2 emissions. Policy makers may choose either to optimize existing parking policies – for example, through sharing of parking places according to people's activities (residents/workers) and enabling them to reduce their parking cost – or to restrict city-centre parking and to enhance peripheral parking capacity (near to public transport facilities) so as to promote modal shift.

Supply side

Binding targets for CO_2 emissions

Emissions standards are difficult instruments to handle when it comes to diffuse emissions. One problem stems from the need to define normative levels for very varied sources: passenger cars, light-duty vehicles (LDVs), trucks, etc.

CO_2 emissions standards for new passenger cars

European Regulation n°443/2009 and the proposal for a regulation of 7 July 2012 respectively set a binding target of 130 gCO_2/km on average for the new fleet in Europe by 2015 and the more stringent target of 95 gCO_2/km by 2020. Moreover, "a further reduction of 10 gCO_2/km, or equivalent if technically necessary, will be delivered by other technological improvements and by an increased use of sustainable biofuel".

Individual manufacturers' targets are differentiated on the basis of the average weight of the cars produced during the year under consideration (from 119.1 gCO_2/km for Fiat to 144.2 gCO_2/km for Volvo by 2015). If a car manufacturer's vehicles are 100 kg heavier than the industry average by 2015, it will be granted an additional 4.57 gCO_2/km as its target (Transport & Environment, 2012).

This legislation has been enforced gradually and through a system of fines. The legally binding target of 130 gCO_2/km to be reached by 2015 currently includes four different periods: a first period in which 65% of the compliance has to be achieved by 2012, a second with 75% compliance by 2013, a third with 80% compliance by 2014 and the fourth with full compliance by 2015. Between 2015 and 2018, penalties for missing the target are €5 for the first gCO_2/km in excess of 130 gCO_2/km, €15 for the second, €25 for the third and €95 for the remainder of the period (Transport & Environment, 2012). From 2018, for each vehicle sold with CO_2 emissions in excess of its target, the manufacturer will have to pay a €95 fine per excess gCO_2/km.

Despite the system of fines, CO_2 emissions will exceed the standards, due to the following loopholes (Transport & Environment, 2012):

— "Eco-innovations" are being rewarded with credits (up to 7 gCO_2/km);

— Manufacturers who produce low-emitting vehicles (LEVs) are being rewarded with "supercredits", which allow them to count each LEV as more than one car (1.3 to be precise). Overall CO_2 reductions are consequently diminished;

— Niche manufacturers (i.e. car manufacturers with between 10,000 and 300,000 sales in the EU) will be allowed to benefit from an alternative target which is 25% lower than their average specific emissions of CO_2 in 2007;

— Carmakers with less than 10,000 sales in the EU can negotiate their own target with the Commission.

CO_2 emissions standards do not seem to be ideal in view of the "cheating" practices of car manufacturers in respect of CO_2 emissions test conditions. In fact, car manufacturers are "optimising" the way they put cars through official tests. Hence test results do not reflect real-life driving conditions, and some emissions reductions (30% according to Ricardo, 2012) are due to such test manipulation rather than to genuine improvements. In addition, the report mentions a €135 annual extra cost due to higher fuel consumption.

CO_2 emissions standards for light-duty vehicles

Regulation EC n°510/2011 of 2011 sets a binding target of 175 gCO_2/km for new LDVs sold, to be achieved progressively from 2014 to 2017. Targets (from 156 gCO_2/km to 342 gCO_2/km) vary according to the vehicle's authorized loaded weight (from 1.5t to 3.5t respectively). Looking to the future, the European Commission is considering setting a target of 147 gCO_2/km for LDVs to be met by 2020.

According to a study by the French Ministry (CGDD, 2011), LPG vehicles (0.5% of the fleet) and diesel vehicles with an authorized loaded weight higher than 1.5t (73% of the fleet) already met the 2017 binding target in 2005.

Binding targets related to biofuels

As from December 2010, the European Commission has given a reference value of 5.75% of biofuels in the petrol and diesel transport fuel for Member States in setting their national targets of a minimum proportion of biofuel. In 2009 and 2012 the European Commission revised the Renewable Energy Directive and provided further incentives to promote "advanced biofuels" (from waste or algae and including sustainability criteria) in meeting the target of a 10% share for renewable energy in the transport sector (the share was 4.7% in 2010 in the EU and biofuels are the main contributor to this, with a 4.4% share (Europa, 2013)).

It should be noted that while the 10% incorporation target is scheduled for 2020 in the EU, it applies as of 2015 in France in accordance with the French biofuels plan. In addition, fiscal instruments in the French biofuels plan include a reduction of domestic consumption tax (from 2005 to 2010, the reduction was €2.65 billion) and a general tax on polluting activities (TGAP in French) for fuel producers and distributors which do not achieve the minimum percentage of biofuel in fuels. However, the French Court of Auditors has pointed out that consumers bore a cost of €3 billion (from 2005 to 2010) due to biofuels policy development and the resulting higher levels of fuel consumption (caused by the relatively lower energy efficiency of biofuels) and higher pump prices (Cour des Comptes, 2012).

From a European standpoint, the regulatory context for biofuels in Sweden is of particular interest. It is characterized by a strong policy support and implemented at an early stage, with the main measures for encouraging the use of biofuels being:

— Energy and carbon taxes exemptions for renewable fuels until 2013;

— Vehicle tax reductions for bioethanol buses, leading to an annual tax of €23 against €2,600/annum for diesel buses (BEST, 2010);

— Regulations regarding filling stations: operators selling over 1,000 m^3 petrol/diesel per year are required to supply at least one type of renewable fuel;

— Investment subsidies.

However, experts claim that developing biofuels in Sweden has been very costly, particularly with reference to the cost of such policy packages and to the underlying cost of "lock-in effects" related to this technology. The total cost for promoting the use of biofuels has been estimated at an average of €350 per tonne of CO_2 avoided (OECD, 2011). But Sweden bears only a very small proportion of the production cost, as it mainly imports biofuels (80% of ethanol supply is imported, mostly from Brazil, incidentally offsetting in part local GHG emissions reductions[54]).

Binding targets related to EV charge plugs

At the European level, the Commission is proposing to Member States a package of mandatory targets on a minimum level of charging infrastructure (e.g. 97,000 publicly accessible charge plugs by 2020 in France) for clean fuel vehicles to roll out by 2020, along with the common EU standards for plug-in charging equipment (Europa, 2013).

At the national level, the French Grenelle 2 Act requires every new building (with building permit application from January 2012) with parking units to have them connected to an electricity supply, while car parks at workplaces and all existing buildings with parking facilities will need to have such electricity connections by January 2015.

54 Since fossil fuels are not taxed for the emissions generated by their production and transportation, this leads to an asymmetry in taxation between fuels.

3. Economic instruments

Demand side

Automobile purchase pricing schemes

Registration taxes allow for the promotion or discouragement of certain vehicle types. Most EU countries (20 out of 27) have therefore adopted registration tax schemes, though tax levels and criteria for calculating the tax rate (CO_2 emissions, EURO class, value of the vehicle, engine power, etc.) vary greatly from country to country. For example, CO_2 emissions are included in the registration taxes calculation in fourteen countries. Note that France is one of the six countries in the EU to also apply registration tax on commercial freight vehicles.

Annual registration tax revenues range from €5.01M (Latvia) to €2,005.00M (Netherlands), with €1,919.00M in France (EC, 2012b).

The "Bonus/Malus" scheme

In France, a bonus has since 2008 been allocated to the purchase or lease of new low-carbon vehicles. As of 2013, the bonus is given to vehicles emitting less than 105 gCO_2/km (from €200 to €7,000 if emissions are lower than 20 gCO_2/km). Maluses vary between €100 once CO_2 emissions exceed 135 gCO_2/km and €6,000 for vehicles emitting more than 200 gCO_2/km. Moreover, since 2012 a bonus of €4,000 is allocated to the purchase of an electric vehicle. In accordance with the French General Tax Codes, bonus and malus amounts are revised annually to reflect the government's financial equilibrium.

Note that preliminary results show that the average CO_2/km level of new light duty vehicles in France has gone from fourth lowest to the lowest (133 gCO_2/km in 2009) across the EU since the programme started in 2007 (Brand et al., 2013). However, due to its success, the tool led to a financial loss of about €525M in 2009 and €490M in 2010, despite regulatory amendments being made (MEDDTL, 2011).

The fact that effects of the bonus/malus scheme have largely exceeded the initial economic forecasts can be explained both by the *normative* component (i.e. the psychological connotation of punishments and incentives, with higher sensitivity to losses when facing losses and gains of the same magnitude), which is often neglected, and by the role of the "information component" of such a feebate scheme (i.e. the underlying energy label).

Other European countries have also introduced a bonus/malus scheme (Table 1).

Table 1: Bonus-Malus schemes in other European countries

Country	Bonus/Malus
Austria	**Bonus:** €300 max for cars ‹120 gCO_2/km; For alternative fuel vehicles and PHEVs*: extra bonus of €500 max (2008-12); €5,000 rebate if the EV is charged with green electricity; €2,500 if charged with conventional electricity; **Malus:** €25 per gCO_2/km for cars ›180 gCO_2/km.
Belgium	**Bonus:** 15% of the price (up to €4,540) for cars ‹105 gCO_2/km and 3% of the price (up to €810) for cars [106;115] gCO_2/km; Eco-bonus in Wallonia of €600 for cars with a list price of maximum €30,000 and emitting less than 99 gCO_2/km
Spain	**Bonus** from €2,000 to €7,000 for the purchase of EV, PHEV, fuel cell, NGV* and LPG* vehicles (2012). In Andalucia, the incentive is maximum 70% of the investment.
Italy	**Bonus** of €700 for cars ‹140 gCO_2/km and diesel ‹130 gCO_2/km in 2010; Bonus up to €5,000 (20% of the price) for vehicles emitting ‹50 gCO_2 km in 2013 and 2014; and up to €3,500 (15% of the price) in 2015;
Luxembourg	**Bonus** of €3,000 for EVs or cars ‹60 gCO_2/km (until 2011); Bonus of €750 for EURO 4 and EURO 5 gasoline vehicles and EURO 5 diesel vehicles for which gCO_2/km emissions are ‹120 gCO_2/km or ‹160 $gCO2_2$km + 6 places or ‹160 gCO_2/km + NGV or PHEV in 2010.
Netherlands	**Bonus** €6,400 max for PHEV in 2010; **Malus** of €125 per gCO_2/km ›110 gCO_2/km (gasoline cars) and › 95 gCO_2/km (diesel cars).
Portugal	**Bonus** of €6,500 max for EVs acquisition applying to the first 5,000 EVs sold until the end of 2012. For other EV purchase, €5,000 rebate.
Sweden	**Bonus** of €1,000 (SEK10,000) for cars classified as "environment friendly" (i.e. conventional cars ‹ 120 gCO_2/km, alternative fuels vehicles and EVs (between April 2007 and July 2009))
United Kingdom	**Bonus** of €6,000 (£5,000) max until 2015 (25% of the value of the vehicle) for OLEV* and ultra-low carbon vehicle (e.g. min. electric range of 70 miles for EVs and of 10 miles for PHEVs + emissions below 75 gCO_2/km for PHEVs). Since 2012, the "Plug-in Van Grant" is of €9,500 (£8,000), i.e. 20% of the vehicle purchase price).

PHEVs: Plug-in Hybrid Vehicles, LPG: Liquefied Petroleum Gas,
NGV: Natural Gas for Vehicles, OLEV: OnLine Electric Vehicle.
From Papaix, C. and Meurisse, B. (2013), "Overview of the policy toolbox for low-carbon road mobility in the European Union", Les Cahiers de la Chaire Économie du Climat, Information and Debates Series.

The scrappage premium scheme

In France since January 2010 the purchase or leasing of a new car emitting less than 155 gCO_2/km has received a premium if accompanied by the scrapping of a vehicle over 10 years old (Decree N°2009-1581). The premium varies between €500 and €700 according to the order and invoice dates. Note that the new car CO_2 emissions threshold, below which the scrapping premium applies, decreased from 160 gCO_2/km in 2008-09 to 155 gCO_2/km in 2010, as has the amount of the premium itself.

An empirical analysis of vehicle ownership by French households (from 1984 to 1998)[55] conducted by Yamamoto et al. (2004) demonstrates that the conditional probability of replacing a vehicle aged 10 years and over is 1.2 times higher when the scrappage premium scheme is in place (i.e. during the 1994-96 reference period) than when it is not operating, and that the average duration of keeping a vehicle is 3.3 years shorter when the scrappage premium applies.

Other European countries also introduced a scrappage premium scheme (Table 2), most of them from 2008 (until the end of 2009 or 2010), in line with the beginning of the economic downturn in the automobile industry. Most scrappage premium schemes were introduced primarily to stimulate the car market rather than to meet any explicit environmental objectives.

Table 2: Scrappage premium schemes in other European countries

	Characteristics of the scrapped vehicle	Scrappage premium for the vehicle purchase
Austria	› 13 years	€1,500 for new or used EURO 4 or 5 car purchase
Portugal	› 10 years	€1,000 to €1,250 for new car ‹140 gCO_2/km purchase
Netherlands	› 9 years	€750 to €1,000 for new or used more environmentally friendly car purchase, and respectively €1,000 to €1,750 for utility vehicles
Germany	› 9 years	€2,500 for new or used EURO 4 car purchase
Italy	› 10 years	€1,500 for new EURO 4 or EURO 5 car, car ‹ 140 gCO_2/km (gasoline) and car ‹ 130 gCO_2/km (diesel) purchase
Spain	› 10 years (if new car purchase) › 12 years (if used car purchase)	€2,000 for new or used (until 5 years old) car ‹149 gCO_2/km

55 In in this study we used the Parc-Auto panel survey, conducted by the French marketing firm SOFRES since 1976.

United Kingdom	>10 years	€2,225 for the purchase of a new car or utility vehicle

From Papaix, C. and Meurisse, B. (2013), "Overview of the policy toolbox for low-carbon road mobility in the European Union", Les Cahiers de la Chaire Économie du Climat, Information and Debates Series.

VAT and income tax reduction for EVs

Norway is the only country to exclude the purchase of EVs from VAT. Norway also has Europe's highest rate of VAT, at 25% of the retail price (Viktoria Institute, 2011), compared to an average of 15% to 25% across the EU (PIPAME, 2010).

Some European countries have introduced an income tax credit scheme for EV buyers, such as Belgium (income tax reduction of 30% of the purchase price) and Sweden (income tax reduction of 40%; ACEA, 2011).

The "CO_2 tax" on the purchase of used polluting passenger cars

Under the French General Tax Code and since June 2004, an additional CO_2 tax has been in operation, and applies to the registration of used polluting passenger cars. Rates depend on CO_2 emissions (€2 per gram of CO_2 if emissions range from 200 gCO_2/km to 250 gCO_2/km, and €4 per gram of CO_2 above that).

Taxing registration of used cars is of particular interest, since in France between two or three used vehicles are exchanged for every new car purchase (CCFA, 2012).

Automobile ownership fiscal schemes

All the EU Member States apply one or more ownership taxes on road vehicles and in most countries HDVs are also subject to them. 12 out of the 27 Member States (including France) use CO_2 emissions level as a criterion in the tax calculation.

Annual revenues from ownership taxes vary between €3.50M (Estonia) and €8,500.00M (Germany), and amount to €1,160.00M in France (EC, 2012b).

According to the French General Tax Code:

— French companies have to pay an annual tax on their passenger vehicles, from €2 to €27 per gCO_2/km depending CO_2 emissions. There are exemptions related to professional activities (vehicles are excluded if they are intended for sale, hire, public transport, driving lessons and competitive sports events) and to the energy use of the vehicles (for example, those powered by natural gas, liquefied petroleum gas or E85);

— Since 2012 an annual tax of €160 applies to passenger cars if CO_2 emissions exceed 190 gCO_2/km (before 2012, the threshold was higher than 190 gCO_2/km). Vehicles are exempt if they are subject to the annual tax for company vehicles.

Automobile use pricing schemes

Fuel pricing

Fuel taxes: Revenues from fuel taxes, a major source of annual revenue for public budgets, are among the highest in France, amounting to €23,539.91M (EC, 2012b). Petrol and diesel tax rates vary greatly among the EU Member States (from 38.7% of the retail price in Denmark to 46.7% in Germany for unleaded petrol, and from 35.1% of the retail price in Finland to 50.4% in the UK for diesel. In France, diesel and petrol taxes have historically been different (generally by about 20%), and favour diesel use. After the Second World War, diesel was predominantly used in freight transport (diesel being a by-product of the oil industry), and so to give a new impetus to the economy, the French Government decided to decrease the rate of diesel tax. This was also justified by the fact that diesel was considered to be less polluting than the other transport fuels (in terms of CO_2). However, this fiscal advantage for diesel is currently under discussion in France. Despite the power efficiency of diesel – 20-40% higher than petrol – and producing 15% less CO_2 emissions than petrol, diesel produces much more nitrogen oxides, carbon monoxide and particulate matter (almost none of which are produced by petrol). Furthermore, the additional revenue from an increase of diesel tax would help the French Government to finance the tax credits for its competitiveness and employment scheme (CICE) planned for 2016.

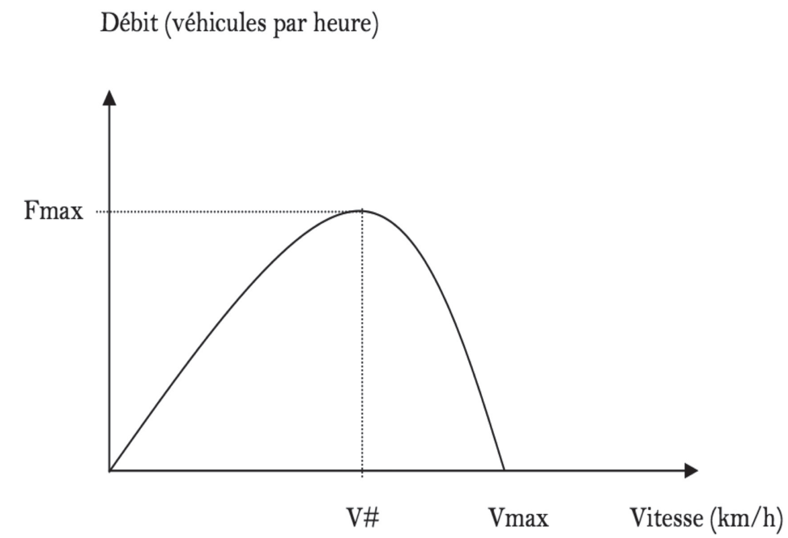
Tax exemption for biofuels: Under the Directive 2003/96/EC on energy products and electricity taxation, petrol or diesel incorporating biofuels benefit from tax reductions. The rate of tax relief (reduction in €/hectolitre) is €8/hectolitre for vegetable oil methyl esters biodiesel, synthetic biodiesel, vegetable oil ethyl esters biodiesel, and €14/hectolitre for ethanol and ethyl tert-butyl ether (ETBE) in 2013. Tax exemptions for biofuels have been a growing cost for the government, from €260M in 2006 to €521M in 2009 (Interactive EurObserv'ER Database, 2012).

Carbon tax: A carbon tax project applying to the sectors not included in the European cap-and-trade system for CO_2 emissions allowances (i.e. residential and tertiary sectors, heating and transportation) is economically justified on the grounds that it is intended as a pricing instrument and in proportion to its efficiency. Through this scheme, by paying less carbon tax and getting financial compensation in return (independent of their energy consumption), people are encouraged to change their behaviour and reduce their energy consumption. The scheme is also particularly appropriate for transport and heating emissions from the household sector, which are diffuse and therefore difficult to regulate through market mechanisms. With regard to equity and acceptability, the implementation of a carbon tax has to be strictly offset by the reduction of other taxes, so as to preserve industrial competitiveness and household purchasing power. Despite these arguments and a favourable political background (one of the outcomes of the "Grenelle de l'environnement" in 2007), the "climate-energy contribution" proposed by the French Parliament was rejected in 2010. It was challenged by the constitutional principle of "equality in public taxation", since sectors under the EU-ETS (40% of CO_2 emissions, 93% of non-industrial emissions) were exempted both from the tax and allowances (under the "grandfathering" allocation at that time), whereas ETS sectors were subject to the carbon tax, resulting in uneven fiscal treatment.

Road user charge

Urban tolls: Urban tolling involves making vehicle drivers who enter a specified geographical zone pay for the cost of the congestion they impose on other drivers. The use of urban tolling avoids having to resort to road capacity investment, which leads to increased traffic (the Downs-Thomson paradox) and therefore other negative externalities (namely environmental impact, unsafety, infrastructure use). In some cases, this instrument can also constitute a funding lever for infrastructure investments. Furthermore, with regard to origins of congestion, Schelling (1978) pointed out that "undesired collective effects, such as road congestion or social segregation, may be caused by the sum of rational individual decisions which together result in a pernicious outcome". It is interesting to note that Crozet et al. (2012) argue the contrary and suggest that macro-motives (such as climate change, congestion, etc.) do disturb micro-behaviours (by affecting, for example, the generalized cost of car use). In France, congestion accounts for about 70% of the external costs from road transportation in dense urban areas (CGDD 2012), for which road tolling appears to be a coherent response. Figure 1 below illustrates the threshold in the use of road infrastructure capacity, indicating the phenomenon of congestion. The shape of the curve reflects two main effects. The first part of the curve refers to the regular situation, while the second refers to the constrained stage. The maximum flow (Fmax) with the associated speed level (V#) corresponds to the maximal capacity of road transport infrastructures from which the congestion phenomenon arises.

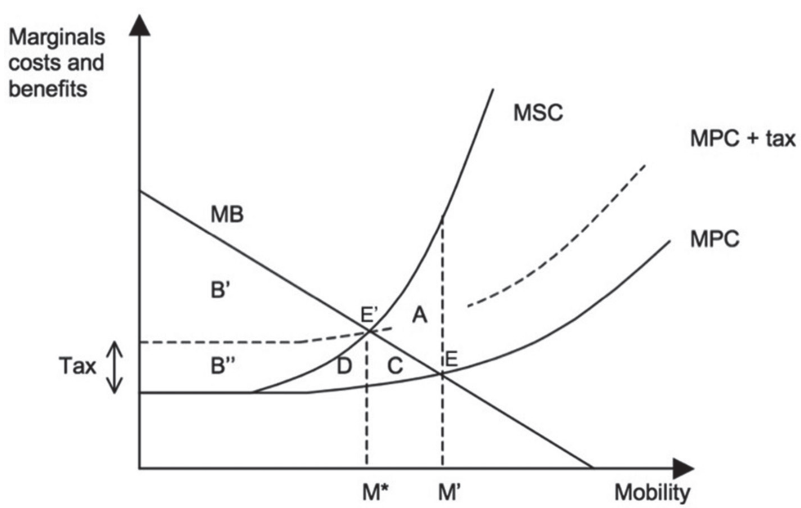
Figure 1: The speed-flow curve



Source: Glachant, M. et Bureau, B. (2004), "Économie des effets distributifs de la tarification de circulation en zone urbaine", ENSMP.

The utility of such a congestion toll scheme precisely lies in its capacity to transform the "laminar" system into a "forced" process by reducing car traffic flow. On this theoretical basis, a congestion static model is developed for the optimal pricing of the congestion toll.

Figure 2: Standard congestion toll model



From World Bank Institute (2002), "The social cost of transport",
Training module for the environmental Economics and Development Policy Course.

Figure 2 shows the curves of both the marginal social costs (MSC) and the marginal private costs (MPC) related to the transport demand level – characterized by the marginal willingness to pay or "generalized costs" to circulate. In the initial situation, the mobility demand (MB) line crosses, at E, the marginal private cost (MPC) curve leading to the total social cost (A) for users.

The introduction of a toll raises the private costs curve (from "MPC" to "MPC + tax") and thus nullifies the social cost area (A), leading to an economic optimum – the crossing point (E') of MB and MSC. However, a social loss is created at C, reflecting the additional charges and the resulting mobility decrease for car users. Moreover, at E' the state gets back the tax revenue from the toll (B''+D) and redistributes it to compensate for the reduced mobility (C).

This model raises two issues:

The price/time congestion trade-off

The toll is in fact a time vs. price trade-off, i.e. opposing the traffic reduction target and the funding motive. Urban toll schemes may vary according to:

— Spatial configuration: cordon charging (e.g. Stockholm) or charging area (e.g. London);

— The rate: which may depend upon the time, the day, duration, mileage and the emissions class, or may include a rate base;

— Revenue allocation: road infrastructures (e.g. Stockholm) or sustainable mobility development (e.g. Milan);

— The objective targeted: congestion, environmental or financing tolling schemes (Meyere, 2010).

Various tolling scheme experiments have been implemented in Europe. They include:

— The London congestion charge (LCC). In operation since 2003, the LCC has resulted in a significant decrease in the number of cars passing through the tolled zone (nearly 30% fewer personal vehicles and 10% fewer commercial vehicles between February and August 2003). This decline was followed by an increase in the urban public transport mode share (15% growth in bus use after 6 months of coming into operation, according to Transport for London);

— The environmental toll "Eco Pass" in Milan. Created to reduce the exhaust emissions related to road transport with pricing targeting the most highly polluting vehicles, and operational since 2008, this system has helped decreasing the proportion of these vehicles (Euro 1, 2 and 3) from 43.4% in 2008 to 14.4% at the end of 2009. As a result, exhaust emissions have fallen sharply, by 42% for NH3, 15% for PM10, 12% for NOx and 6% for CO_2 over the period (Bocconi, IPT 2010);

— Toll financing in Oslo. "For over 100 years, toll financing in the traditional sense has successfully been used in Norway as a supplement to government funding. To date about 100 toll projects have been realized successfully and only one has been declared bankrupt..." (Odeck and Brathen, 2008). Since its creation in 1984, the company Fjellinjen managing the toll has contributed, by almost €1.4 billion over 10 years, to transportation infrastructure funding (tunnels and bypasses) as well as reducing congestion in the city (Raux, Souche and Pons, 2009).

In France, in accordance with the Grenelle 2 Act, urban toll experiments are limited to areas with populations over 300,000 and with an "Urban Transportation Plan" (PDU) that provides transport infrastructures to receive transferred and diverted traffic following the implementation of the urban toll. In addition, urban toll revenues must finance actions taken under the "Urban Transportation Plan".

Social equity for users

Equity is a concept that refers to the notion of justice pertaining to a society (Boltanski and Thévenot, 1991). Under congestion tolling, the price-time trade-off raises the question of the exclusion of some users (in particular those with the lowest incomes).

Small (1983) shows that tolls create four direct effects:

— Two of which are negative (payment for the right to enter and the cost of mobility patterns change for users who no longer use the infrastructure);

— And two positive (benefits related to the reduction of congestion and benefits stemming from the redistribution of income).

A balance between the positive and negative effects must therefor be found so as not to reduce collective welfare. Income redistribution plays a central role in the fairness of the toll by compensating those who lose out through its introduction. In a study of congestion pricing in Stockholm, Eliasson and Mattsson (2006) demonstrate the equity performance of income redistribution. Depending on the three different distribution choices addressed:

— The revenue is fully redistributed to citizens;

— The revenue is used for the development of public transport;

— The revenue is used to reduce income tax.

Some users will benefit more than others, depending on socio-demographic variables (gender, income, household type, social status and geographical distribution).

During the Stockholm toll testing phase, the partial income allocation to the development of public transport, coupled with a successful information campaign and the visible and rapid reduction in traffic congestion, led to its broad social acceptability.

Highway tolls: Highway tolls are currently aimed at financing road investment (as in France, Greece, Ireland, Italy, Poland, Portugal and Spain) (EC, 2012b). Toll rates may also depend on GHG emissions. This is the case of the LKW-Maut toll (DHL Freight, 2012), which charges trucks weighing more than 12 tonnes on German highways (covering 12,800 km) and the primary road network (covering 1,100 km)[56], depending on the distance travelled and the vehicle's emissions class. In operation since 2005, the German toll system generated €600M in revenue in 2009, redistributed in particular in the form of reductions in other vehicle taxes and investment support to environmental enhanced vehicles (EEVs). Originally made to reduce unloaded trips and to foster investment in cleaner high-duty vehicles (characterized by new EURO V or EURO VI vehicle acquisitions and by a reduced use of older vehicles, in particular for long-haul freight transport, but much less for local traffic), the scheme has been a success (Viktoria Institute, 2011). However, the resulting modal shift has been almost non-existent and traffic continues to divert onto roads not subject to tolls. The French "eco-tax for heavy-duty vehicles" project, applied on HDVs of more than 3.5t regardless of their nationality, circulating on the national road network (i.e. 15,000km), (inspired by the German Maut), scheduled under the "Grenelle 2 Act" to start in October 2013, is currently under discussion.

Parking pricing: Parking pricing policies are effective in reducing transport externalities to deter car use and to increase the share of alternative modes (Ecorys, 2011). Parking pricing management generally involves an increase in parking charges and/or an extension of the priced area (either geographically or in terms of duration). Several case studies (Ecorys, 2011) have shown that parking pricing measures result in a decrease in vehicle kilometres. The corresponding elasticity values indicate that a 10% increase in parking charges can result in a reduction of vehicles kilometres of 1% to 3% (depending on the number of users and the type of policy). Most of the larger urban areas in France, as in many other European countries, have opted for free parking for electric vehicles.

Supply side

Since freight will in future continue to a large extent to be transported by road, probably with a 30% to 60% share depending on the scale of the modal shift towards other transportation solutions, investment in infrastructure for EVs and time-share car services cannot be ignored (de Perthuis and Jouvet, 2011), despite the inertia characterizing transport infrastructures (Meurisse and Papaix, 2013).

Most public investment in sustainable mobility concerns vehicle electrification and charging stations for EVs. At the European level, the European Union provides €100M support to the CIVITAS initiative, involving 25 cities in 2013 which are introducing ambitious sustainable transport policies (ADEME, 2009). At the national level, France is trying to catch up with the lead taken by Asian countries, in particular by targeting power electronics, battery charging and fuel cells, rather than electric engine technology, which has already been developed. As planned in the "Grand Emprunt", €750M along with a half of the national R&D programme for the inland transport (PREDIT) budget, was invested in R&D around vehicle electrification in France in 2009. Furthermore, 900,000 private and 75,000 public charging stations are expected to come into service in France by 2015, and 4 million private and 400,000 public charging stations by 2020 (Assemblée Nationale, 2010), with a view to achieving the target of 2 million electric and hybrid vehicles on the road by 2020 (Nègre, 2011). The French Government is also currently (during the 2011-15 period) contributing 50% towards investment costs in the pilot cities, which signed a charter in 2010 to develop demonstration projects related to the electric charging infrastructure (Nègre, 2011).

4. Summary table

The broad range of policy instruments concerning greenhouse gases emissions from road transport in France and the European Union can be classified in various relevant ways. In this report we have adopted a classification of the tools based on the form of action taken by the instruments (command and control vs. economic). Each category in the decision-maker toolbox can then operate on either the demand side or the supply side with regard to the low-carbon mobility system's stakeholders.

56 Apart from national traffic, a key target of the LKW Maut toll is foreign flows, since they account for about a third of total freight transport volume in Germany (Viktoria Institute, 2011).

Table 3: Command and control and economic instruments

Command and Control	Demand side	**— Speed limit** — Low Emission Zones — High-Occupancy Vehicle lanes (bus lanes only) — Parking access management
	Supply side	*Related to CO_2 emissions: **CO_2 emissions standards for new passenger cars and light-duty vehicles** *Related to biofuels: **Minimum of biofuel content in fuels** *Related to EV charge plugs: **Norms on publicly accessible infrastructure** **Mandatory EV charge plugs in buildings**
Economic Instruments	Demand side	* Automobile purchase pricing schemes: **Bonus-malus** **Scrappage premium** VAT and income tax reduction **CO_2 tax for used polluting passenger cars** * Automobile ownership fiscal schemes: **Annual tax for company vehicles** **Annual tax for polluting vehicles** * Automobile use pricing schemes: **Fuel pricing (fuel tax, tax exemption for biofuel,** carbon tax) **Road user charge** (urban toll, **major roads and highways toll)** **Parking pricing** **Free access to public transport**
	Supply side	**Investment in R&D** **Investment in infrastructures**

In bold type: In France
Source: Authors from Leurent, F., and Windisch, E., (2011), "Triggering the development of electric mobility: a review of public policies" European Transport Research Review.

5. Conclusion

According to economic theory, policy-makers should prefer one measure only to achieve a specific goal. However, as this report has made clear, several policy tools (taxes, subsidies, etc.) can indirectly target the same objective (i.e. fight against climate change). The various policies must therefore be considered simultaneously. The effects of one policy may reduce those of another, thus lessening the overall effectiveness of the system. But the effects of one policy may also amplify the effects of another, in which case overall effectiveness is improved. The key would then be to achieve good coordination between the multilateral effects of such measures, in order to transform transportation systems and to ensure they move in the desired direction. A second caveat regarding the first assertion is that when one particular measure becomes fully effective (for example, when fossil fuel carbon taxation manages to deter or reduce conventional fuel consumption), it may run counter to the functioning of another policy tool (for example, raising public funds through an energy tax). This is the well-known paradox of green taxes.

As well as insuring the overall consistency of the policy toolbox for regulating transport emissions, transport and the other policies in the sector must evolve in a compatible way. Expressed schematically, if public transport services are improved in city centres, land rents and land prices increase, and poorer populations are forced to leave the centre and relocate to peripheral zones. The resulting "urban sprawl" then tends to run counter to land planning policies. Another consequence might then be the construction of housing in lightly populated areas where transport facilities are insufficiently developed – there appears to be a density threshold of 50-150 inhabitants/ha below which mass transportation systems are not economically feasible (Russo and Boutueil, 2011) – resulting in a mismatch between transport demand and infrastructure supply, thereby encouraging car use.

Finally, it should be noted that the automotive industry is facing numerous structural challenges, in which reducing CO_2 emissions from new cars sold is part of a wider strategy (ERIEP, 2013). As a result of the economic downturn of 2008, the automotive industry is struggling with overcapacity, a saturated European market and increasing competition from companies in Brazil, India and China. In this context, the emerging questions around "green cars" and new forms of mobility both represent an additional challenge for the industry – environmental concerns and the need for a transition to sustainable systems – but also a way out from other issues by creating new strategic opportunities for innovation and growth.

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Part 4

Law, regulation, climate

European strategy has resulted in substantial changes with regard to energy over the last decade, both from a market structure perspective and in terms of the diversity of market actors, with major consequences for the legal and regulatory fields pertaining to energy and carbon markets. The economic toolbox is subject to legal constraints, as regards, for example, its compatibility with liberalisation rules or the qualities of legal protection, and gives rise to renewed questions around the insertion of these new regulations into institutional systems (to be approached through comparative law)

Two aspects of these legal and regulatory issues are presented in Part 4.

Chapter 9, *The obligation to purchase electricity produced by wind energy and legislation pertaining to State aid,* deals with the tensions between the promotion of renewables and competition issues, around the definition of State aids.

Chapter 10, *The financial markets and energy: European cooperation between energy and financial regulatory authorities,* presents and discusses the regulatory framework of European financial energy markets and the existing European model of cooperation between energy and financial authorities.

Chapter 9

The obligation to purchase electricity produced by wind energy and legislation pertaining to State aid

Claudie Boiteau

1. Introduction

The action taken by France in relation to electricity production from renewable energy sources clearly conforms to European energy policy[57]. Thus, since the first directive on liberalization of the internal electricity market, of 19 December 1996, it is understood that "Member States may impose on undertakings operating in the electricity sector, in the general economic interest, public service obligations which may relate to (...) environmental protection"[58]. This provision was adopted and enriched by the following directives, the last of which was Directive 2009/72/EC of 13 July 2009, which in addition to environmental protection, specified "energy efficiency, energy from renewable sources and climate protection"[59].

In parallel, Directive 2001/77/EC of 27 September 2001 on the promotion of energy produced from renewable sources in the internal electricity market[60], modified then replaced by Directive 2009/28/EC[61], stated that "the need for public support in favour of renewable energy sources is recognized by Community guidelines for State aid for environmental protection".

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57 C. Boiteau, Mise en perspective des fondements internationaux et européens du droit de l'énergie renouvelable, Énergies maritimes renouvelables – Enjeux juridiques et socio-économiques, AMURE, dir. G. Gueguen-Hallouet and H. Levrel, ed. A. Pedone, 2013, 7.

58 Dir. 96/92/EC of 19 December 1996 concerning common rules for the internal market in electricity (art. 3-2).

59 Dir. 2009/72/EC of the European Parliament and the Council of 13 July 2009 concerning common rules for the interior electricity market and replacing directive 2003/54/EC, JOUE, L. 211/5, 14 February 2009.

60 JOUE, L 283, 27 October 2001.

61 Dir. 2009/28/EC of the European Parliament and the Council of 23 April 2009 on promoting the use of energy produced from renewables sources and modifying, then replacing, Directives 2001/77/EC and 2003/30/EC.

However, the same directive specifies that "the rules of the treaty, and in particular Articles 87 and 88 thereof, will continue to apply to such public support" (pt 12) and "without prejudice to Articles 87 and 88 of the Treaty, the Commission shall evaluate the application of mechanisms used in Member States according to which a producer of electricity, on the basis of regulations issued by the public authorities, receives direct or indirect support, and which could have the effect of restricting trade (…)" (art. 4).

In the wake of EU policy for the development of renewable energy, the French government introduced a mechanism for compulsory purchase of renewable energy, based on two alternative economic instruments.

The first of these is the compulsory purchase tariff. Incumbent suppliers – EDF and local distribution companies (formerly non-nationalized distributors, DNN) in France, EDF-SEI in non-interconnected zones, as well as Électricité de Mayotte – have an obligation to purchase, over a fifteen to twenty year period, electricity produced from renewable sources at a rate set by ministerial decree after consultation with the Energy Regulatory Commission (CRE).

The second instrument is based on issuing calls for tender for the means of production. It means defining ex ante the amount renewable energy receiving public support. Under this constraint, bids are selected according to various criteria, in particular the purchase price proposed by bidders. The electricity produced is sold to the incumbent supplier at a price set in the offer.

This chapter is concerned solely with the first of these instruments and in particular the purchasing system for electricity produced by wind energy, which focuses on the legal debate. The wind power purchase procedure forms part of the mechanism provided for in Article L. 314-1 of the energy code, from Article 10 of Law n° 2000-108 of 10 February 2000 concerning the modernization and operation of the public provision of electricity, which requires EDF and local distribution companies to enter into agreements with producers, who require a purchase contract at a guaranteed price for the energy produced by cogeneration installations and production plants using renewable energy at a level less than 12 MW[62].

62 The following installations are concerned: facilities for recycling household and other waste referrred to in Articles L. 2224-13 and L. 2224-14 of the General Code on Local and Regional Authorities or which supply heating systems; electricity generating plants that use mechanical wind power in a non-interconnected area or plants that use high performance techniques in terms of energy efficiency such as cogeneration; production facilities using mechanical wind power located on land, in the maritime public domain or in the exclusive economic zone; installations that use marine energy, solar thermal energy or geothermal or hydrothermal energy; windmills refurbished for electricity production; water mills refurbished for electricity production; installations that enhance energy recovery within the limits and conditions defined; and, in overseas departments, power plants that produce electricity from biomass, including sugar cane.

These rates, which vary according to the industry concerned, are intended to be incentives. They are therefore higher than the market price of electricity. Thus, with regard to onshore wind, the Law of 17 November 2008[63], supplemented by the Law of 23 December 2008[64], sets the rate, within the framework of contracts entered into over fifteen years, at €0.082/kWh for ten years, then between €0.028/kWh and €0.082/kWh for five years depending on the site[65], whereas the market price is estimated at about €0.05/kWh.

The additional cost of this purchase obligation imposed on EDF and local distribution companies is fully reimbursed. Until 2003, compensation was provided through a public service electricity generation fund fed by contributions from operators in proportion to the electricity delivered to their final customers or consumed by themselves. Since 2003, compensation is funded by contributions from the electricity public service (CSPE), provided for in Article L. 121-6 of the energy code, directly received by final consumers, which consists of an additional price per kilowatt hour paid by electricity consumers. As well as the additional cost arising from the purchase obligation, the CSPE reimburses the extra production costs resulting from the balancing of rates in the "non-interconnected zones" and the costs of social programmes, particularly the provision of the basic necessity rate[66].

63 JO 13 Dec. 2008.

64 JO 28 Dec. 2008.

65 However, the setting of these rates is framed by law and the regulatory authority. Thus Decree N°. 2001-410 of 10 May 2001, for the application of Article 10 of the Law of 10 February 2000, specifies, in Article 8, that ministerial decrees issued after consultation with the CRE set the conditions for the purchase of electricity benefiting from purchase obligation, stating that "Les tarifs d'achat de l'électricité sont égaux aux coûts de production, incluant investissement et exploitation, évités sur le long terme au système électrique" [Electricity purchase rates are equal to the cost of production, including investment and operating costs, averted in the long term for the electricity system] and that the purchase price could include "une rémunération supplémentaire correspondant à la contribution des installations à la réalisation des objectifs définis au deuxième alinéa de l'article 1er de la loi du 10 février 2000" [an additional charge equal to the contribution of facilities to attaining the objectives defined in the second paragraph of Article 1 of the Law of 10 February 2000], that is to say "l'indépendance et à la sécurité d'approvisionnement, à la qualité de l'air et à la lutte contre l'effet de serre, à la gestion optimale et au développement des ressources nationales, à la maîtrise de la demande d'énergie, à la compétitivité de l'activité économique et à la maîtrise des choix technologiques d'avenir, comme à l'utilisation rationnelle de l'énergie" [the independence and security of supply, air quality and the fight against the greenhouse effect, the optimal management and development of national resources, control of energy demand, competitiveness of the economy, and control of future technology options and the rational use of energy].

66 Decree N°. 2004-90 of 28 January 2004 on the reimbursement of the cost of the electricity public service.

The Energy Regulatory Commission has estimated the projected costs of the electricity public service for 2012 to be €4.3 billion, including €2.2 billion of costs related to renewable energy[67].

Since its introduction in 2000, the system of mandatory purchase of electricity produced by wind farms has given rise to the question of whether or not it constitutes State aid, and therefore needs to be notified to the European Commission, under Article 108 of the TFEU (ex. 88 TEC). The question is important since Article 107 of the TFEU (ex. 87 TEC) states the principle of incompatibility of State aid with the internal market[68]. The Commission may, nevertheless, deem that aid is compatible with the internal market (108 TFEU). Otherwise, State aid must be ended by the State concerned.

Since the Commission had not been notified of the French system of compulsory purchase of electricity generated by wind turbines, it could not assess and decide on its possible compatibility.

However, since 2000, the plea alleging of qualification as State aid has been raised by applicants, who are demanding the nullification of tariff laws. If, as we believe, the device counts as State aid because of the method of financing the incremental costs it entails, it should be annulled by the administrative judge. The French government would then be obliged to repay the aid improperly paid to the beneficiary producers. In addition, the architecture of the compulsory purchase system, i.e. the main method of public support for the development of renewable energy, would irredeemably affected.

Having hitherto sidestepped the definition of State aid (I), in 2012, for the first time, the Council of State came close to agreeing to it. It decided, however, to consult the Court of Justice[69], further delaying the inevitable definition and the moment of reconfiguration (II).

2. Evading the issue

If it has been possible to avoid defining State aid, it has been in part because of the difficulty of specifying the conditions leading to its definition (A). But it is also due to a deliberately oriented interpretation of the Court of Justice's judicial precedents (B).

67 The supplementary budget for 2011 nevertheless set the level of the CSPE at €9/MWh up to 30 June 2012 and €10.5/MWh until 31 December 2012. Consequently, EDF had a compensation shortfall estimated at around €1.3 billion in 2012, which will be covered by the CSPE in the coming years.

68 Art. 107 TFEU: "Save as otherwise provided in the Treaties, any aid granted by a Member State or through State resources in any form whatsoever which distorts or threatens to distort competition by favouring certain undertakings or the production of certain goods shall, in so far as it affects trade between Member States, be incompatible with the internal market."

69 CE, 12 May 2012, Association Vent de colère!, n° 324852.

Conditions for the definition of State aid

As already mentioned, Article 107 TFEU (ex. 87 TCE) establishes the principle of the incompatibility of State aid with the internal market without, however, defining what constitutes State aid. It is the Commission and the Court of Justice of the European Union which have given an definition of State aid.

The Commission considers that Articles 107 and 109 TFEU are applicable to all activities covered by the treaty, i.e. "to all gainful activities whether of an economic, cultural, social or other nature"[70]. As for the Court, it considers that Article 87 § 1 "does not distinguish between measures of State intervention by reference to their causes or aims but defines them in relation to their effects"[71].

In addition, State aid can take extremely varied forms. The Commission considers that "*subventions, exonérations d'impôts et de taxes, exonérations de taxes parafiscales, bonifications de taux d'intérêt, garanties de prêts consenties dans des conditions particulièrement favorables, cessions de bâtiments ou de terrain à titre gratuit ou à des conditions particulièrement favorables, fournitures de biens ou de services à des conditions préférentielles, couvertures de pertes d'exploitation ou toute autre mesure d'effet équivalent » peuvent constituer des aides d'Etat*" [subsidies, tax exemptions and parafiscal tax-exemptions, interest rate subsidies, loan guarantees under particularly favorable conditions, sales of buildings or land free of charge or at highly concessional rates, supplies goods or services on preferential terms, coverage of operating losses or any other measures having equivalent effect may constitute State aid][72]. The Court of Justice added that the advantages granted by public authorities, in various forms, which distort or threaten to distort competition by favouring certain undertakings or productions, may include "not only positive benefits, such as subsidies themselves, but also State measures which, in various forms, mitigate the charges which are normally included in the budget of an undertaking and which thus, without being subsidies in the strict sense of the word, are similar in character and have the same effect"[73].

According to established precedents[74], clearly summarized in the Altmark decree[75], the definition of "aid", within the meaning of Article 107 TFEU (for-

70 Decree n° 89/441 of 21 December 1988 on aid given by the Greek government to the film industry, OJEU L 208, 20 July 1989, p. 38.

71 CJEU, 26 Sept. 1996, France c/Commission, Case C-241/94.

72 Reply to a written question, OJEC C 125, 17 August 1963, Q. n° 48.

73 CJEU 15 June 2006, Liquid Air Industries Belgium, Decree C-393/04 and C-41/05.

74 CJEU 21 March 1990, Belgium c/ Commission, so-called "Tubemeuse", C-142/87, Rec. p. I-6645, pt 74;

75 24 July 2003, Altmark Trans and Regierungsspräsidium Magdeburg, C-280/00, Rec. p. I-7747, merly § 87 1 TEC), requires that all the conditions laid down in Article 107 TFEU are met. Four conditions are thus required:

— it must concern aid granted by the State or through state resources in any form whatsoever;

— this intervention must be liable to affect trade between Member States;

— it must confer an advantage on the recipient;

— it must distort or threaten to distort competition.

Despite a broad definition of State aid, the purchase obligation mechanism eluded the categorization as a result of a favourable reading of Community law.

Definition avoided through a favourable interpretation of the Preussen Elektra precedent

The case of the German mandatory purchase mechanism

On the occasion of a preliminary ruling in the context of a dispute over the German mechanism, which is quite similar to the French mandatory electricity purchase mechanism, the Court of Justice, in its judgement of 13 March 2001, Preussen Elektra AG and Schleswag AG[76], came up with a solution that France thought it could depend on.

In Germany, the system requires private electricity supply companies to purchase electricity produced in their area of supply from renewable energy sources and to pay a regulated price.

The Court stated that it is result of its ruling that " Only advantages granted directly or indirectly through State resources are to be considered aid within the meaning of Article 92(1) of the Treaty" (now 107 TFEU). In addition, it stated that the distinction established between "aid granted by a Member State" and "aid granted through State resources" does not mean that all the advantages granted by a State constitute aid, whether or not financed through state resources, but aims only to include in this notion the advantages which are granted directly by the State as well as granted through a public or private body, designated or instituted by that State[77].

Consequently, legislation by a Member State which, on the one hand, requires private electricity supply companies to purchase electricity produced in their area of supply from renewable energy sources at minimum prices higher than the real economic value of that type of electricity and, on the other hand, distributes the financial burden arising from this obligation between said electricity supply companies and private operators of

pt 74; 1 July 2008, Chronopost et la Post/Ufex e.a., C-341/06 P and C-342/06 P, pt 121.

76 CJEU 13 March 2001, PreussenElektra and Schleswag AG, Case C-379/98.

77 CJEU 24 Jan. 1978, Van Tiggele, Case 82/77, Rec. 25; 1 Dec. 1998, Ecotrade, Case C-200/97, Rec. p. I-7907.

electricity networks situated upstream does not constitute State aid within the meaning of Article 92 § 1 of the Treaty.

The French interpretation

When, in 2003, the Union of Energy-using Industries (UNIDEN) submitted to the Council of State a request for the nullification of the tariff order of 8 June 2001 on the grounds, inter alia, that this decree would have instituted State aid and should therefore have been submitted to the European Commission, the judge directly drew on the PreussenElektra decision to reject the plea.

Thus, in his ruling of 21 May 2003, UNIDEN[78], the administrative judge noted, firstly, that the contested mechanism led EDF and DNN (non-nationalized distributors) to purchase electricity produced by plants using mechanical energy from wind at a higher price than the economic value of this electricity. Secondly, he noted that the additional costs imposed on these operators were, pursuant to Article 5 of the Law of 10 February 2000, subject to full compensation by the public service electricity fund and that this fund was fed by contributions payable by producers, suppliers and distribution organizations, by electricity producers generating for their own use more than the amount of electricity generated annually and set by decree, as well as by end users importing electricity or making intra-Community acquisitions of electricity. And it was by explicitly using the ruling of the Court of Justice, that the Council of State found that the financial burden of the purchase obligation was based on the contributions of a number of companies "*sans que des ressources publiques contribuent, directement ou indirectement, au financement de l'aide*" [without public resources contributing, directly or indirectly, to funding the aid]. Therefore, the first of the four criteria identifying State aid within the meaning of Article 87 TEC was not fulfilled and the aid did not have to be notified to the European Commission.

A questionable reading

As we have seen, the debate focuses on the first condition for State aid: it must be granted by the State or through State resources in any form whatsoever.

It is clear from the decision of the Court of Justice that this condition is fulfilled if two cumulative criteria are met. First, the resources used must be State resources, i.e. monetary resources under public control; and second, their use must be attributable to the State[79].

This criterion of imputability could be considered fulfilled in the case of the French support mechanism involved in the UNIDEN case. This mechanism

78 n°237466.

79 CJEU, 16 May 2002, France c/ Commission (Stardust Marine), Case. C-482/99.

was established by statute and regulations, and the legal regime of the mechanism (name of the organization receiving the contribution, the amount of the contribution, the use of resources for financing the additional costs incurred by the requirement purchase and, finally, the price itself) is fully secured by the instruments pertaining to the public authority.

Next, as regards the first criterion, the interpretation made by the administrative judge was unable to stand up to a more comprehensive reading by European jurisprudence. Indeed, in its Steinike ruling of 22 March 1977[80], the Court considered the question of whether the resources of a fund, established by a German federal law, with the mission of promoting the sale and export of agricultural, forestry and food products, and which was funded by federal grants and contributions from agricultural, forestry and food industry companies, were State resources. The answer was positive, and it was in this case that the Court used, for the first time, the formula "granted by a Member State" or "through State resources in any form whatsoever". And the Court stated that "The prohibition contained in article 92 (1) covers all aid granted by a member state or through state resources without its being necessary to make a distinction according to whether the aid is granted directly by the state or by public or private bodies established or appointed by it to administer the aid".

This formula was taken up in the PreussenElektra case. But this time, the Court ruled (pt 59) that the obligation imposed on private electricity supply companies, to purchase, at minimum set prices, electricity generated by renewable energy sources did not entail any direct or indirect transfer of state resources to companies producing this type of electricity, because private companies were not mandated by the State to manage a state resource but were obliged to purchase using their own financial resources.

It follows from this solution that if the benefit is given to a private organization, it is necessary to assess the State character of the resources mobilised and to examine whether the State has mandated a private organization to manage the aid system.

In the French case, under the influence of the initial aid mechanism, the public service electricity fund was fed by mandatory contributions, imposed by legislation, which in addition appointed the Caisse des Dépôts et Consignations as the manager of the FSPE. Consequently, it could be considered that in the French system of support, unlike the solution adopted in the UNIDEN judgment, the government had designated an organization with a view to managing the aid and had made available to it the necessary resources in the form of mandatory contributions.

However, this was not the interpretation made by the Council of State, which thereby temporarily maintained the support mechanism. Law N°. 2003-8 of

80 CJEU, 22 March 1977, Steinike, Case 78/76.

3 January 2003 on gas and electricity markets changed the system of financing public service expenditure. The Council of State seems to see in this the origin of the system's legal uncertainty. Indeed, "compte tenu du changement de nature du mode de financement de la compensation intégrale des surcoûts imposés…" [given the change in the way in which full compensation of the extra costs incurred is financed ...], the administrative judge considered it necessary to address a preliminary question to the Court of Justice. Though far from certain, the fragility of the system thereby revealed could now result in its reconfiguration.

3. Time to reconfigure the system

Since its inception, the support mechanism for the development of wind energy has, for want of notification, put the sector's operators in a position of major legal uncertainty. The correction process will inevitably involve defining State aid in relation to the mechanism (B). One can, however, consider that it has been initiated by the tax definition given to the contributions compensating public service expenditure (A).

The tax definition of contributions claimed for compensation of public service outgoings

A quick reading of the internal rulings and of the formulation of the preliminary question raised in the Vent de colère! case suggests that the weakening of the mechanism was triggered by the shift from the FSPE (Fonds du Service Public de la Production d'Électricité) to the CSPE (Contribution au Service Public de l'Électricité)[81]. But this is not so. The contributions claimed under financing from the public service electricity fund were first defined, by the Council of State, as "*d'impôt dont le contentieux est compris parmi le contentieux général des actes et des opérations de puissance publique*" [a tax with regard to which any litigation falls within the general litigation with regard to the public authority's actions and operations] [82], this lying within the jurisdiction of the administrative courts.

Contribution to the public service electricity fund (FSPE) and tax definition

To ensure full compensation for additional costs associated with public service missions, the Law of 10 February 2000 had initially created the public

81 O. Beatrix, La contribution aux charges de service public de l'électricité: de l'ombre à la lumière, RFDA 2012, 935.

82 CE, 13 March 2006, SA Eurodif (1e esp.), n° 255333, Réseau Ferré de France and SNCF (2e esp.), n° 265582 and n° 273093, Dr. Fiscal 2006, comm. 600, concl. C. Vérot; conf. CE, 30 March 2007, RFFF, n° 292776, JCP G 2007, IV 1922; 13 July 2011, Sté Bretonne de fonderie et mécanique, n° 318788, BDCF 12/2011, n° 143, concl. C. Legras.

service electricity fund (FSPE), which was financed by contributions from producers or their subsidiaries, suppliers and distributors of electricity in proportion to the kilowatt hours (kWh) delivered. Electricity producers generating power for their own use over and above an annual quantity set by decree and end users importing electricity or carrying out intra-Community acquisitions of electricity also contributed. End users, with the exception of the special case just mentioned, were not, or only indirectly, affected.

The system involved three actors[83]. The ministers with responsibility for the economy and energy, on a proposal from the CRE, decided on the amount of public service expenditure payable to operators incurring such expenditure. Next, the aforementioned ministers decided on the amount of net contributions that operators and those liable paid into the Fund or received from it, always on a proposal from the CRE. Finally, the Caisse des Depots et Consignations was responsible for accounting and financial management of the Fund and the collection of contributions.

In addition, the operation of the Fund was based on a declarative system. It was up each contributor to declare, prior to a specified date, the number of kWh delivered or consumed, accompanied by payment of its contribution. Then the following year it made an adjustment to the exact amount of the contribution in relation to the expenditure actually incurred and the management costs incurred by the Caisse des Depots.

On the occasion of a dispute concerning a demand for relief from contribution to the FSPE, presented by SA Eurodif and Réseau Ferré de France, the Council of State had to define such a contribution.[84] In its conclusions on these two cases, the government commissioner noted the analogy between the mechanism in question and the mechanism instituted by Articles L. R. 35-3 and 20-31 et seq of the Law pertaining to Posts and Telecommunications, in their pre-2001 version, for finance the costs of the universal telecommunications service. Only one difference was apparent: the contribution to the universal telephone service was then established and settled by individual assessment, on the basis of a ministerial decision, whereas the contribution to the FSPE was self-paid by those liable. However, with regard to the contribution to the universal telephone service, the Council of State, in its Société Tiscali Télécom[85] ruling, had deemed that the contribution was *"une imposition innommée"* [an unnamed tax] i.e. it did not fit into any of the tax categories referred to in Article L. 199 of Book of Tax Procedures. Consequently the dispute, with regard to the assessment basis, was the concern of the administrative court, in accordance with the judicial precedents of the Tribunal des Conflits [86] and of the State Council[87]. Following the proposal of the Government Commissioner, the Council of State, without further motivation, transposed this solution to contributions paid for the financing of the FSPE, this causing a collateral effect: the fiscal nature of contributions to the FSPE reinforces the idea the mandatory purchase mechanism constitutes an intervention by the State or through State resources within the meaning of and for the application of the provisions of Article 107 TFEU (formerly 87 TEC). In addition, such a definition indirectly invalidates the solution adopted in the UNIDEN ruling, in 2003.

Contribution to the electricity public service (CSPE) and tax definition

Law N°. 2003-8 of 3 January 2003 on the gas and electricity markets and the public energy service ended the public service electricity fund (FSPE) and replaced it by the CSPE. The compensation mechanism was changed with regard both to its tax base and it collection method.

Henceforth, Articles L. 121-10 et seq. of the Energy Code (formerly Article 5 L. 10 Feb. 2000) specify, on the one hand, that the compensation of public service costs, for the benefit of operators that bear them, is provided by contributions payable by the final consumers of electricity installed in the national territory and, on the other, that the amount is calculated in proportion to the quantity of electricity consumed. Those liable, namely the administrator of the public transmission or distribution network or the electricity supplier, are responsible for settling the CSPE when the invoices of the various consumers are drawn up.

The tax definition previously given to the contribution to the FSPE was not challenged by the Council of State, which had to rule on an application for the nullification of the refusal of the CRE to restore to the Stop Hotel Villeneuve d'Ascq SNC part of the CSPE it had paid for the years 2003 to 2007, on the grounds that this tax, in its opinion, constituted illegal State aid within the meaning of Article 87 TCE, for want of prior notification to the European Commission.

In its judgment of 9 November 2011, Stop Hotel Villeneuve d'Ascq SNC[88], the Council of State, in line with its RFF case, implicitly deemed the CSPE to be a tax. However, citing the case law of the Court of Justice, it dismissed the plea that the contribution was affected by the lack of notification of State aid.

83 D. n° 2001-1157 of 6 Dec. 2001, regarding the production of electricity public service fund, implementing Article 5 of Law n°. 2000-108 of 10 February 2000 on the modernisation and development of the electricity public service.

84 CE, 13 March 2006, SA Eurodif (1e esp.), n° 255333, Réseau Ferré de France and SNCF (2e esp.), n° 265582 and n° 273093, prec.

85 CE, 18 June 2003, Sté Tiscali Télécom, n° 250608 and n° 250613, Rec. 255.

86 T. confl., 10 July. 1956, Sté Bourgogne-Bois, n° 1565, Rec. 586.

87 CE, ass., 20 Dec. 1985, SA Ets Outters, n° 31927, Rec. 382.

88 CE, 9 November 2011, SNC Stop Hôtel Villeneuve d'Ascq, n° 323273, Dr. Fiscal 2012, comm. 127, concl. F. Aladjidi, note A. Maitrot de la Motte.

Taking a preamble previously formulated in its Sté Boucherie du Marché ruling[89], the Council of State Conseil d'Etat found "*qu'il résulte de la jurisprudence de la CJCE, d'une part, que les taxes n'entrent pas dans le champ d'application des stipulations précitées du TCE concernant les aides d'Etat, à moins qu'elles constituent le mode de financement d'une mesure d'aide, de sorte qu'elles font partie intégrante de cette mesure, d'autre part, que, pour qu'une taxe, ou une partie d'une taxe, fasse partie intégrante d'une mesure d'aide, il doit exister un lien d'affectation contraignant entre la taxe et l'aide en vertu de la réglementation nationale pertinente, en ce sens que le produit de la taxe soit nécessairement affecté au financement de l'aide et que le montant de la taxe influence directement le niveau de l'aide*". ["that it follows from the case law of the ECJ, on the one hand, that taxes do not fall within the scope of the aforementioned provisions of the EC Treaty concerning State aid, unless they constitute the method of financing an aid measure, so that they are an integral part of this measure, and on the other hand, that for a tax, or part of a tax, to be an integral part of a aid measure, there must be a hypothecation between the tax and the aid under the relevant national legislation, in the sense that the revenue from the tax is necessarily allocated for the financing of the aid and the amount of the tax directly influences the level of aid"].

Indeed, the Court of Justice ruled that while not constituting State aid in itself, a tax measure must be notified to the Commission if it is used to finance aid and is an integral part of the proposed measure[90]. Thus it applies when there is a hypothecation between the tax and the aid. This hypothecation is established when the revenue from the tax is necessarily allocated for the financing of aid and directly influences its size[91]. It is therefore only in this case that notification of the aid measure must also concern its financing so that the Commission can carry out a comprehensive review.

In the Stop Hôtel Villeneuve d'Ascq SNC case, the issue concerned the financial compensation of TaRTAM by the CSPE[92]. The Council of State

89 CE, 27 July 2009, Société Boucherie du Marché, n° 312098.
90 CJEU, 21 Oct. 2003, Van Calster and Cleeren, Case C-261/01, pt 51; 27 Oct. 2005, Distribution Casino France SAS, Case C-266/04, Dr. Fisc. 2006, n° 8, comm. 196.
91 CJEU, 13 Jan. 2005, Streetgewest, Case C-174/02; 27 Oct. 2005, Distribution Casino France SAS prec.: The amount of aid financed by the tax to support trade and craft, in favour of certain categories of merchants, was specified in the legislation and was independent of the amount of tax collected. It concluded that the possible unlawfulness of the original indemnity under the provisions on State aid was not likely to affect the legality of the tax in question.
92 It was a matter of the right of clients having exercised their eligibility, i.e. having left EDF, to benefit from a regulated and transitory market adjustment rate (tarif réglementé et transitoire d'ajustement au marché – TaRTAM), which was lower than market rates (Law n° 2004-803 of 9 August 2004, art. 30-1 and 30-2). The ending of TaRTAM was established by Law n° 2006-1537 of 7 December 2010, known as NOME (art. 19).

therefore relied on the provisions establishing TaRTAM and the terms under which compensation of expenditure resulting from this is only partly covered by the funds collected under the CSPE[93], so that even if TaRTAM constitutes State aid, it appears that "*le montant de la CSPE n'influencerait pas directement le niveau de cette aide de sorte que cette contribution puisse être considérée comme en faisant partie intégrante*" ["the amount of the CSPE would not directly influence the level of aid, such that this contribution can be seen as forming an integral part."]

The Council of State thus "saved" the CSPE, on the grounds that it could not directly affect the amount of aid that might possibly constitute TaRTAM and could not, therefore, fall within the scope of the provisions on State aid. But in this particular case, it was the tax measure that was directly attacked and suspected of being State aid in view of the conditions set by European law. But the question is not settled as to of whether the mandatory purchase mechanism in itself constitutes State aid, in particular because of its funding method.

However, the fiscal definition thus given is similar to the definition of State aid.

The inevitable definition of State aid: the "Vent de Colère !" association case

In 2008, the association *Vent de Colère!* and the association *Vent du bocage* had obtained the nullification of the decree of 10 July 2006 due to a procedural defect that made it null and void[94]. Following this nullification a new decree, dated 17 November 2008, supplemented by the decree of 23 December 2008, set the purchase price of electricity produced by plants using the mechanical wind energy. Once again the association *Vent de Colère!* asked for the nullification of the decree, arguing, inter alia, that it instituted State aid and should annulled due to the absence of prior notification, in violation of Article 88 § 3 ECT (Article 108 TFEU)

For the first time, the Council of State acknowledged that the aid mechanism for the development of wind energy might constitute State aid. But in view of the scale of the economic and financial implications of nullification, when its public rapporteur suggested doing so, it drew back from taking on the consequences of European law and its own findings and preferred to ask the Court of Justice whether, given the change in the funding procedure for compensating the additional costs imposed on EDF and DNN, resulting from the law of 3 January 2003, this mechanism should be regarded as intervention by the State or through State resources.

93 Law n° 2006-1537 of 7 Dec. 2006, art. 16.
94 Req. n° 297723.

The definition of State aid now seemed inevitable, since the four conditions of State aid were now clearly satisfied (2), given that the Essent Netwerk judgement, in which the Council of State seemed to have seen a change in the law, in any event had no effect on the definition (1).

A solution without effect on the definition

In its order for reference, the Council of State, saw, in the Court of Justice ruling, Essent Netwerk Noord BV[95], of 17 July 2008, a legal shift likely to influence the legal definition of the French mechanism. Another reading of this judgement can be made.

A Dutch court, in support of a preliminary question, asked whether a supplementary charge imposed by law, depending on the amount of electricity carried, billed to every customer by the network manager for a transitional period, and paid to a subsidiary company of the national electricity generating companies to fund "non-market costs" resulting from investments made prior to liberalization, for reasons of security of supply and sustainable provision and use of energy sources, with any surplus being paid to the State, constituted State aid.

The Court described this surcharge on electricity as a "state intervention through state resources", noting that the allocation of the proceeds of the levy had been decided by the legislature, whereas in the mechanism in the PreussenElektra case, the companies were not mandated by the State to manage a state resource, but were required to purchase using their own financial resources. In other words, in the Dutch case, the State had put the necessary resources at the disposal of the agency responsible for granting the aid and Essent, the network manager, was entitled under the law to recover an additional amount per kWh from the various end users. In so doing, the Court redeployed an argument that it had already used regarding a tax based on the consumption of petroleum products and accruing to the Agency for energy savings, thus ruling that a special tax could, depending on the application of its proceeds, constitute State aid. Aid funded from mandatory contributions is State aid, even if the tax revenues are not channelled through the government budget and are distributed by bodies other than of the public authority[96].

Ultimately, the Essent Netwerk Noord BV solution of the Court of Justice does not limit the scope of the solution in the Preussen Elektra judgment and the two rulings should not be opposed but viewed as applications, to different situations, of the principle of the Steinike ruling[97].

95 Case C-206/06

96 CJEU, 11 March 1992, Case 79/90 to 83/90 plen., Compagnie Commerciale de l'Ouest and other companies, RJF 10/92, n° 1441.

97 prec.

Meeting the conditions of the State aid

Three of the four conditions required for State aid to be established are met. The Council of State had already admitted as much in its Association Vent de Colère! order for reference.

Thus the first, that the intervention is likely to affect trade between Member States, is deemed to be satisfied. In this respect, according to the Court of Justice, there is no threshold below which it could be considered that trade between Member States is not affected. Accordingly, in the Tubemeuse (pt 43) ruling, the Court observed that the relatively small amount of aid or the modest size of the recipient company does not in principle exclude the possibility that trade between Member States is affected. Similarly, in the Essent Netwerk Noord BV ruling, it noted that national electricity companies were competing with electricity producers in other Member States and, furthermore, with regard to the liberalization of the electricity market and the resulting intense competition, this fact was sufficient to establish that aid was liable to affect trade.

Second, the condition requiring that intervention brings a benefit to the recipient is necessarily satisfied since the purpose of the purchase mechanism is to confer an advantage on the beneficiary of the aid.

Third, the support inherently distorts or threatens to distort competition. In this way the production of electricity from wind energy can be helped to develop, by artificially ensuring the profitability that market mechanisms do not appear to secure.

The outstanding question, finally, is whether the support mechanism constitutes an intervention by the State or through state resources.

As stated previously, the condition is met if the resources used are financial resources under public control and if their use is imputable to the State.

Imputability is not in doubt when the setting of the CSPE is required by law and regulations, as is also indirectly confirmed by the tax definition given by the Council of State[98].

Public control over the financial resources at issue does not any longer appear to be in question. The amount of the contribution is determined by ministerial decree on the proposal of the Commission for Energy Regulation, the independent administrative authority responsible for the proper functioning of the electricity and gas markets. In addition, since the law states that the additional costs linked to the purchase requirement are subject to full compensation, it can be inferred that the State is the guarantor of the system as a whole, even if there is no perfect equivalence between the additional costs borne by the distributors and the amount of the contribution

98 CE, 13 March 2006, RFF, prec; 30 March 2007, RFF, prec.; CE, 9 Nov. 2011, SNC Stop hôtel Villeneuve d'Ascq, prec.

that is paid to them. In addition, the management of the moneys raised is entrusted to the Caisse des Depots, a public institution, which operates a specific account on which it records the transactions and ensures the transfer of funds to the recipients of the aid.

For all these reasons, the ministerial decree setting the mandatory purchase price of electricity produced from wind energy thus seems to us to constitute State aid.

Ultimately, the most surprising thing is not so much the legal definition as the decision made by the French government to put the operators of this sector, which account for no less than ten thousand jobs, in such a legally uncertain position, even though the European Commission has examined, over the last decade, a significant number of other Member States' support systems that are comparable to the French system, and has regularly concluded by defining aid "granted by the State or through State resources in any form whatsoever"[99]. Adopting the same line of interpretation, on 11 July 2013 the Advocate General Nilo Jääskinen announced his conclusions on the application for a preliminary ruling by the Council of State and deemed that the mechanism in question clearly falls within the notion of intervention by the State or through state resources within the meaning of Article 107 § 1 TFEU[100].

Subject to the very likely confirmation by the Court of Justice of the conclusions of the Advocate General, we are heading towards a nullification of the decree setting the purchase price. The Council of State will be required to quash the wind tariff decree attacked by the Association Vent de Colère! and to order the recovery of aid unduly paid to beneficiaries.

The retroactive nullification is likely to have a cataclysmic impact on the wind sector and it can be assumed that the domestic court, if the matter is submitted to it, will in due course use its power to modulate the effects of the nullification[101].

Furthermore, recovery of the aid may be very difficult to accomplish. In fact it would be necessary to calculate, for each unit of production, the amounts unduly received. And the beneficiaries affected would be certain to turn to the state in support of an action for damages. However, on the assumption that the Commission would subsequently find the system to be consistent with the rules of the internal market, EU law does not require a national court to determine the full recovery of unlawful aid. It can only order

99 For example, Decree 2007/580/CE of 24 April 2007 on the State aid scheme implemented by Slovenia in the framework of its legislation on qualified energy producers, State aid C-7/2005, OJ L 219 of 24 August 2007, 9; December 2009/476/CE for aid in the form of the creation of a compensation fund as part of the organization of the electricity market implemented by Luxembourg, OJ L 159 of 20 June 2009, 1.

100 Case C-262/12.

101 CE, ass., 11 May 2004, Association AC !, n° 255886.

the recipient of the unlawfully implemented aid to pay the interest due over for the period concerned[102].

Even though the solution will be valid only for the purchase of electricity generated by wind power, and only concerned with the preliminary question, the nullification of the tariff decree, based on the definition of State aid pertaining to the mechanism, risks causing collateral damage. Indeed, the very structure of the mechanism is in question. Yet since 2000, this mechanism has been the main support tool for the development of renewable energy and is not concerned solely with wind power. Other sectors may also be affected: for example, the obligatory purchase mechanism with regard to the biogas industry and biomethane fed into the natural gas grid is comparable to the one used for the production of renewable electricity[103].

It is therefore very urgent that the French government ceases placing the operators of these sectors in a situation of such legal uncertainty and proceeds, finally, to the notification of mandatory purchase mechanism[104], in the hope that the European Commission, this time regularly informed, deems them to be compatible with the Treaty, in view, especially, of the guidelines on State aid for environmental purposes[105].

102 CJEU 11 July 1996, SFEI, Case C-39/94.

103 Energy Code, art. L. 121-43 and Decree N°. 2011-1595 of 21 November 2011 relating to the compensation of public service costs for the purchase of biomethane fed into the natural gas grid.

104 On the announcement of the Advocate General's conclusions, the Minister responsible for the economy said that the government had agreed, on 22 April 2013, to a pre-notification procedure for the onshore wind power support system.

105 While national courts are entitled to sanction a national system establishing State aid in breach of the obligation to notify the project to the Commission, the European Commission on the other hand has sole authority, under the control of the Court of justice, to decide whether or not said State aid is compatible with the common market.

Chapter 10

The financial markets and energy: European cooperation between energy and financial regulatory authorities

Vincent Derbali

1. Introduction

The European Union needs an internal Energy market that is competitive, integrated and liquid, providing well-functioning, flexible and secured electricity and gas markets all across Europe[106] in order to achieve its Energy[107] and climate goals. Fully integrated European Energy networks and systems and open Energy markets are essential in making the transition to a low-carbon economy and promoting secure supplies at the lowest possible cost. Though much has already been achieved, the fast evolving structure of the Energy markets requires further improvement, especially in terms of transparency and prevention of market abuse.

Just like other commodity markets, Energy markets have evolved profoundly over the last decade and have attracted much attention from policy makers and financial regulators. Alongside their growing globalisation and interaction with the financial system (commonly referred to as "*financialisation*") since 2000, Energy markets showed exceptional volatility in 2008-2009, creating price insecurity and leading to an increased use of hedging tools on financial derivatives markets.

In an environment where wholesale Energy markets encompass both physical commodity markets and financial derivatives markets, becoming increasingly intertwined with respect to their price formation process and their trading strategies, a number of legislative and regulatory initiatives have been taken to strengthen the consistency of their regulatory framework. Among these regulatory initiatives, promoting cooperation between

106 Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Making the internal energy market work, COM(2012) 663 final, November 15, 2012

107 In this chapter according to the European Union regulatory semantic "Energy" shall refer to electricity and gas

Energy and financial regulators is central. A series of recent cases of market abuses on Energy markets have indeed highlighted the necessity to promote close cooperation between Energy and financial regulators[108].

This chapter aims at presenting and discussing (2) the European regulatory framework for the regulation of European financial Energy markets and (3) the existing European model of cooperation between Energy and financial authorities.

2. Regulating energy markets in an evolving environment

From a European regulatory perspective, there are two types of Energy markets: markets trading non-financial instruments, whether they are spot or derivatives contracts, and markets trading derivatives contracts qualified as financial instruments. This segmentation is supported by a distinct – but not independent – regulatory framework and dedicated competent authorities.

Energy market structure evolution

From a market structure perspective, Energy markets have substantially changed over the last decade, as well as in terms of the diversity of the active market actors.

Pure financial players (investment banks, hedge funds and institutional investors), have assumed a growing share in Energy trading activities whether on financial or non-financial contracts. Commercial and industrial players have, for their part, adapted their trading strategies on financial derivatives markets, not only to cover their price risk exposures on the physical markets but also to support liquidity and to seize speculative opportunities. As a result, the use of a large variety of derivatives contracts (such as, *inter alia*, futures and forward, options, exchange traded funds and index funds) has increased and returns from commodity trading activities are increasingly pooled with returns from pure financial assets (a "*pooling effect*').

Derivatives markets are of vital importance in providing risk management tools in commodity markets. However, this financialisation has raised

108 On July 22, 2013 the UK's Financial Conduct Authority and the US Commodity Futures Trading Commission, each fined US-based High Frequency Trading company "Panther Energy Trading" and its founder for deliberate manipulation of commodity derivatives contracts including Brent Crude, Gas Oil and WTI futures traded on the UK's Ice Futures Europe exchange. On July 30, 2013, the US' Federal Energy Regulatory Commission (FERC) approved an agreement under which JP Morgan Ventures Energy Corporation will pay $410 million in penalties for allegations of market manipulation stemming from the company's bidding activities in electricity markets in US from September 2010 through November 2012.
STAFFORD Ph., High-frequency trader fined in transatlantic clampdown, Financial times, July 22, 2013.

questions as to whether it has improved price discovery and liquidity or on the contrary, contributed to price and volatility surges in financial derivatives markets[109]. It also raises a question in determining if it has impacted the underlying physical markets. As Energy markets evolve to a more global and interconnected environment, they get exposed to new and greater risks, which requires a sophisticated monitoring mechanism and more coordination between supervisory authorities at a supranational level.

Moreover, to complicate their monitoring and regulation, these markets include regulated markets, Multilateral Trading Facilities (MTF) and over-the-counter (OTC) transactions and bilateral contracts that are direct or through brokers, each subject to specific rules and dedicated competent authorities.

Such complexity generates extra costs for both market actors and regulators and illustrates the need for strong coordination among competent national and supranational authorities and for international regulatory harmonisation.

Overview of the European Regulatory framework: segmentation between financial and non-financial markets

On an international level, on September 15, 2011 the International Organization of Securities Commissions published a report on the principles that should guide national regulators and legislators in the regulation and supervision of commodity derivatives markets, prompted by the G20. Following these recommendations, it was determined that commodity market regulators should cooperate closely in order to improve market transparency (access to both financial and non-financial market data, including spot contracts) and to better prevent market abuse. In this context, the example of European Union Energy markets regulation was taken.

Indeed, at a European level, significant progress along the road to more effective regulation of commodity markets has been made through a corpus of rules for both non-financial and financial Energy markets.

On October 25, 2011, the European Union adopted Regulation N° 1227/2011 on Wholesale Energy Market Integrity and Transparency (regulation REMIT), which imposes stringent new rules on Energy markets. Its main objectives are to prohibit and prevent abusive practices (market manipulation and insider dealing), which can distort wholesale Energy prices and improve the markets' transparency. It also provides the new European agency, the Agency for the Cooperation of Energy Regulators (ACER) the powers to monitor such markets at a European level in cooperation with the European financial authority known as the European Securities and Markets Authority

109 For further information, see Report of the G20 Study Group on Commodities under the chairmanship of Mr. Hiroshi Nakaso, November 2011.

(ESMA) and the competent national authorities. REMIT entered into force in December 28, 2011 and its full implementation is still in progress. This sectorial regulation of the Energy market is unique in the European commodity markets' landscape.

Though the transparency requirements apply to both non-financial and financial contracts, the market abuse provisions do not cover Energy financial derivatives contracts traded on a regulated market, covered by Directive N°2003/6/EC of January 28, 2003 on insider dealing and market manipulation (MAD directive), which prohibits market abuses. Thus, despite their very close correlation, the first category of contracts is monitored by the Energy Authorities – *Commission de Régulation de l'Énergie (CRE)* in France – whereas the second category of contracts is monitored by the financial authorities.

Furthermore, the scope of MAD depends on the definition of financial instruments with regards to derivatives contracts for which the underlying is a commodity, as provided by the Directive N° 2004/39/EC of April 21, 2004 on markets in financial instruments[110] (directive MiFID). In other words, even if financial and non-financial markets are co-dependent (in terms of utility and price formation), there is a legal segmentation between financial and non-financial contracts. Nonetheless, their regulation by competent authorities does not follow the exact same segmentation.

It should also be noted that the European Union has adopted Regulation N° 648/2012 of July 4, 2012 on Over-The-Counter (OTC) financial derivatives (including commodity derivatives), central counterparties and trade repositories (regulation EMIR), which imposes mandatory clearing and reporting obligations. These provisions should improve market transparency but may create regulatory overlaps with REMIT, particularly in terms of reporting obligations. Full implementation of EMIR is still in progress and will be kept under close scrutiny in that regard.

Finally, the on-going revision of MAD and MiFID, should substantially improve the regulatory environment for Energy markets, notably in terms of supervision and transparency. It might also rearticulate the competency distribution between energy and financial regulators. The review of MiFID should, *inter alia,* introduce a reporting position requiring the systematic transfer of information on the positions held by traders for Energy Financial contracts (Article 60 of the proposed recast of MiFID). The revision of MAD should notably provide for a differentiated approach to inside information and should extend the market abuse prohibitions to behaviours involving both financial derivatives and non-financial contracts in commodity markets. This draft provision will eliminate regulatory loopholes but might create important overlaps (reporting requirements and double administrative sanction by Energy and financial regulators for the same market abuse).

110 Annex I, Section C of the Directive (EC) N° 2004/39/EC of April 21, 2004 on markets in financial instruments.

Considering that each of these regulations and directives requires a close cooperation between Energy and financial regulators at a European level, ACER was created by the Third Energy Package[111] and officially launched in March 2011 [112].

3. Cooperation mechanisms between energy and financial regulators

On July 18, 2013, the European Agency for the Cooperation of Energy Regulators (ACER) and the European Securities and Markets Authority (ESMA), its financial markets counterpart, have signed a Memorandum of Understanding (MoU) for their cooperation and exchange of information regarding their regulatory responsibilities related to European Union wholesale electricity and gas markets[113]. This MoU is the culmination of a very long process for the establishment of a consistent regulation framework for the regulation of power and gas markets.

From voluntary cooperation between national regulatory authorities to the European Agency for the Cooperation of Energy Regulators

Following the progressive development of an Energy policy at the European level in order to reach the internal Energy market, an independent and dedicated advisory group, the European Regulators Group for Electricity and Gas (ERGEG) was founded in 2003 by the European Commission[114]. Its main objective was to facilitate consultation, coordination and cooperation between the competent national authorities, established pursuant to 2003 directives concerning common rules for the internal market in electricity and natural gas[115], and with the Commission.

As an advisory body, ERGEG had neither supervisory nor sanctioning powers. Thus, the member states decided in 2009[116] to build an independ-

111 For further information on the Third Energy Package consult the following internet link: http://www.acer.europa.eu/the_eu_energy_market/Legislation/Pages/default.aspx

112 ACER was founded by Regulation (EC) N° 713/2009 of July 13, 2009.

113 Memorandum of Understanding between ACER and ESMA concerning the consultation and cooperation regarding their regulatory responsibilities in relation to EU wholesale energy markets, July 18, 2013.

114 European Commission Decision (EC) 2003/796/EC, November 14, 2003.

115 Directive (EC) N° 2003/54/EC of June 26, 2003 concerning common rules for the internal market in electricity and Directive N° 2003/55/EC of June 26, 2003 concerning common rules for the internal market in natural gas.

116 Regulation (EC) N° 713/2009 of July 13, 2009 establishing an Agency for the Cooperation of Energy Regulators.

ent European structure, the ACER, which monitors the effective functioning of the internal Energy market and coordinates and promotes cooperation among competent energy regulators.

Thus, ACER not only provides a framework for national Energy regulators to cooperate, but also plays a central role in the monitoring at a European level of the Energy market, particularly in collecting data and applying the prohibition rules on abusive practices affecting such markets. Considering that Energy markets actors apply trading strategies that involve the trading of both non-financial and financial contracts, it is therefore important to apply consistent rules in both markets.

In this perspective it is of vital importance to strengthen the cooperation between financial and Energy regulators at the national and European levels, through clear cooperation processes and consistent interpretation of European legislation.

European cooperation for Energy markets' transparency and integrity

Considering that ACER and ESMA, should cooperate closely to ensure a coherent, consistent and coordinated approach on the regulation of Energy markets, the two European institutions have recently signed a MoU which sets up formal communication channels for their mutual consultation and assistance and for the consistent approach to market abuse rules.

According to their respective competencies and expertise, ACER and ESMA hold complementary overviews on Energy markets. Strong consultation and exchange of information processes between them can therefore provide legislators and regulators with a full picture of the European Energy market. Only such a picture can enhance consistent, efficient and effective regulatory practices for reaching the internal Energy market. ESMA and ACER should consequently "*consult each other in preparing guidelines and recommendations and draft regulatory technical standards concerning their respective competences in order to ensure that the particularities of the financial and the energy sectors are fully taken into account*"[117].

These complementary competencies are particularly noticeable when it comes to market abuse prohibitions. As developed in section 1.2 above, Energy and financial regulators share the sanctioning powers for breaches of market abuse rules in Energy markets. In that respect, not only do they share their respective expertise, but they also alert one another in case of market abuse suspicions[118].

At the member states level, each national financial and Energy regulator has also developed such cooperation mechanisms in order to fulfil their respective growing competencies. In France for instance, the French financial market authority, the *Autorité des Marches Financiers* (AMF), and the French Energy regulator, the CRE, have signed a similar cooperation MoU on December 10, 2010119.

4. Conclusion

Despite the growing interactions between Energy financial and non-financial markets, there is, from a European regulatory perspective, a clear segmentation between dedicated competent authorities. The reporting requirements provided under financial regulations reflect the reporting requirements provided under wholesale Energy regulations. The market abuse prohibitions provided under wholesale Energy regulations reflect the market abuse requirements provided under financial regulations. This obviously pleads for a consistent regulation and for a strong and close cooperation between financial and Energy regulators. We can however wonder if the fundamental distinction between financial and non-financial energy markets is still appropriate as it creates regulatory overlaps (although these are preferable to regulatory loopholes). As ACER has progressively proven to be effective in the regulation of Energy markets at the European level, we can question whether European legislators shouldn't orientate their regulatory efforts towards a unique Energy market set of rules with a unique competent authority.

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117 Memorandum of Understanding between ACER and ESMA concerning the consultation and cooperation regarding their regulatory responsibilities in relation to EU wholesale energy markets, July 18, 2013, page 3.

118 According to Article 16(3)(b) of REMIT, ACER shall inform ESMA where it has reasonable grounds to suspect that acts are being, or have been, carried out on wholesale energy markets which constitute market abuse within the meaning of Directive 2003/6/EC and which affect financial instruments subject to Article 9 of that Directive.

119 Memorandum of Understanding between the commission de Régulation de l'Énergie and the Autorité des Marchés financiers, Decembre 10, 2010.

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Part 5
Ecological transition

The direct and indirect costs incurred in enforcing more stringent environmental policies have often been pointed out by opponents to these policies. The direct costs associated with the funding of support for renewable energies are, for instance, at the core of the policy debate around energy in Germany. The indirect costs due to adjustments in the job market and effects on competitiveness compared to alternative energy policies based on nuclear power (in France) or shale gas and oil (in the United States) are also central to the debate around energy transition. Combining environmental policies with innovation policies may be an effective way of tackling their potential drawbacks. For instance, recycling the revenue from environmental taxes in the form of subsidies for "green" innovation may reduce the cost of switching to less polluting technologies for polluting firms, while avoiding the need to raise moneys in a distortional way in support of innovation.

The two following chapters consider the main theoretical dimensions of this problem of policy coordination and the related instruments.

Chapter 11, *Theoretical grounds for coupling environmental policies and innovation policies*, argues that policy instruments aimed at addressing the free-riding problem characterizing innovation economics and the pollution externality that is the basis of environmental economics have to be jointly analysed in shaping efficient "green innovation" policies.

Chapter 12, *An overview of policy instruments for green innovation,* offers an overview of the main policy instruments for promoting "green" innovation and the spread of "green" technologies. Though this chapter does not reject the standard dichotomy between "demand pull" and "technology push" instruments, it argues that the distinction is not as obvious as it seems. Emphasis is placed on the crucial role of details in designing instruments, illustrated by *feed-in tariffs* and *tax credits*.

Chapter 11

Theoretical grounds for coupling environmental policies and innovation policies

Marc Baudry

1. Introduction

The recent economic literature points to loss of efficiency due to a separate treatment of market failures that result from environmental externalities on the one hand, and market failures that result from knowledge spillovers on the other hand. The idea, referred to as the "double externality" problem, is that the interplay between environmental and innovation policy calls for a joint analysis of the two types of policies in order to define an optimal "green" innovation policy (Jaffe, Newell and Stavins, 2005). To date, the drawback of most existing studies is that they consider only one facet of "green" innovation. For instance, theoretical studies have either examined how the different instruments of environmental policy affect the incentives to patent an invention that improves pollution control, but take the different environmental policies as exogenously defined (see e.g. Downing and White 1986 or Milliman and Prince 1989), or they have studied how the monopolistic position conferred by the existing patent may justify departing from a Pigouvian tax set at the marginal pollution damage (Parry, 1995). Similarly, empirical studies have been essentially "one way" and have focused on the assessment of the impact of environmental policies on innovation. This strand of literature has greatly benefited from the increasing availability of data on patents. Popp (2002), Brunnermeir and Cohen (2003), Johnstone Hascic and Popp (2010) or Popp Hascic and Medhi (2011) are illustrative of the development of this type of work throughout the last decade. To our knowledge, we are still lacking studies for which the emphasis is the interplay between environmental policy and innovation policy, rather than how these two policies affect the other when taken as exogenously defined.

With this aim in view, the first part of the chapter attempts to set the framework of a basic model that illustrates how both the design of patents and the design of an environmental tax should be jointly adapted, at least for a period of time, in the case of a "green" invention that lowers the emissions of a pollutant per unit of production. The second part of the chapter aims at extending the discussion to the interplay between resource economics and innovation economics. Following Hartwick (1977), the literature on sustainable development advocates in favour of a two-step policy: i) the taxation of rents from natural resources, more specifically fossil fuels; ii) the recycling of the tax revenue in the form of investments in additional units of non-natural capital. Part two of this chapter proposes to get some insights into the impact of recycling tax revenues into R&D programs, which aim at improving either efficiency in the use of fossil fuels or efficiency in alternative sources of energy, such as renewable sources of energy for instance. The question addressed is whether the consequences on the level and time paths of the price of the natural resource are similar, whatever the type of R&D program considered, or not. The consequences in terms of explicit and implicit transfers among generations are also discussed.

2. The intrinsic interdependency between innovation and environmental policies when facing "green" inventions

Both innovation policies and environmental policies are multifaceted. As the purpose of this chapter is to argue that they interplay and should be jointly defined with a perspective to correctly dealing with the "double externality" problem, the focus is voluntarily made on two specific policy instruments. As regards environmental policy, the focus is on a Pigouvian tax. As regards innovation policy, we stress the case of the patent system, which is a common instrument used in most developed countries and which also receives more and more attention in developing countries (and among them, more specifically China and Brazil). This first part starts with a section that sets the basic framework for the analysis of the optimal life of patents, a key element of the patent system. In a second section, this basic model is adapted to deal with patents applied for "green" inventions. We stress that, in spite of the proximity with the initial basic model, some key differences justify departing from the optimal life of "standard" patents but also from the optimal Pigouvian tax, at least during the life of the patent.

The canonical model of optimal life for patents

The basic model initially proposed by Nordhaus (1967) and further discussed by Nordhaus (1969), Sherer (1972) and Nordhaus (1972) is considered as the canonical model for optimal patent life. The model considers the market for a good with a linear demand curve and a constant marginal cost of production c_0. Perfect competition is assumed to prevail at first in the market so that the exchanged quantity q_0 of the good and the corresponding market price are respectively characterized by the abscissa and the ordinate of the crossing point of the demand curve and the supply curve in Figure 1. Under perfect competition the supply curve is the horizontal line associated with the constant marginal cost of production c_0. Since the market equilibrium price equals the constant unit price, the profit generated for producers amounts to zero. A process innovation lowers the marginal cost of production from c_0 to c_1. The invention possibility function $B(R)$ is defined as the functional relation that links the drop $c_0 - c_1$ of the marginal cost of production to the R&D expenditures R being devoted to this process innovation. Copying the process innovation costs nothing so that in the absence of appropriate innovation policies there are no monetary incentives to invest in R&D. Indeed, immediate replication of the process innovation would cause the marginal cost of production to fall to c_1 for all producers, which also results in a drop of the market equilibrium price to the same level, increasing the exchanged quantity from q_0 to q_1. Consequently, the process innovation leaves profits unchanged at zero for all producers, including the inventor. Conversely, if a patent is awarded to the inventor, it confers the right to be the only producer benefiting from the drop of the marginal cost of production. It is in the interest of the patent holder to exploit this cost advantage to monopolize the market. Nevertheless, a patent does not systematically induce monopoly pricing. The reason for this is that monopoly pricing may lead to a price that exceeds the initial marginal cost c_0. In such a case, the demand addresses other producers who supply the good under perfect competition with the old technology. It is then better for the patent holder to price the good just a little bit less than c_0 and to capture the entire market. The quantity demanded remains unchanged at q_0. This pricing strategy generates a rent $c_0 - c_1$ per unit of product produced and sold. The total rent that accrues to the patent holder is thus the area ABEF on Figure 1. Nevertheless, as this price departs from the price that would prevail under perfect competition, there is an associated dead weight loss corresponding to the triangle EFH on Figure 1. The economic literature on patents refers to this case as the case of "run of the mills", or non-drastic, invention. Arrow (1962) has shown that it occurs when the ratio between q_0 and q_1 is greater than one half, which is considered a reasonable assumption. For ease of presentation, we follow the mainstream literature and focus on this case of non-drastic invention.

If the lifespan of a patent is T the discounted sum of rents that accrues to the patent holder from the application date $t = 0$ assimilated to the current date up to the statutory life limit $t = T$ is defined as

$$\int_0^T q_0 \left(c_0 - c_1\right) e^{-\rho t} \, dt \quad (1)$$

where ρ is the discount rate. Once the statutory life limit of the patent is reached, competitors are allowed to use the invention for free. Perfect competition then applies again and the new market equilibrium is characterized by the quantity q_1 priced at the marginal cost c_1. The rent received by the patent holder before the patent ends is then converted into an additional surplus for consumers and the dead weight loss vanishes. Given that $B(R) = c_0 - c_1$, the discounted sum of profits received by the inventor is written as

$$\int_0^T q_0 B(R)e^{-\rho t}dt - R \quad (2)$$

Assuming a positive but decreasing marginal productivity of the R&D effort (i.e. $B' > 0$ and $B'' < 0$), the optimal R&D effort R^* solves the first order condition

$$B'(R)q_0\left(1 - e^{-\rho T}\right) = \rho \quad (3)$$

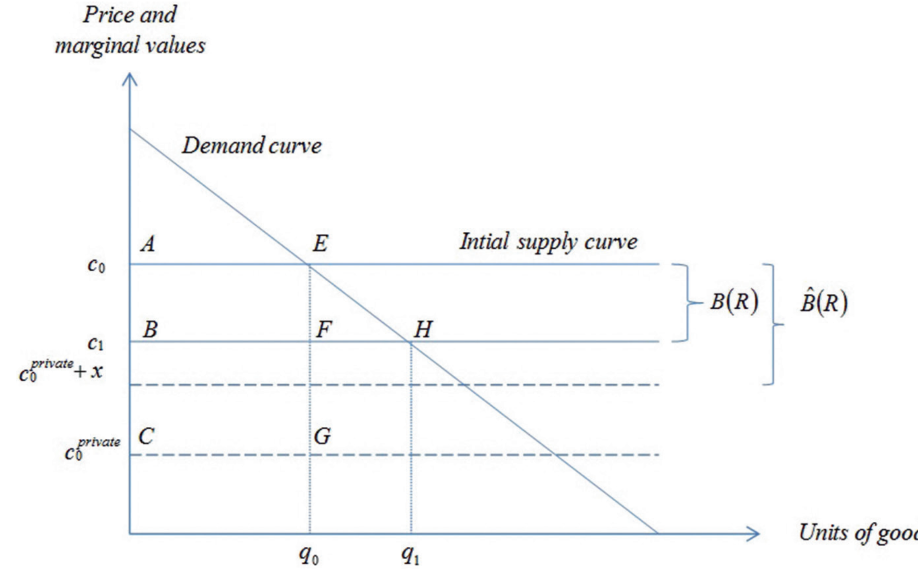
The literature assumes that the patent office acts as a Stackelberg leader and chooses the lifespan of patents so as to maximize the social surplus given the optimal R&D effort induced for the patent holder. In this Stakelberg game, (3) is the implicit reaction function that characterizes how a patent holder, the follower of the game, adjusts his R&D effort to the lifespan of patents chosen by the patent office. Focusing on the part of the social surplus that depends on *T* this is equivalent to maximizing

$$\int_0^\infty q_0 B(R)e^{-\rho t}dt + \int_T^\infty \frac{1}{2}(q_1 - q_0) B(R)e^{-\rho t}dt - R \quad (4)$$

The challenge that the patent office faces consists in optimally balancing the advantage of long living patents in terms of incentives to invest in R&D and innovate on the one hand, and the induced social cost corresponding to the dead weight loss on the other hand. In spite of the inability to obtain an analytical solution to the problem, Nordhaus (1967) discusses how the optimal lifespan T^* of patents depends on the elasticity of demand, the magnitude of the invention measured by $c_0 - c_1$ and the curvature of the invention possibility function $B(R)$. He also calibrates the model with realistic values of parameters that support the choice made by most of patent offices of an optimal lifespan of patents in the range of twenty years[120].

120 Patent offices actually conform to Art. 33 of the TRIPS Agreement that sets a minimum period of protection and states that "the term of protection available shall not end before the expiration of a period of 20 years counted from the filing date" but this provision is often considered as the maximum period of protection.

Figure 1: Nordhaus' framework for the analysis of the optimal life of patents



The peculiarity of "green" patents

We now adapt the canonical model of Nordhaus (1967) to the context of an invention that primarily aims at reducing the emissions of a pollutant. In order to ease the analysis, we stress the case of a constant marginal pollution damage θ for all units of pollutant released. Let e_0 denote the initial amount of pollutant released per unit of good produced. Then, the marginal social cost of one additional unit of production is θe_0, which is also the optimal Pigouvian tax to be charged per unit of good produced. Assuming a constant private marginal cost of production $c_0^{private}$ as in Nordhaus' model, the total marginal cost of production obtained amounts to $c_0^{private} + \theta e_0$. By contrast to a "standard" invention that reduces $c_0^{private}$, we now consider a "green" invention one that reduces the amount of pollutant released per unit of good produced from e_0 to e_1. The main difference compared to a "standard" invention is that it makes sense for producers to engage in a R&D program that aims at obtaining a "green" invention only in the presence of the Pigouvian tax, or any such policy instrument with similar effects on the total cost of production considered by producers.

At first glance the analysis of the impact of a patented "green" invention on market equilibrium seems to be formally identical to that of a "standard" invention just discussed above. Setting $c_0 = c_0^{private} + \theta e_0$ and $c_1 = c_0^{private} + \theta e_1$, Figure 1 may alternatively illustrate the case of a "standard" invention or that of a "green" invention. Nevertheless, at least in the case of a non-drastic invention, there exists a hidden difference. Indeed, it has been stressed that in the case of a non-drastic invention, the quantity of good produced remains unchanged before the patent is applied for and during the life of the patent. For "green" inventions, it implies that the level of the Pigouvian tax θe_1 charged during the patent life has no direct incidence on the level of pollution released during this life. More precisely, substituting any tax level x per unit of good produced to θe_1 with $0 \leq x \leq \theta e_0$ during the life of a patent does not affect the production level and thus the pollution emissions. The only consequence of such a change would be a change in the level of the rent that accrues to the patent holder per unit of good produced. Of course, there is an indirect effect in the sense that changing θ without changing the lifespan T of patents affects the monetary incentives to innovate and thus the optimal R&D effort and the resulting level of e_1. Nevertheless, the point is that it is possible to jointly modify the tax x per unit of production and the lifespan T of patents without affecting the discounted sum of royalties received by the patent holder. For this purpose, we can solve the following equation with respect to x

$$\int_0^T q_0 \left(\theta e_0 - x\right) e^{-\rho t} dt = \overline{V} \quad (5)$$

where $\overline{V}$ is an arbitrary fixed level for the discounted sum of royalties received during the life of the patent. The solution yields the equation of the iso-revenues curve associated to $\overline{V}$ in space $\{T, x\}$. Some computations show that the iso-revenue curve is increasing and concave in space $\{T, x\}$ and admits a positive abscissa at the origin. The marginal rate of substitution of x to T is

$$\frac{e^{\rho T} \rho^2}{y\left(e^{\rho T} - 1\right)^2} \overline{V} \quad (6)$$

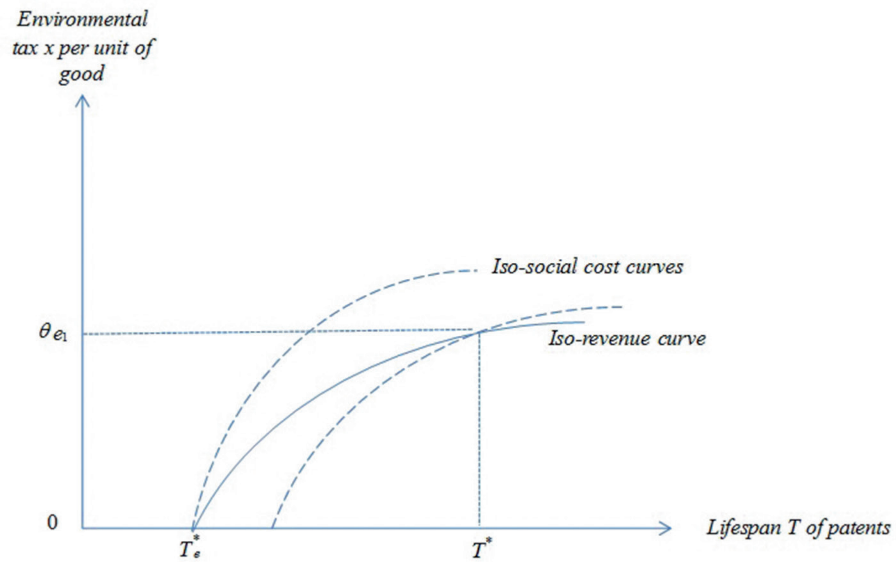
We are more specifically interested in the iso-revenue curve associated with the optimal lifespan of patents T^* that maximizes (4) under the reaction function (3) of patent holders and is associated with the corresponding discounted sum of royalties obtained by substituting $B(R^*)$ to $\theta e_0 - x$ in (5). We denote by V^* this discounted sum of royalties. For public authorities, the arbitrage between the magnitude of tax per unit of production and the lifespan of "green" patents depends on the respective cost of these two instruments.

As already outlined above, the cost associated with a higher lifespan of patents results from the fact that the deadweight loss measured by the area EFH on Figure 1 is incurred for a longer period. We thereafter denote δ as the yearly deadweight loss induced by a patent. Conversely, an environmental tax x per unit of production that is lower than the initial tax θe_0 implies a shortfall of tax revenues that amounts to $q_0 \left(\theta e_0 - x\right)$. Given that the production level remains unchanged during the life of the patent compared to before the invention, this shortfall is interpreted as a cost for public finance. Both costs are incurred during the whole life of a patent. The optimal arbitrage of public authorities between how long patents should extend and how high the environmental tax x should be is the combination of T and x which minimizes the discounted sum of the two types of costs under the constraint that the monetary reward received by the patent holder equals V^*. The discounted sum of costs is written

$$C = \int_0^T \delta e^{-\rho t} dt + \int_0^T q_0 \left(\theta e_0 - x\right) e^{-\rho t} dt \quad (7)$$

This cost systematically exceeds the discounted sum of revenues received by the patent holder (i.e. the left hand side of (5)), which corresponds to the second term in (7). The expression of iso-cost curves in space $\{T, x\}$ is obtained by fixing C to a predefined level and solving (7) with respect to x. The slope of iso-cost curves is identical to (6) with C in place of $\overline{V}$. Consequently, iso-cost curves have a steeper slope in Figure 2 than iso-revenue curves. Minimizing the cost of a "green" patent consists of searching for the highest iso-cost curve in Figure 2 which admits at least one common point with the iso-revenue curve associated with V^*. Due to the systematic difference in slopes of the two types of curves, we conclude that it is optimal to fix the environmental tax at zero euros per unit of production during the life of "green" patents in order to obtain the highest yearly royalty from these patents and to compensate by applying the shortest lifespan T_x^* of patents that leave the discounted sum of royalties unchanged compared to "standard" patents. Said another way, the solution consists of implementing any tax level x per unit of production (with $0 \leq x \leq \theta e_0$) and then allocating the entire tax revenue to the patent holder. The solution clearly illustrates that the link between environmental taxation and innovation policy is strong when it comes to "green" invention.

◊ Figure 2: The optimal lifespan of « green » patents compared to « standard » patents



3. Efficient taxation of fossil fuels to finance "green" innovation

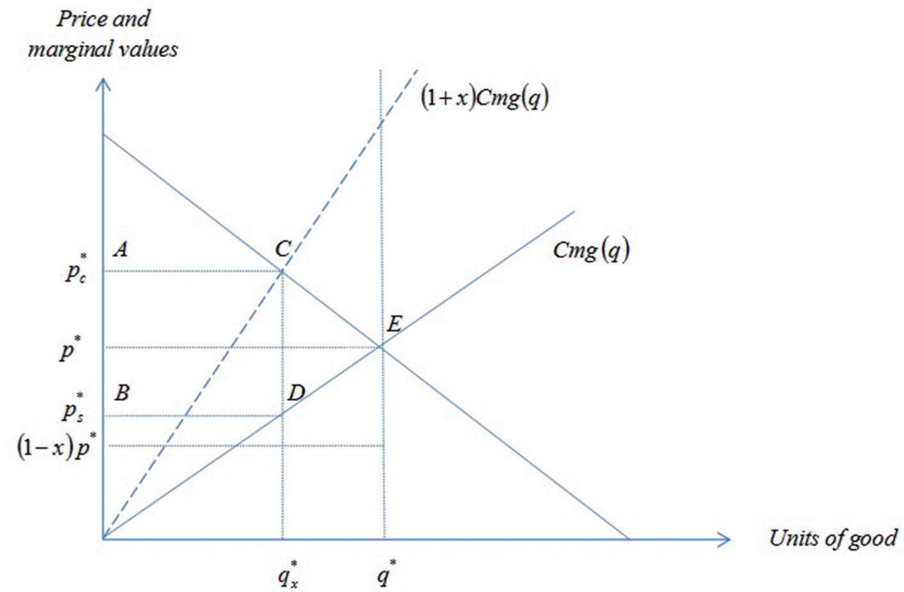
A common feature of fiscal policy in most developed and less developed countries is that it relies on distortive taxation. A noticeable exception is taxation of natural resources and, among others, of fossil fuels. Moreover, since Hartwick (1977), it is argued that recycling the revenue from the taxation of rents that accrue from the exploitation of natural resources in investments that benefit to future generations is the key idea to moving the economy toward a sustainable path. This second part of the chapter presents a simple partial equilibrium analysis that goes one step further. It more specifically examines the impact of recycling tax revenues in the financing of R&D programs that either improve the efficiency of fossil fuels used in production or improve the productivity of alternative sources of energy, rather than in the increase of capital. The first section presents the principal of an efficient taxation of fossil fuels. In the second section, we turn to the analysis of the impact of recycling tax revenues in different types of "green" R&D programs.

A partial equilibrium approach to the efficiency of taxing rents from fossil fuels

A tax is said to be distortive when its implementation induces a change in the behaviour of suppliers and/or consumers and, consequently, a modification of market equilibrium. This modification of market equilibrium is associated with a disconnection of the price p_c paid by consumers and the price p_s actually received by suppliers, inducing a deadweight loss. Figure 3 illustrates this point in the case of an *ad valorem* tax paid by suppliers. Under perfect competition, the supply curve coincides with the marginal cost of production $Cmg(q)$. On Figure 3, $Cmg(q)$ is assumed to increase with the quantity q of good produced so as to obtain a supply curve that increases with the price. An *ad valorem* tax with a taxation rate that amounts to x implies that the actual marginal cost of production is $(1+x)\,Cmg(q)$. Consequently, the supply curve rotates upwards around the origin, the exchange quantity of good drops from q^* to q_x^* and the equilibrium price switches from p^* to p_c^* for consumers while suppliers actually receive p_s^* per unit of good sold. The vertical gap between p_c^* and p_s^* is the equilibrium tax level perceived on each unit of good produced and sold. The deadweight loss compared to the pre-tax equilibrium is the area CED on Figure 3. Its ratio with the total amount of tax ABDC collected on the market measures the social cost of public funds.

Whereas taxation of labour and value added taxes are considered as typical examples of distortive taxes, it is generally acknowledged that taxation of natural resources is a typical example of a non-distortive tax. The rationale for the non-distortive nature of taxes on natural resources is that, at least for a first basic analysis, their supply may be considered as inelastic. Coming back to Figure 3, lets assume that instead of the increasing supply the supply is fixed and given by the vertical line associated with quantity q^*. As in the previous case, the pre-tax equilibrium is characterized by quantity q^* and price p^*. When an *ad valorem* tax with a taxation rate *x* is implemented, market clearing requires that the exchange quantity equals the inelastic supply and thus remains at q^*. Hence, the price paid by consumers still amounts to p^* but the price actually received by suppliers is $(1-x)\,p^*$. The tax has not affected the quantity of good exchanged and only implies a transfer of revenue from suppliers to public authorities without generating a deadweight loss.

◊ Figure 3: Distortive and non-distortive taxation in a static framework



The analysis of the non-distortive nature of taxation affecting natural resources developed above is static. Transposition to a dynamic framework is necessary if one aims at studying tax-recycling in the form of intergenerational transfers and in terms of innovation financing. Hotelling's rule is at the core of this transposition. For ease of presentation, the focus in this chapter is on a non-renewable resource such as fossil fuel. The key idea introduced by Hotelling (1931) is that natural resources constitute economic assets in the sense that they make it possible to maintain or even create value over time. As such, natural resources are substitutable to other economic assets, more specifically financial assets. If these different types of economic assets are assumed to be perfectly substitutable, equilibrium on the asset market requires that no one is willing to buy or sell one or the other of the different assets. This arbitrage-free characterization of the equilibrium on the asset market implies that each type of asset generates the same revenue per unit of asset. Hence, keeping one unit of natural resource *in situ* (i.e. unexploited) must be exactly as profitable as extracting the resource to sell it for production purposes and then investing the revenue of the sale on a financial asset. The return on keeping the natural resource unexploited is given by the growth rate of its price *in situ*. In a partial equilibrium analysis of the dynamics of the price of the resource *in situ*, the rate of return on alternative assets is assumed exogenous and is assimilated to a constant risk-free interest rate r. Therefore, Hotelling's rule states that the annual growth rate of the price of a natural resource *in situ* equals the risk-free interest rate r.

In order to outline the implications of Hotelling's rule for the dynamics of the stock of the resource, Figure 4 combines two graphics. The left hand side illustrates the dynamics of the price of the resource *in situ* starting from a given price v_0 at the current date $t = 0$. Hotelling's rule implies that

$$v_{t+1} = v_t \left(1+r\right) \quad \Leftrightarrow \quad v_t = v_0 \left(1+r\right)^t \qquad (8)$$

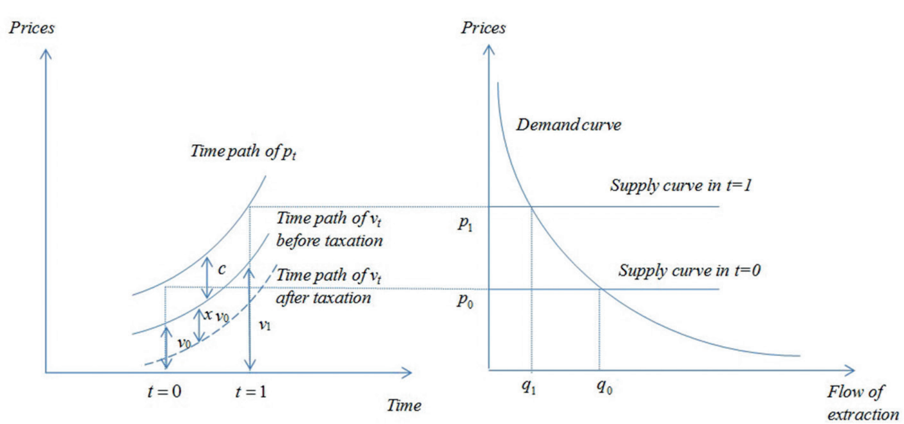
The typical time path of the price of the resource *in situ* is thus increasing exponentially. Assuming that extraction costs per unit of resource *ex situ* (i.e. once extracted and made available for production) are constant and amount to c, the dynamics of the price p_t *ex situ* directly follows on from the dynamics of the price v_t *in situ* because it is required that owners of the resource are indifferent to extracting the resource or not. At each date, the price *ex situ* must equal the price *in situ* plus the extraction cost:

$$p_1 = v_t + c \qquad (9)$$

In Figure 4, the time path of the price *ex situ* is thus obtained by an upward translation of the time path of the price *in situ*. The right hand side of Figure 4 illustrates the market of the resource *ex situ*. The supply curve is infinitely elastic but changes at each date. This results from the fact that, for a price p_t defined at date t according to (9) and (8), owners of the resource are indifferent to keeping the resource *in situ* or extracting it and will thus supply any quantity demanded at that price for this date. The demand curve represented on Figure 4 has two important features. First, it is decreasing with the price of the resource. Though rather usual in microeconomic analysis, this assumption actually means that consumers are able to substitute something else for the natural resource when its price increases. As will be made explicit later on, this substitutability assumption is crucial for the dynamics of the price to correctly signal the rarefaction of the resource. Second, it is assumed that the demand curve admits the ordinates axis as a vertical asymptote when the price p_t goes to infinity. In the economic literature on sustainable growth, this is known as the assumption of an "essential" resource. It means that some other goods may be substituted for the natural resource but an infinitesimal quantity of the resource is always required to produce. For now, the demand curve is assumed to be the same at any date. Combining the two graphics in Figure 4 shows that the quantity of resource extracted from date to date decreases. Using for instance an iso-elastic demand function, it can be shown that whatever the initial stock S_0 of the resource, there always exists an initial price v_0 of the resource *in situ* (and thus $p_0 = v_0 + c$ for the resource *ex situ*) so that the total quantity of the resource demanded from the current date $t = 0$ to the time horizon T equals only the initial stock S_0, even if the time horizon T goes to infinity.

In a dynamic framework, the fixity of the initial stock of resource plays a role similar to that of the inelastic supply curve in a static framework. Likewise, in a dynamic framework, introducing an *ad valorem* tax on the price of the natural resource *in situ* does not affect the quantities of the resource actually extracted and only implies monetary transfers from the resource owners to the public authorities. An *ad valorem* tax on the resource *in situ* is thus non distortive. Note that it is the resource *in situ* that is taxed, not the resource *ex situ,* which is considered as already transformed and is thus assimilated to a standard input rather than to a natural asset. For a given price p_t of the resource *ex situ*, taxing units of the resource *in situ* at a rate *x* implies that the net value of each unit of the resource *in situ* amounts to $(1-x)(p_t-c)$. Multiplying each side of (8) by $(1-x)$ does not change the dynamics of the *in situ* price *Vt* but requires a decrease of the initial price from v_0 before taxation to $v_0(1-x)$ after taxation for the total quantity of resource demanded over the time horizon not to exceed the initial stock S_0. In Figure 4, the time path of the price p_t *ex situ* is thus unaffected whereas the time path of the price v_t *in situ* undergoes a translation downwards. The vertical difference between the time path of v_t before and after taxation corresponds to a transfer xv_0 per unit of resource *in situ* from the owners of the resource to public authorities.

Figure 4: Hotelling's rule and the impact of taxation of natural resources in situ

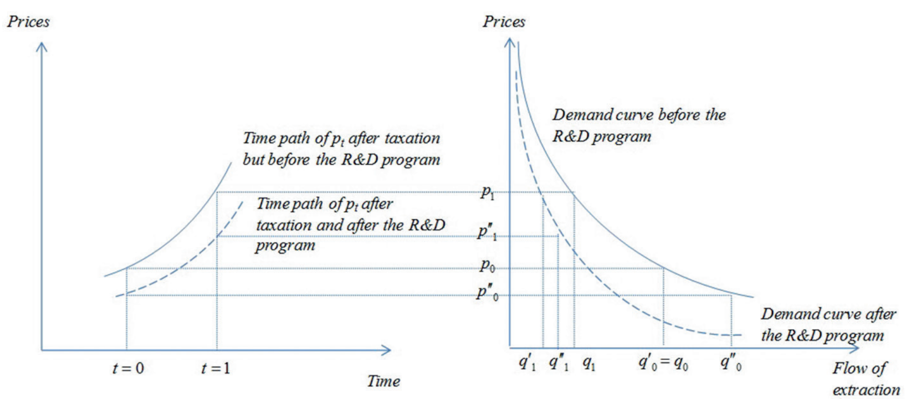


The effects of recycling tax revenues to promote "green" innovation

If the funds thereby collected are invested for the benefit of future generations, the partial equilibrium analysis of the taxation of natural resources detailed in the previous section may be thought of as a way to drive the economy toward a more sustainable path. This interpretation is based on Hartwick's rule (Hartwick, 1977), which states that the rent from extracting non-renewable resources should be invested in physical capital in order to maintain the utility of future generations, at least as high as that of the current generation. The efficiency of the transfer is consistent with the macroeconomic approach proposed by Howarth and Norgaard (1990) who develop an overlapping generation model to show that sustainable development is not a matter of market efficiency but a matter of social (intergenerational) choice. However, the macroeconomic literature on sustainable development is essentially intended to determine whether investment in existing types of capital is able to make future generations better off in spite of the depletion of non-renewable resources. Little attention has been paid to investment in innovation, with the argument that sustainable development should not rely on the highly uncertain outcome of an invention process. Nevertheless, it clearly appears that, in practice, technological change is a *sine qua non* condition to move the economy towards a sustainable path. Therefore, we hereafter attempt to get some insights into the effects of a recycling of tax revenues collected thanks to an efficient taxation of fossil fuels as analyzed just above. For this purpose, we focus on a two period model, but the conclusions may be extended to a more general context.

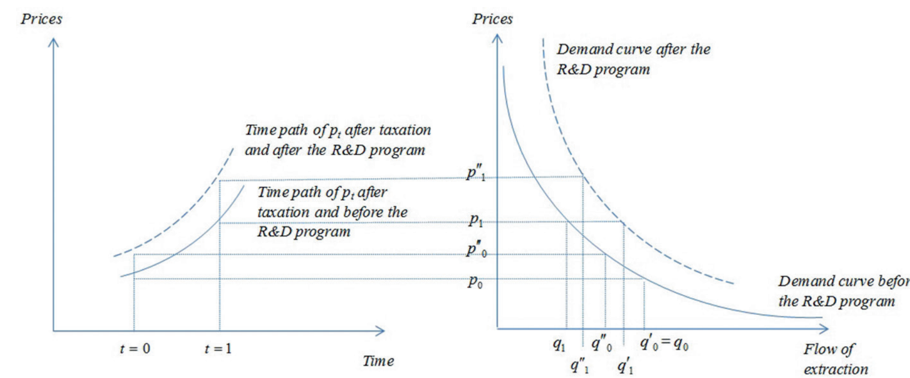
Consider first the recycling of tax revenues from the taxation of fossil fuels in R&D programs that aim at increasing the performance of alternative energies, typically renewable sources of energy. A direct consequence of such programs is that, once they succeed in increasing the performance of renewables, they induce a drop in the demand for fossil fuels. This is illustrated in Figure 5 by a switch to the demand function with a dashed line in the second period, whereas the demand remains unchanged in the first period. With an unchanged initial price of the natural resource at $t=0$, the quantity extracted at this date remains at $q'_0 = q_0$ while it decreases to $q'_1 < q_1$ at date $t=1$. It is pointless to leave the natural resource un-exhausted at the time horizon $t=1$. Therefore, in order to adjust the total quantity of resource extracted during the two periods to the initial stock S_0, it is required that the initial price v_0 decrease. As a result, the time path of prices v_t and p_t are translated downwards. The equilibrium prices at dates $t=0$ and $t=1$ respectively drop from p_0 to p''_0 and from p_1 to p''_1. Meanwhile, the quantity of resource extracted at date $t=0$ increases to q''_0. Consumers alive at that period thus benefit from the R&D program even if that program has not yet made alternative sources of energies more efficient. Actually, consumers at $t=0$ indirectly benefit from the expected future negative impact of the R&D program on the future demand for fossil fuels. Of course, consumers at date $t=1$ also benefit from that program. Even if the price v_0 was unchanged compared to the absence of the R&D program, they would switch to the alternative sources of energy in their own interest. As the same quantities of fossil fuels are available at lower prices in the presence of the R&D program compared to the absence of such a program, they additionally benefit from the decrease of prices. Hence, the fact that they finally demand less fossil fuels with the R&D program than without (i.e. that $q'_1 < q_1$) has not to be interpreted as a negative impact for them. Of course, the assumption of a perfectly predictable outcome of the R&D program is questionable. Actually, as outlined above, R&D programs have highly uncertain impacts in terms of efficiency gains for renewables so that the exact position of the demand at date $t = 1$ is unknown, except that it is expected to be on the left of the initial demand. The analysis of the incidence of this uncertainty is beyond the goals of this chapter and is left to further research.

◊ Figure 5: Hotelling's rule and the impact of recycling tax revenues in R&D programs promoting the efficiency of alternative sources of energy



Consider now the case of a recycling of tax revenue in R&D programs that aim at improving the efficiency of energy fuels. A direct consequence is that at date $t = 1$ each unit of fossil fuel has a higher productivity and producers are thus willing to pay more for marginal units. In other words, the marginal willingness to pay for fossil fuels increases. This consequence is illustrated in Figure 6 as an upward switch of the demand function at date $t = 1$. If the time path of the price of the resource ex situ was unchanged, the quantity of the resource extracted at date $t = 0$ would remain constant (i.e. $q'_0 = q_0$ on Figure 6) but the quantity extracted at date $t = 1$ would substantially increase (i.e. $q'_1 > q_1$). As the total quantity extracted over the two periods cannot exceed the initial stock S_0, market clearing imposes a rise of the price P_0 of the resource *ex situ* at date $t = 0$ and, according to Hotelling's rule, of all subsequent values P_t of this price. The consequence of these higher prices is a net drop in the quantity finally extracted at date $t = 0$ (i.e. $q''_0 < q_0$) and a net increase of the quantity extracted at date $t = 1$ (i.e. $q'_1 > q_1$) compared to the absence of the R&D program. We conclude that R&D programs that seek to reinforce the efficiency of fossil fuels are detrimental to present generations but favour future generations. The fact that such R&D programs induce an increase of the consumption of fossil fuels in the long term is known in the economic literature as Jevons' paradox. Actually, the simple analysis developed in this chapter typically shows that the paradox may be explained by basic economic mechanisms.

◊ Figure 6: Hotelling's rule and the impact of recycling tax revenues in R&D programs promoting the efficiency of fossil fuels



4. Conclusion

The aim of this chapter is not to propose a comprehensive analysis of the interplay between environmental or natural resource problems on the one hand and innovation on the other hand. It is rather to set some basic elements that contribute to supporting the case for a joint analysis of instruments in these two domains. With this aim in view, the emphasis is on partial equilibrium analysis. Similarly, the intrinsic uncertainty that surrounds the outcome of R&D programs is disregarded. The chapter thus essentially paves the way for further works to remedy these shortcomings and to develop realistic modelling that could help shape policy in favour of energy transition.

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Chapter 12

An overview of policy instruments for green innovation

Clément Bonnet, Marie Renner

1. Introduction

In scenarios with ambitious climate targets, such as the IPCC[121] 2°C scenario, renewable energy (RE) plays a vital role in reducing the greenhouse gas emissions responsible for climate change. In the International Energy Agency (IEA) 2DS (2 DegreeS) scenario (ETP 2012), the contribution of RE in global electricity generation increases from 19% to 57% by 2050, a six fold increase in absolute terms. In its Roadmap 2050, the European Union presents four scenarios for reducing greenhouse gas emissions by 80% compared to 1990 levels, in which RE produces between 40% and 100% of the electricity.

However, these so-called green technologies are currently at very different stages of development. While onshore wind and solar are in advanced degrees of maturity, marine energy is still at the pilot/demonstration stage (for example, the Paimpol-Bréat tidal farm).

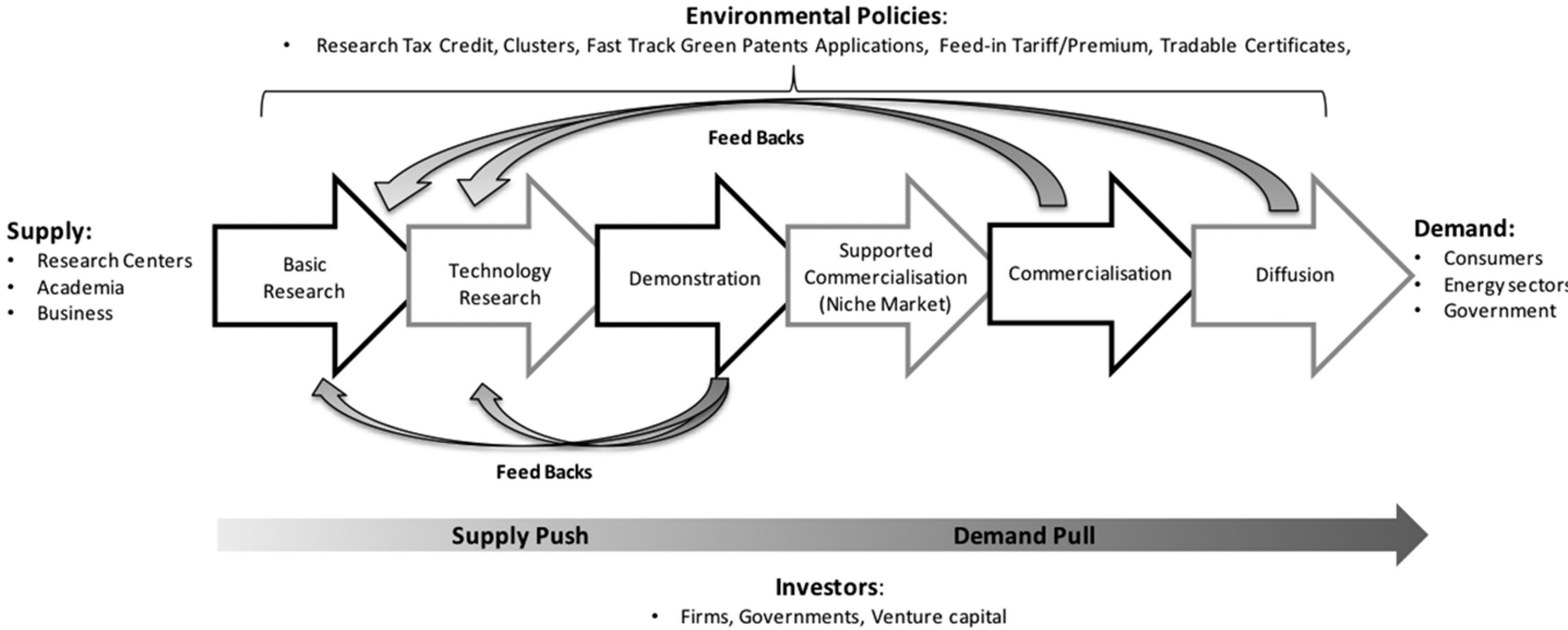
It is therefore only through sustained green innovation that we will be able to attain this climate goal and achieve energy transition at least cost. Since the environment is a global public good, specific public support policies, steering the private sector toward green innovation in a broad sense, are necessary.

As Figure 1 below shows, the innovation process or chain covers different stages: from basic research through to the development, demonstration, marketing and eventual spread of the innovation. Feedback of various kinds provides guidance to developers on the market reaction and enables them to adjust research and development (R&D) in the technology (a linkage of demand to the innovation process).

Each stage of the innovation process has a corresponding set of support tools. The public authorities can therefore in principle intervene at different stages of green innovation.

121 Intergovernmental Panel on Climate Change.

◊ Figure 1: The Innovation Chain



Source: IEA, WEO 2008

To minimize the cost of climate policies and a fortiori of the energy transition, it is important to assess the effectiveness of these support instruments applied at different stages of the innovation process. The standard economics literature distinguishes between:

— supply-push instruments (working on supply), which are involved in the initial stages of the process by supporting producers/business/scientists in innovation on products and production techniques without focusing on the needs of consumers;

— demand-pull instruments (creating and stimulating demand), which are involved in the downstream part of the process by ensuring that there is a market for clean technologies.

The debate on the instruments to be put in place to stimulate innovation goes back to the 1950s, or even further if we include Say's Law or the demand stimulus advocated by Keynes. However, in recent years a consensus as to complementarity of these two types of tools has emerged.

The use of supply support instruments helps develop the "absorption capacity" of new technologies, i.e. the propensity of an industry to integrate and put into practice the new opportunities provided by the innovation. Depending on the supply support given to various industries, there are differing rates of adaptation and development in response to technological breaks (Mowery, 1983; Rosenberg, 1990).

Demand is also an effective driver of innovation: the size of the market and consumer expectations influence the private income that the innovative firm obtains from a product or production method. The case of green technologies is more specifically related to the relative price of fossil fuels, making more viable the use of price-quantity instruments such as those we discuss below (Lichtenberg, 1986). The major limitation of support for demand is that it focuses on existing consumer needs and risks missing out on the most important innovations (Mowery and Rosenberg, 1979). Demand support instruments may be ineffective in stimulating fundamental research because any potential market emerges in the long term and involves a high level of uncertainty. Uncertainty is particularly difficult to regulate since it is linked to political and legal developments; the recurrent texts in French legislation on purchase rates presented to the Council of State in the 2000s illustrate this danger. Support for demand therefore primarily promotes incremental innovations. Yet if even widely adopted, such innovations will be insufficient to achieve the 2°C climate target.

The optimal combination of supply support and demand support in fact depends on the technology in question (Sagar and van der Zwaan, 2006) and on its maturity. State support is of major importance for the development of radical innovations, since they are "discrete, discontinuous events, usually involving deliberative effort; and they may have only a minor relatedness to existing products" (Garcia and Calantone, 2002; Dahlin and Behpens, 2005).

There are a number of support tools for supply and demand and each tool may take different forms. We review these instruments by considering the innovation process, examining firstly supply-push instruments and then demand-pull instruments.

2. Instruments supporting the supply of renewable energy

Legislators have various instruments to support the supply of RE and improve the technological capabilities of firms and the interrelationships within an industrial sector with a view to stimulating innovation. Of these, the Research Tax Credit (RTC) (known in the UK as the Research and Development Tax Credit) is the most frequently used, but governments also rely on guaranteed public loans, competitiveness, fast track "green" patent applications systems and public-private partnerships.

Research Tax Credit (RTC)

Definition and design modalities

Depending on the country, the RTC concerns companies' expenditure on research, whether basic, applied or pre-commercial. Through the RTC, part of this expenditure is tax deductible for the company, so as to encourage it to invest in R&D. Unlike a lambda tax reduction, RTCs can lead to a refund from the tax authorities if the tax credit exceeds the tax payable by the company. The advantage of such a tool is that it assigns R&D to the private sector and thus benefits from its knowledge of the market and consumer expectations (Atkinson, 2007). Despite the considerable heterogeneity in the way RTCs are designed from one country to another, the following forms are generally distinguished.

— Incremental-based. R&D expenditure that exceeds a given threshold is tax deductible, which causes an increase in Net Present Value (NPV). Theoretically, the optimal threshold is the maximum amount that the firm would have agreed to spend on the supported project. In practice though, since information is imperfect and the firm's willingness to pay varies according to the project, incremental credit policies produce windfall effects[122] for companies.

— Volume-based: A proportion of the expenditure eligible is refunded by the state, which makes it a more transparent mechanism for companies. It results in an increase in the respective NPV of each research project irrespective of criteria. Volume-based RTC also produces windfall effects.

Governments usually provide RTCs which are a hybrid of these two types. Other characteristics of RTCs also deserve mention.

— Systematic versus specific: The government chooses either to provide systematic support for the company's R&D projects or to discriminate between projects on the basis of its own criteria. Such discrimination may concern the type of agents benefitting from the RTC (for example, favouring small businesses) or the degree of maturity of the various projects. Here, the main risk is that of technological lock-in, which constitutes an argument in favour of a technology-neutral RTC (Jaffe, Newell, 2005).

— The RTC can be applied either to gross expenditure or to modulated expenditure, for example, corrected according to the size of the company's workforce. The use of modulated expenditure eliminates the size effect of the company.

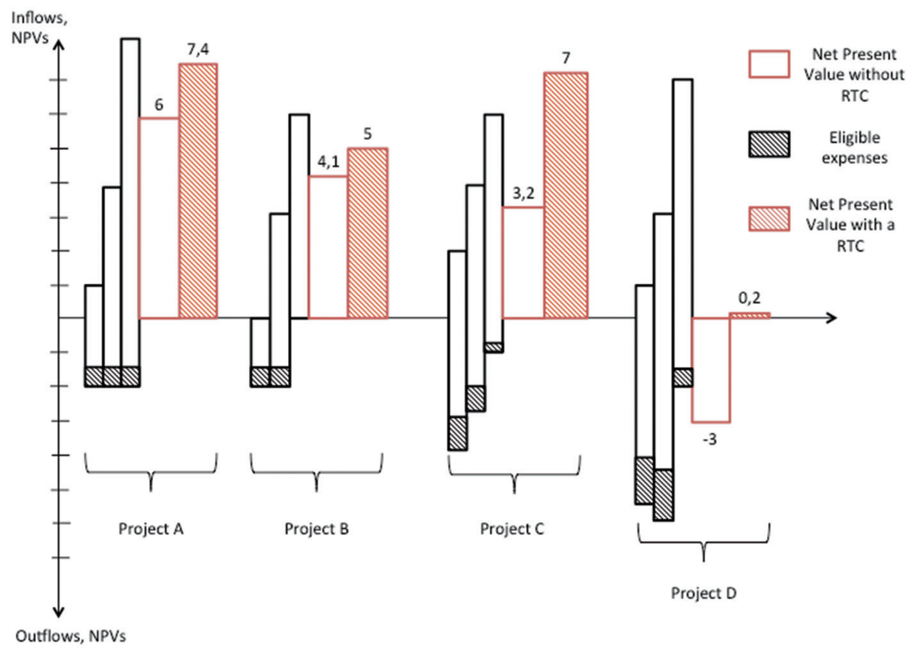
— Increased expenditure: This widely used method applies an RTC that is more advantageous in proportion to the size of the expenditure compared to previous spending levels. This criterion determines the extent to which the RTC favours increasing expenditure over time, or alternatively, acts as a restraint on excessive expenditure.

Analysis of the effects of the Research Tax Credit on firms' behaviour.

To illustrate the incentives produced by RTCs we look at four R&D projects. We consider a volume-based RTC of 25% of total expenditure in each period. For each project, successive periods are represented by the three narrow columns.

122 Producers receive a subsidy for a decision they would have taken even in the absence of the incentive.

◊ Figure 2: The impact of a volume-based (25%) research tax credit on the cost effectiveness of a firm's R&D project[123]



Source authors

As expected, the RTC increases the NPV of each project. Two effects can be distinguished.

— A windfall effect, benefiting projects A, B and C, which makes them more attractive to the company. Note that the windfall increases with the cost of the project.

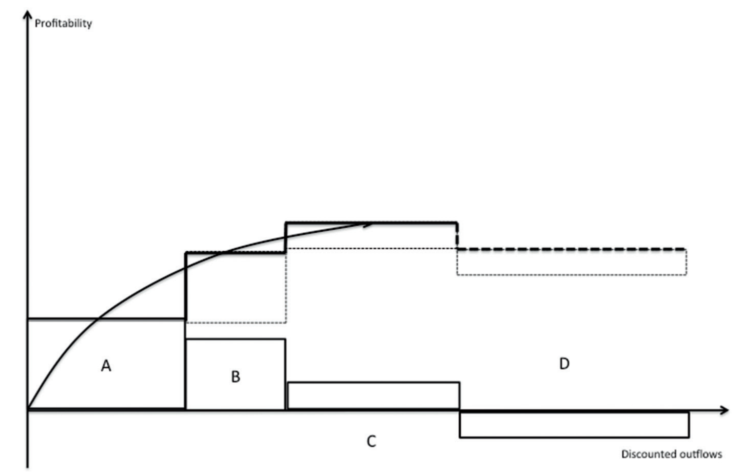
— A profitability effect, from which only project D benefits. NPV becomes positive after implementation of the RTC, and the number of profitable projects increases. This is the effect sought by the public authorities.

We define the following decision rule: first firms implement the most profitable project, followed by other projects in decreasing order of profitability. The profitability of a project is expressed as the ratio between the NPV and the sum of the discounted costs. In a context of scarce capital, it makes sense to focus on projects with the highest return per euro spent. By aggregating the four projects we construct the curves representing the order of implementation of projects by the company. The company first prioritizes project A, the most profitable, then continues investing until it arrives at a non-profitable project. Generalizing over a continuum of projects allows us to draw concave curves.

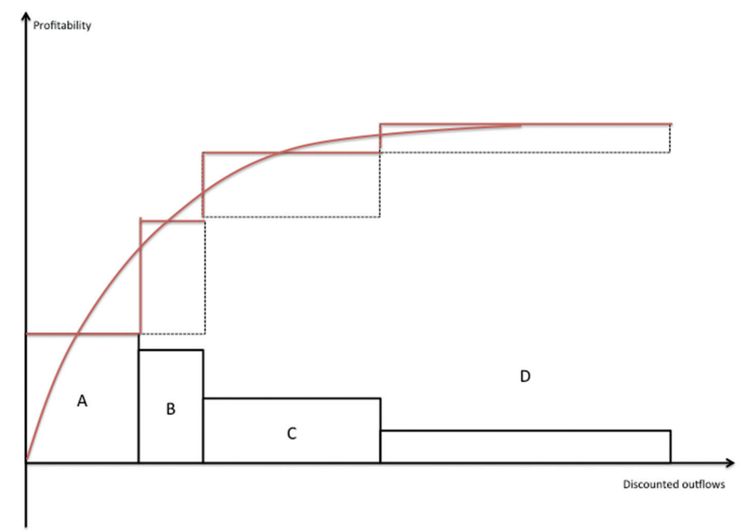
123 Discount rate of 8%.

◊ Figure 3: Cumulated project before and after applying the RTC

Before RTC



After RTC



Source authors

The two effects noted above are illustrated in the graphs.

— The windfall effect increases companies' overall profitability: the project implementation curve moves upwards.

— The profitability effect increases the number of profitable projects: the curve extends to the right.

The U.S. Energy Research Consortium Tax Credit (ERCTC): an example of a targeted RTC

The United States has four types of RTC: Regular Credit, Alternative Simplified Credit, Basic Research Credit and the Energy Research Consortium Tax.

The first two, Regular Credit and Alternative Research Credit, cover R&D activities in general and are volume-based credits. They take effect beyond a threshold defined by past expenditure. The company must choose between these two RTCs.

The two types of RTC may be received concurrently with:

— The Basic Research Credit, which concerns research with no predefined commercial intent.

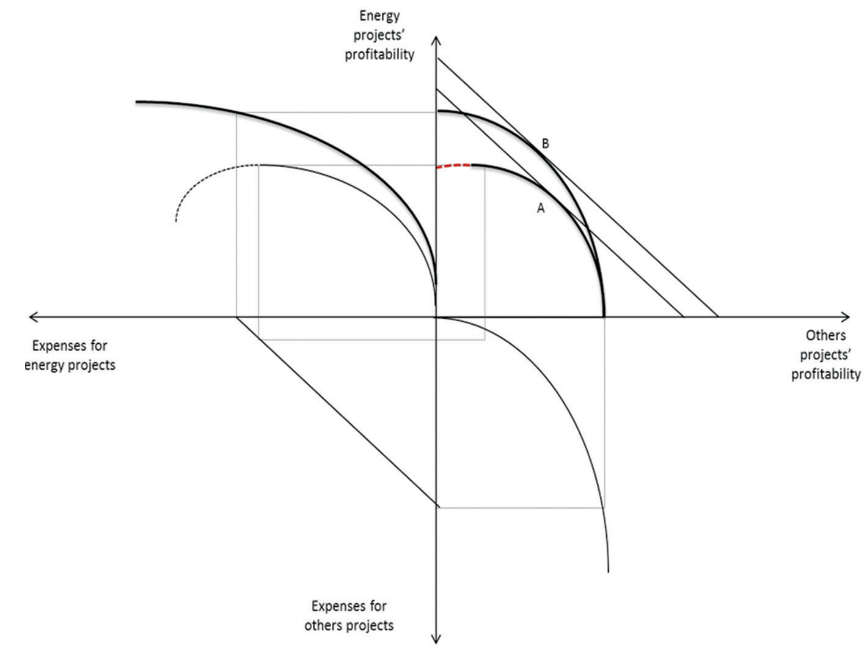
— The Energy Research Consortium Tax Credit (ERTC), which applies to projects oriented towards the theme of energy. It covers renewable energy, as well as fossil fuels and energy efficiency projects.

We focus on the ERCTC because it is an example of targeted support to energy technologies. To be eligible, the research project must be implemented by a consortium[124] and 20% of payments to the consortium are tax deductible to the company. We illustrates graphically how this tool reorients the allocation of R&D expenditure.

Accordingly, we distinguish two groups of R&D projects: those geared towards energy, and others. To simplify the reasoning, we consider only one input, capital, which the company divides between the two types of projects. All possible combinations of the two types of project without ERCTC are represented in the northeast quadrant by the curve below. This is interrupted at its left extremity (red dotted part), since no additional R&D energy project is profitable. The optimal combination is given by the point of tangency between this curve and the budget constraint line (point A).

124 The definition of consortium is based on specific criteria, such as the presence of at least five independent entities.

Figure 4: Firms' trade-off with the role of the Energy Research Tax Credit



Here the RTC has two effects.

— The number of profitable projects increases: the project curve extends to the left in the northwest quadrant. This is reflected in the northeast quadrant where the producer can then choose combinations that are more oriented toward energy projects. However, this effect does not change the allocation of its assets between the two types of project (we exclude possible corner solutions).

— The overall profitability of projects increases: the curve of feasible projects moves upward in the northwest quadrant. This effect allows the allocation of the company's capital to be redirected to energy projects, making them more profitable compared to other projects.

This windfall effect, from which the whole group of projects benefits, encourages developers to reallocate their funds toward these projects. As a result, there is an increase in the number of projects implemented within this group.

Other supply support instruments

Although the RTC is a widely used tool to promote innovation, governments have recourse to other instruments too. Which ones are chosen is based on the criteria of technological maturity, cost intensity of the investment and the type of agent concerned. However, it makes sense to create an optimal portfolio of instruments to hedge against technological lock-in

(Olmos Ruester and Liong 2012). Below we detail the various instruments supporting investment in research on green technologies.

Public loans guaranteed by the state

These loans are a form of supply-side support, suitable for intensive capital projects. The state makes a trade-off in relation to the size of the actors it wants to help. Large enterprises are less likely to default on repayment and face fewer financing problems. In contrast, small players have more funding difficulties and face a greater risk of insolvency. To overcome this problem, the government can set rules for eligibility and project tracking so that businesses with viable projects are self-selected.

In France, the zero-interest loan for innovation (Prêt à Taux Zéro pour l'Innovation – PTZI) provided by Oséo Bank[125] allows small and medium enterprises (SMEs) with fewer than 2,000 employees and created more than three years previously to obtain a loan from €50,000 to €300,000, depending on their funding requirement. These loans are granted according to the eligibility of the expenditure on the R&D project and are not restricted to *green technologies*.

Competitiveness clusters

Competitiveness clusters are geographical areas in which businesses and/or research laboratories enjoy a favourable tax regime and government subsidies. This preferential treatment concerns enterprises sharing the same types of research and business. Clusters are centred around an activity that has an existing or potential competitive advantage and is a source of on-going employment in the area. The different entities composing the cluster share a local public good and benefit from positive externalities due to the dissemination of knowledge and skills. The economics literature on Localised Knowledge Spillovers (LKS) discusses these phenomena through analytical models of the new geographical economics. Empirical studies find that there are higher returns to scale in these zones than in isolated companies belonging to the same sectors.

In France, a number of competitiveness clusters have recently been created in the RE sector. Two of them, in the maritime industry, are on a global scale – the Mer PACA cluster and the Mer Bretagne cluster – and several others, on a national scale, have been developed in sectors such as wind, storage, building, etc.

Alongside these competitiveness clusters, and closely associated with them, various institutes of excellence in the area of carbon-free energy

125 A privately operated public company to be integrated into the Banque Publique d'Investissement in 2013.

(Institut d'Excellence dans le domaine des Énergies Décarbonées – IEED) have been set up. Certified by the French government in the context of future investments, IEEDs are interdisciplinary platforms bringing together expertise from industry and public research within a "logic of public-private co-investment", with a view to industrial development. These IEEDs are specifically concerned with so-called future energy industries having a positive impact on climate change: energy efficiency in buildings, marine renewables[126], and so on.

Following two calls for proposals in 2011 and 2012, the government finally selected five institutes: France Énergies Marines (€34.3 m), Greenstars (sustainable algae-based fuel, €23.8m), Institut des Matériaux Agro-sourcés (agro-based materials, €30.8m), Institut Photovoltaïque Île-de-France (photovoltaic, €18.1m) and Supergrid (high voltage and very high voltage grids, €72.6m). Subject to improvements, two projects may be funded: Géodenergies (subsoil technologies, €15.9m) and the Institut Véhicule Décarboné et Communicant et de sa Mobilité (new car technologies, €54.1m). In total, a billion euros will be invested in IEEDs.

Fast -track "green" patent application systems

In recent years, various systems have been introduced to accelerate the process of granting patents on inventions of an industrial nature. These systems focus on so-called green innovations, although their definition varies according on the country concerned. Among the first countries to set up programmes of this kind were the United States, the United Kingdom, Japan, Israel and Korea in 2009; and more recently, in 2011, Canada, Australia, China and Brazil have also opted for such systems.

In countries that have adopted fast-track patent applications, green patents represent only a tiny fraction – 0.05% to 0.9% – of the patents filed. However, in some of these countries there has been a demand for an accelerated issuance process, as is the case in the United Kingdom, where 20.91%[127] of green patents between 2009 and 2011 went through these fast-track systems. The average waiting period for all patents over the period 2009-11 was 40 months in the United Kingdom against less than a year through fast-tracking, eight years against two and a half in Canada, and almost three years in the United States against a year and a half.

Companies generally prefer long patent prosecution periods. Since the final step in the granting of a patent involves payment, a longer waiting time

126 Technological research institutes (Instituts de Recherche Technologique – IRT), which also aim to strengthen the ecosystem formed by the clusters, cover all other areas of activity.
127 Dechezleprêtre Antoine, 2013, "Fast-tracking Green Patent Applications: An Empirical Analysis".

allows the company to establish the commercial viability of the invention and the advantages it hopes to gain from it. This delay also gives the company the opportunity of adjusting the field of application of its patent, thus better aligning it with the final version of the invention.

However, companies can sometimes be induced to speed up the issuance process of patents for their inventions. For example, when a company anticipates that its competitors will position themselves around a similar technology, it may wish to expedite the issuance process so as to block the use of its inventions. Another example is that of funding aid that is given subject to compliance with predetermined conditions, which may include a patent requirement.

Procedures for fast-track issuance consequently operate on a voluntary basis: the company has to expressly state that it wishes to benefit from the system. Companies therefore self-select according to their optimal trade-off between a standard procedure and a fast-track procedure. This flexibility is intended to strengthen the incentive to innovate. Dechezleprêtre's (2013) study also sheds light on the effect of this fast-track procedure on:

— The value of patents, measured by the number of claims by the patent holder against competing companies and the number of Patent Offices in which the patent is granted. The study concludes that patents which have benefited from the fast-track system have greater value.

— Technological diffusion, measured by the number of citations of the patent. The author's empirical study shows that patents granted through fast-track procedures are cited twice as often as patents in the same technology segment, with the same value and granted at the same time.

Public-private partnerships (PPPs)

For governments, PPPs are a means of financing investments of public utility with the help of private capital and of reducing the asymmetry of information regarding the costs and risks of private sector projects. There are several kinds of PPP, but the one generally used is the Private Finance Initiative, extensively deployed in the UK since 1992.

In France, in November 2010, the Syndicat Départemental d'Énergie et d'Équipement de la Vendée (SyDEV), Ineo (a subsidiary of GDF SUEZ), la REVe (Régie d'Électricité de Vendée), and the investment fund InfraVia signed a PPP for the development, design, financing, construction and maintenance for 20 years of four ground-mounted solar installations. With an installed capacity of 14.7 MWp in the Vendée, these solar installations have been constructed on four waste landfills, two of them still in operation. Since October 2012, they have been providing the equivalent to the consumption of 5,500 households (16 GWh). The 64,000 solar panels reduce annual CO_2 by some 4,600 tonnes. Under this €85 million contract, InfraVia and Ineo have invested €44 million.

3. Instruments supporting the demand for renewable energy

Renewable energy production technologies are not competitive with fossil fuel and nuclear energy sources. The full production cost for electricity exiting the plant is €70-75/MWh for coal and gas, and €54/MWh for nuclear if the extended investment costs are included. Wind energy in France cost €69/MWh in 2011, and photovoltaic €293/MWh[128]. An important factor to take into account regarding the real production costs of wind and solar energy is its intermittent production, due to climate conditions and the location of production sites. Other types of renewable energy, such as tidal power, do not face this problem of intermittence, but are still at very early stages of development.

The immaturity of RE technologies and the role they will be expected to play in reducing greenhouse gas emissions justify policies to support their deployment. At the European level, Directive 2001/77/EC of 27 September 2001 encourages the promotion of RE and its beneficial impacts in terms of reducing greenhouse gas emissions, the security of European energy supplies, and creating jobs.

The aim of policies to support demand is the creation of a market that provides investment security through the existence of private income. Establishing support for demand is justified by the flexibility it provides to firms, since it effectively guides private developers who have an informational advantage over the public sector and will therefore turn to less costly processes. However, demand support policies have been criticized for intervening in favour of the most mature technologies, and hence only encouraging technological diffusion or even incremental innovation, but without inducing radical innovation.

The most frequently used RE demand support instrument is currently a price instrument, namely feed-in tariffs (FITs). These guarantee producers purchase tariffs that are higher than the market price. Although less popular, tradable green electricity quotas are also used by governments. Other fiscal and financial tools can also help stimulate demand for green electricity.

Feed-in tariffs (FITs)

Definition

Feed-in tariffs are the most frequently used demand support tool for promoting RE. They make it obligatory for distributors to buy electricity from RE sources. This obligation is combined with electricity purchase tariffs that

128 Statement by H. Proglio, President and Director General of EDF, to the parliamentary commission of inquiry on electricity costs, 14 March 2012.

are higher than the market price. These tariffs are defined for a given period, usually 10 to 20 years, and thus ensure the security of investments.

Different types of FIT

The way FITs are designed varies considerably from country to country, and even within a particular country. However, three main types of design may be distinguished.

— *Specific FITs versus Flat FITs*: the degree of technological maturity is crucial. Specific FIT technologies apply different purchase tariffs according to the source of the electricity. This system contributes to long-term diversification of the renewables portfolio, thereby reducing windfall effects (Bergh 2008).

Flat FITs involve the opposite approach, in that remuneration is the same for all technologies, which are thus placed in competition with each other so that the most cost effective can emerge.

Which of these alternatives is chosen turns on a trade-off by the government. With the first, there is a risk of supporting inefficient technologies and producing windfall effects. With the second, the risk is that producers will be led into technological dead ends, since by favouring the most mature technologies, a limited number of new forms of energy are deployed.

— *Fixed premiums versus fixed tariffs*. With the first, the state pays a premium on top of the wholesale price of electricity, and the final price is restricted. Fixed premiums are usually adopted with a view to supporting the transition from a niche market to a competitive market. The final payment varies with the price of electricity, thereby introducing market risk for the producer (through the volatility of electricity spot prices). The other solution is to make fixed payments to producers, enabling them to anticipate stable support over time. For example, in Spain in 2007 (Real Decreto 661/2007), the operator of a concentrating solar power plant could either choose the first tariff option, guaranteeing a constant rate of €278.399/MWh, or opt for the second, enabling it to price its production at the hourly spot price plus a constant premium of €262.509/MWh, with the final purchase price being constrained by a lower (€262.548/MWh) and upper (€355.499/MWh) boundary. The bonus system helps reduce the risk of overproduction and market destabilization entailed by fixed payments.

— *The degression principle*. An inter-cohort principle is applied and not an intra-cohort principle. The rate paid to a cohort is the same throughout the life of the project, but tends to decrease from one cohort to the next so to reflect the producers' learning process and lower costs. The producer surplus is thereby minimized. However, since production costs and the learning process are imperfectly known by the government, it may use various methods to reduce the payments over time. For example, the degression principle

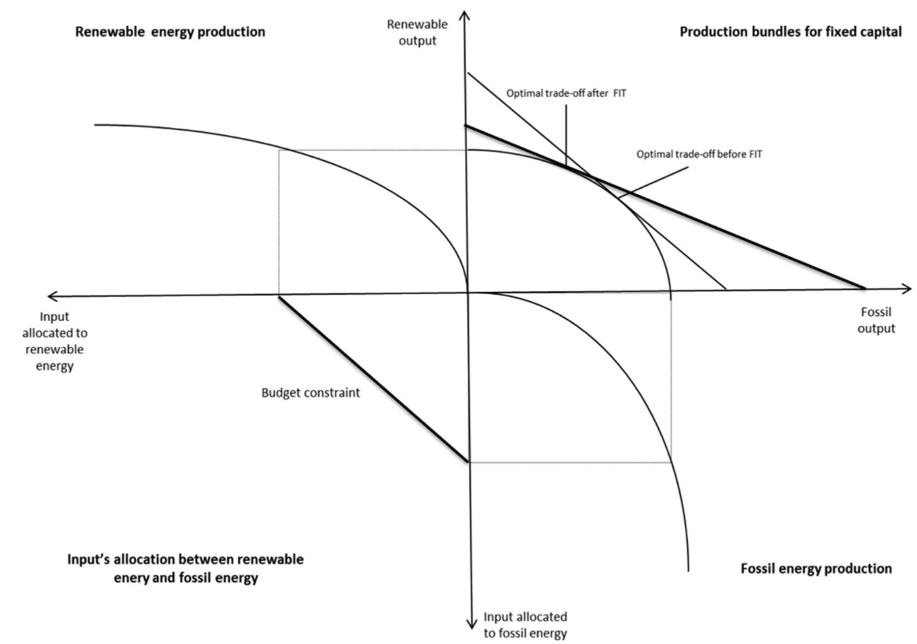
may be an annual percentage of the tariff or be scaled to the productivity of the site or to the quantities fed into the market in previous years.

Various other design options also exist, including the duration of the payment, the programming of re-adjustment levels of the payment (as in Germany), adjustment of tariffs according to the size of the installation, indexing on inflation, and different support funding arrangements.

Graphical analysis

We represent graphically a producer's trade-off between the production of fossil energy and the production of renewable energy. For a fixed amount of input, all production combinations are represented by the concave curve in the northeast quadrant.

◊ Figure 5: Impact of the Feed-In Tariff on an energy producer's trade-off

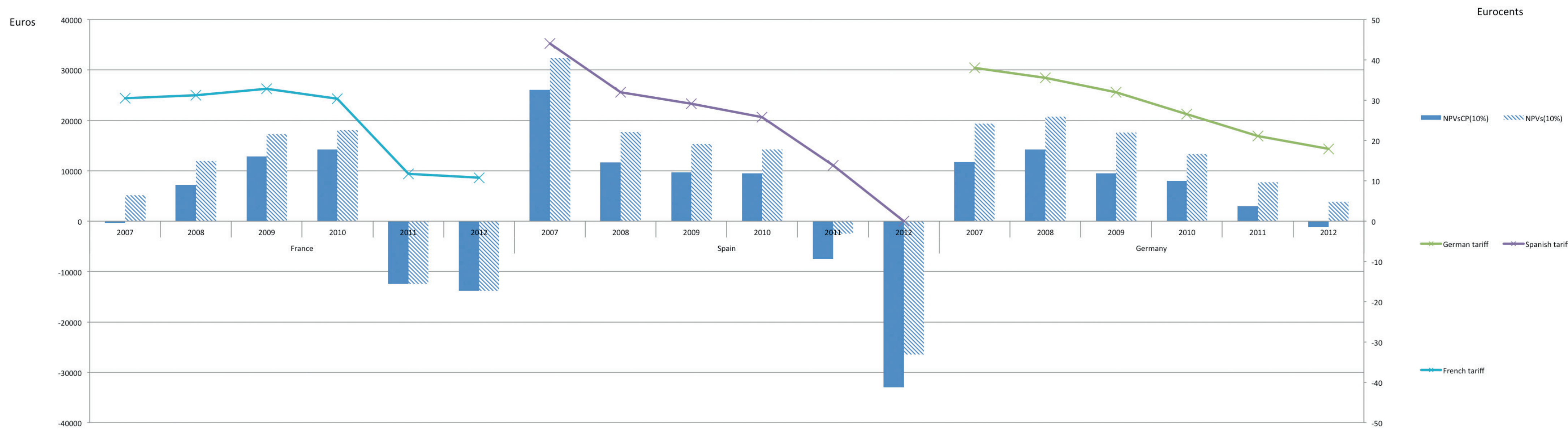


By introducing a FIT that remunerates the production of RE, the government changes the budgetary constraint on the producer, which then re-orients its optimal trade-off by increasing the proportion of renewables in its energy mix.

Case study: photovoltaic production

Spain, France and Germany have all used FITs to support the deployment of photovoltaic (PV) on their national territories. The main characteristics of their FITs are as follows.

Figure 6: NPV of the project according to the year of signing the purchase contract



Source: authors, based on NREL's System Advisor Model

— In Germany, the FITs are paid over a 20-year period. The German system is illustrated by its degression system[129]. The degression of payments to photovoltaic remained constant until 2008, and then followed a process based on the increase in installed capacity during the previous year. This process corresponds to the establishment of a "volume responsive corridor" for a degression of 5.5% to 7.5% in 2008, on the basis of three scenarios on the evolution of installations over the preceding year. In 2010, the range was 6% to 13%, depending on eight possible scenarios, which enables the cost of support to be minimized while reducing the uncertainty investors face, by insuring them against too large a decrease in payments.

— In 2007 Spain ended the possibility for PV power producers of choosing between a fixed payment and a flat rate (Schallenberg-Rodriguez, Haas, 2012), leaving only the flat rate[130]. In 2012, the government announced that it would no longer accept new contract applications (regardless of technology). The duration of support to installations was 25 years.

129 Fulton, Mellquist, The German feed-in tariff for PV: managing volume success with price response.

130 The premium option is still possible for thermodynamic solar energy.

— In France, tariffs are paid for 20 years and are indexed on cyclical indices. Degression is based on the country's installed capacity.

We consider a photovoltaic plant with an installed capacity of 20kWp, located in an area with 1230 DNI (Direct Normal Irradiance). Electricity production costs[131]:

	2007	2008	2009	2010	2011	2012	2013
Average cost of the module ($/W)	2.06	2.22	1.9	1.55	1.39	1.29	1.23
Total cost of the system c-Si (including BOS) ($/W)	5.09	4.76	4.19	3.45	3.24	3.12	3.07

We make the following assumptions:

— The interest rate is 5% over 20 years, i.e. throughout the project lifetime. By means of taxation, producers are encouraged to have full external financing; the debt to equity capital ratio of 75% of the total cost of the installation is a proxy for imperfections in the credit market.

131 Based on the reports Photon Consulting, Solar Annual 2009: Total Eclipse and Photon Consulting, Solar Annual 2012: The Next Wave.

— Profits are subject to a 15% tax rate. Depreciation is linear over 20 years.

The blue bars in the histogram below represent, ceteris paribus, historical purchase prices. We thus isolate the impact of FITs on the profitability of projects. We also consider a second situation, illustrated by the striped bars, to take account of the effect of other climate policy instruments introduced by the governments concerned.

— In Germany: low-interest loans offered by KfW bank for investment in renewable energy. The interest rate in the example is 2%.

— In Spain: a tax credit of 12% of the cost of investments.

— In France: until the end of 2010, it was possible to use accelerated depreciation over a year.

We show the project's Discounted Net Values[132] for each payment year in each of the two situations.

Over the years, Germany has provided linearly decreasing support through its degression system. Note that Germany is planning to move to a system of fixed premiums in order to progressively make RE competitive fossil electricity.

The high NPVs of Spanish projects are due to the 25-year coverage period and the differentiation of five geographical zones according to the amount of sunshine they have. In our case, sunshine levels are low and payments more advantageous to compensate for the lower output.

NPVs of French projects fell sharply in 2011, as a result of the introduction of a degression mechanism[133] (Sunshine Order – arrêté Soleil – of 4 March), which amended inter-cohort quarterly payments. Previously degression was low, and more than offset by the annual indexation of tariffs, which explains the increasing NPV over time. The Sunshine Order also significantly decreased the French FIT level.

Quota purchase obligations

The introduction of quota purchase obligations provides a quantity-based instrument for RE deployment, in contrast to the price approach of FITs. These quotas are distinctive in being exchangeable between the actors subject to the purchase obligation and minimize the total production costs (Coase, 1960; Dales, 1968). Such systems have been introduced in Australia, Japan and the United Kingdom (Berry and Jaccard, 2001), as well as in several American states.

132 Simulations carried out using NREL's System Advisor Model.

133 Applying solely to PV.

Definition and design modalities

Quota purchase obligations require agents, distributors and consumers to consume/produce some electricity from RE sources. These quotas may be expressed as an amount (per MWh) or as a proportion of the quantity used/distributed. They ensure that RE producers have a market. However, the support mechanism operates not only through the existence of quotas, but by the establishment of a parallel certificates market.

"Tradable Green Certificates" (TGCs) allow agents subject to the purchase obligation (retailers or consumers) to demonstrate that they have complied with quotas. The rule of equivalence between TGCs and the production of green electricity is defined by the government; for example, a TGC may represent the production one kWh of green electricity. TGCs issued by the producers of green electricity will then be traded on a certificates market. The price resulting from the matching of the producers' supply and the distributors' demand is the financial supplement that is added to the price of electricity.

A TGC system has a number of distinctive features:

— There is a bounded certificate price. The upper limit is equal to the fine that bondholders pay in the event of non-compliance with the quota. This penalty is applied for each unit of green electricity, although some systems impose overall fines. The introduction of a lower limit is optional, but reassures investors by providing them with a minimum revenue.

— The weighting of technologies is a key feature. Often attacked for advancing only the most efficient and hence most mature technologies, the TGC system can, however, overcome this limitation. Indeed the equivalence of certificates and the kWh of green electricity can be modulated according to the production technology. However, the technology mix that then emerges no longer derives from a market process but from public policy choices, which introduces other limitations.

— Agents may be allowed to retain excess certificates from one year to the next (banking), or alternatively to borrow certificates lacking in one period subject to presenting them in the next period (borrowing). These two possibilities give agents more flexibility and reduce their costs, but introduce uncertainty as to the price of certificates, thereby reducing the attractiveness of green electricity for investors.

— The progressive adjustment of equivalences between electricity production and certificates is needed to prevent a gradual fall in prices due to increasingly high levels of green energy production. Another way to avoid this price decline is to gradually increase the obligation quotas.

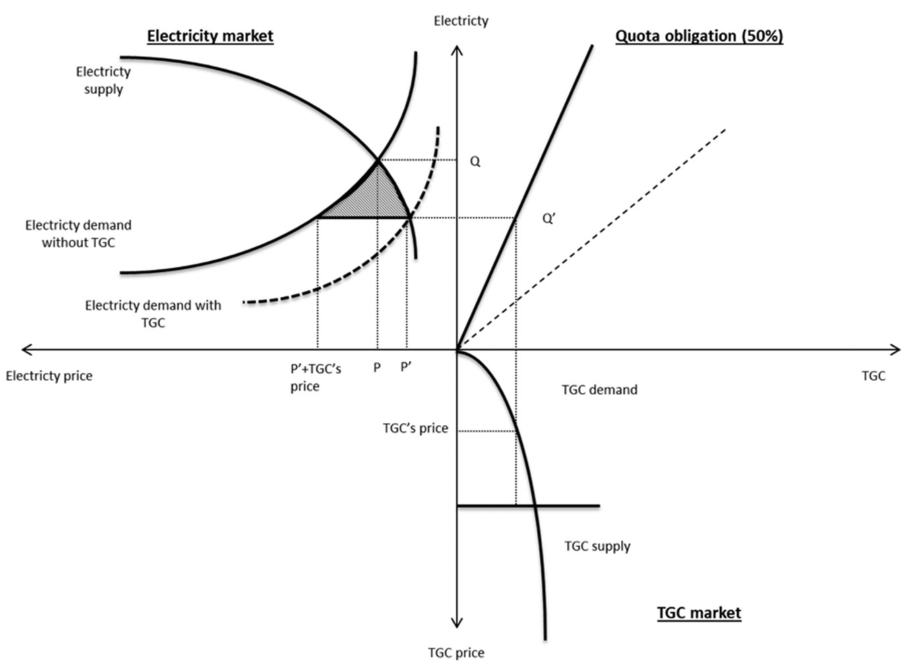
In Europe there is a system of green certificates – the European Energy Certificate System –which is not subject to quotas since it is constructed on the basis of voluntary agreements (Nielsen and Jeppesen, 2003). Its primary aim is to ensure the traceability of green electricity; there then develops a parallel certificates market in which the price is added to the electricity spot price (or to FITs if they exist in the country concerned). This system includes 19 European countries, and accounted for 27% of European production of renewable energy in 2011 [134].

Interdependence of the certificates market and the electricity market

The demand for certificates is determined by the quota level imposed. If the certificate price is less than the penalty, demand will be equal to the quota. If it is higher, demand will be zero. The supply of certificates is directly related to the supply of green electricity, and hence its marginal cost of production.

We represent below the equilibrium between a certificates market and an electricity spot market. We assume that there are no flexibility mechanisms (banking and borrowing) and there is a certificates supply function that aggregates the supply functions of the producers already in the market and producers who will enter it.

◊ Figure 7: Equilibria in the electricity and TGC markets



Source: authors

The (Q, P) pair in the northwest quadrant represents the market equilibrium before the quota system is in place. The quota obligation results in an additional cost equals to the price of the certificate for the consumer or distributor, as the case may be. The revenue allocable to the consumption of electricity is reduced and this homothetically shifts the demand curve downward. A new equilibrium (Q', P') emerges from the encounter between electricity producers' supply and the "constrained" demand shown in dotted lines on the graph. Consumers pay P' plus the price of the certificate. This therefore results in a "deadweight loss". Borne by the consumer, this deadweight loss is represented by the grey area in the graph.

We can see that the TGC system is uncertain in the medium to long term for producers of green electricity (Lemming, 2003), since the total supply increases when they enter the market, which reduces the spot price. This is reflected by a proportionally smaller increase in electricity consumption than the increase in the supply of green electricity. The price stability of TGCs therefore requires an increase in the quota (even if it is defined by volume).

134 According to data provided by the Observ'ER, observatory for renewable energy.

Other demand support instruments

Climate policies to support demand can also count on other instruments. Two categories may be distinguished: financial instruments and tax instruments.

Financial instruments

State banks can play a role in supporting demand by facilitating the financing of infrastructure and equipment. These banks are fully or partially owned by the state and considered to be in the public interest; they interact with companies either directly or through private banks. The funding they provide is based on lower interest rates and easy access to credit.

The German bank KfW Bankengruppe (1948) has extensively contributed to RE in Germany and elsewhere. It is owned by the state but goes through the private sector to issue low rate loans. Its missions are housing and the environment, economic development and assistance to Small and Medium Enterprises (SMEs). It is estimated that KfW Bank programmes have financed 40% of German PV arrays and 80% of German wind turbines. The "Solar Power Generation Programme" has benefitted more than 30,000 investors by granting them loans of up to €50,000 that can cover 100% of the eligible expenditure.

Other countries have similar entities, such as:

— Oséo in France (part of the Banque d'Investissement Publique).

— The Green Investment Bank in the United Kingdom, which was created in 2012 following the Climate Change Act.

Third-party investors are private actors who facilitate the financing of a project. With regard to RE, third-party investors can function as a link between electricity purchase contracts offered by the government and the site operator. In this capacity they finance infrastructure, carry the technological risk and are compensated with a proportion of the payments received by the operator.

The cornerstone of the relationship between these different actors is the form taken by the contract. In France, the Energy Performance Contract (EPC) applies to the thermal renovation of buildings and ensures that work carried out by the contracting authority brings a gain in energy efficiency to its client. The contracting authority is remunerated by the contract for a defined period, beyond which the client benefits through the reduction of energy bills.

Tax instruments

The tax credit mentioned earlier can be applied to activities other than R&D. Two mechanisms can be identified:

— The Investment Tax Credit (ITC) deducts from taxable revenue a portion of the investment made for the production of green electricity.

— The Production Tax Credit (PTC) provides a productive incentive similar to FITs. The amount of electricity produced is deducted from the taxable revenue.

The design modalities are the same as those of an RTC. Spain provides two types of ITC to promote the use of renewables and environmental protection:

— An ITC of 20% of the expenditure incurred during the renovation of a building. To be eligible, this outlay must provide an energy efficiency gain or facilitate the use of RE.

— A second ITC of 12% of the investment in tangible assets. The aim is to reduce air and water pollution, process waste or generate RE.

The United States has a similar ITC system: the Energy Investment Tax Credit, introduced in 2008. Not cumulable with the PTC, it allows a portion of the investment to be deducted from taxable revenue. Depending on the technology, the rates applied vary from 10% to 30%. The USA also introduced a PTC for green electricity in 1992. Tax deductions for 2013 are 2.3 cents/kWh for wind, biomass (produced in closed circuit) and geothermal energy and 1.1 cents/kWh for other forms of energy (marine, hydraulic, solar). The duration of the PTC is ten years, except for biomass produced in open circuit, where it is only five years. The PTC is reduced in proportion to any federal aid received by the producer.

4. Conclusion

In conclusion, energy climate policies vary considerably around the world, both in terms of the procedures implemented and their effects. They can be characterized on the basis of two main axes:

— The design modalities used by the regulating authorities

— The portfolio of instruments used to support the transition, from basic research through to commercial deployment.

As this chapter makes clear, the design of the instrument is at least as important as the choice of the instrument itself.

It is tempting to try and rank the various instruments in order of merit. Yet their many different types of design gives them great flexibility, as is illustrated by the examples of FITs and TGCs: green electricity purchase tariffs may be adjusted on the basis of production thresholds or quantity triggers, which brings RE producers as well as TGCs close to market conditions. Similarly, a TGC system with a strong floor price is equivalent to a FIT in terms of security and support for the producer (Menanteau et al., 2003). The diversity of RTCs from country to country also reflects the type of support desired, particularly the willingness of the government to remain technologically neutral or to direct private investment. The proper implementation of support instruments should be based on ex ante evaluations of their effectiveness, as well as on flexibility mechanisms. The latter allows support costs to be minimized through fine-tuning practices that take account of economic developments, although they must be defined in a transparent way so as to reduce investor uncertainty.

To be optimal, climate policies should comprise a portfolio of instruments mobilising both supply and demand.

The two main constituents of technical progress are research, development and demonstration (RD&D) and learning-by-doing. Policies to support supply emphasize companies' RD&D efforts, while policies to support demand create the niche market that precedes commercial deployment, by protecting innovative companies from competition and allowing them to build up the necessary skills for innovation. With regard to the deployment of RE, complementarity is all the stronger since one of the determinants of green innovation is the additional benefit gained by the consumption of the product; yet green electricity cannot be distinguished from brown electricity since it is fed into the same network (Kammener et al., 2009). One solution would be to label the green electricity delivered, for example by a system of green certificates.

This notion of complementarity requires a balance between support for supply and support for demand. A climate policy based on supply can be costly for governments and the result may be disappointing, while support for demand, even if strong, has difficulty in triggering radical innovation. Counting solely on demand risks producing an ousting effect for the public authorities, by bringing forth a small number of technologies and hindering radical innovations (with the available funds being channelled towards production[135]).

135 See the study by Nemet, 2009, on the decline in patents on Californian wind energy after

The linear model of innovation illustrated by the slogan “science finds, industry applies, man conforms”[136] is thus obsolete. Innovation is a non-deterministic process that is built around actors and institutions, and the actions and interactions between them (Wieczorek, 2012). A recent literature has developed around a systemic approach to innovation and identifies three determinants of a successful innovation policy (Negro and Hekkert, 2008).

— Support a long-term vision by emphasizing the continuity of support policies introduced and by explicitly reaffirming the commitments undertaken,

— Develop infrastructure favourable to technological diffusion,

— Give companies the wherewithal to develop their expertise capacity and take part in the transition, in that they are better informed about the feasibility of projects than the government and reduce the risk of technological lock-in.

It is essential to set up feedback systems between demand and the upstream stages by creating interfaces between heterogeneous agents (researchers, developers, producers, consumers, etc.).

The sustainability and credibility of such policies depends on their funding. Yet since the ecological transition seeks to curb the environmental damage caused by the energy sector, it is inseparable from environmental taxation, the revenue from which can be reallocated to support green innovation in the energy sector, thus contributing to a “double dividend” (Goulder 1995).

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Part 6

Carbon economy in the construction sector

Building is the sector offering the best prospects for reducing greenhouse gas emissions in the medium and long term, but the efforts being made are far lower than they should be on the basis of purely economic criteria, such as return on investment. This “energy efficiency gap” needs to be analysed in depth with a view to implementing a relevant strategy based on carbon price.

Chapter 13, *Climate economics in the construction and housing sector*, presents an overview of these issues and looks at the key research questions that needs to be addressed in a programme designed to define a carbon strategy in this area.

Chapter 13

Climate economics in the construction and housing sector

Jean-René Brunetière

1. Introduction

According to UNEP (United Nations Environment Programme, 2007), building is the sector offering the best prospects for reducing greenhouse gas emissions in the medium and long term: "The challenge to achieving energy efficiency, and reduced climate change impact, in buildings is therefore usually not a lack of access to technical solutions, but a lack of signals to the building sector stakeholders to adopt such solutions".

Energy consumption and GHG emissions in the building sector

According to IEA[137] data, in 2010 the housing sector was responsible for 32.2% of final energy consumption worldwide (23.9% for residential and 8.3% for tertiary) and about 27% of CO_2 emissions. For France, IEA estimates are 41.4% in terms of energy consumption (27% for residential and 14.4% for tertiary). On slightly different definitions, the figures given by the Service de l'Observation et des Statistiques (SOeS 2013) are around 68.7 Mtep, or 44.5% of French energy consumption (29.8% for residential and 14.7% for tertiary) and 25% of CO_2 emissions[138], varying from year to year mainly according to the harshness of the winter. The proportion of energy consumption attributable to buildings has been remarkably constant for several decades (42% in 1973). The relatively low rate of emissions in France stems in particular from the prevalence of nuclear power and electric heating. Nevertheless, the potential for French buildings-related emissions reduction is in the order of 45%, since "decarbonated energy" saved in housing may be substituted

137 http://www.iea.org/statistics/statisticssearch/report/?country=WORLD&product=balances&year=2010 and http://www.iea.org/publications/freepublications/publication/name,32870,en.html
The IEA does not specify tertiary sector CO_2 emissions

138 Around 18% of total GHG emissions. The building sector emits very little GHG apart from CO_2.

for “carbonated energy” in other economic sectors. Buildings thus emerge as the largest source of emissions economies.

▶ Table 1: Energy consumption and CO_2 emissions in the building sector (2010)

		Total energy consumption (Ktep/yr)	Residential energy consumption (Ktep/yr))	Tertiary energy consumption (Ktep/yr)	Total CO_2 emissions ($MtCO_2$)	Residential CO_2 emissions ($MtCO_2$)
France	value	162,814	4,4049	23,404	357.8	74.4
	%	100.0 %	27.05 %	14.37 %	100.0 %	20.8 %
EU 27	value	1,194,909	307,000	152,548	3,659.5	859.8
	%	100.0 %	25.69 %	12.77 %	100.0 %	23.5 %
World	value	8,681,959	2,072,308	721,815	30,276.1	5,376.3
	%	100.0 %	23.87 %	8.31 %	100.0 %	17.8 %

Source: IEA

The energy efficiency of buildings depends very much on when they were constructed, since France has only relatively recently (2000, 2005 and 2012) introduced strict regulations for new construction.

▶ Table 2: Breakdown of main residences by age and final energy consumption (normal climate 2010)

	Housing stock (million)	Consumption (TWhEF/yr)	Average consumption per residence (kWhEF/yr)
Individual houses	19	290	15,300
Collective buildings	14	150	10,700
Total	33	440	13,300

Source: Renerter

▶ Table 3: Examples of heating consumption by type of main residence (normal climate 2010) and period of construction (in kWhEF/m²/yr)

	Before 1915	1915-1948	1949-1967	1975-1981	2001-2006
Rural house	214				
Middle-class house	154				
Detached house	225	225	226	142	78
Haussmann-style apartment building	132	177			
Middle-class apartment building			230	85	49
Low-cost housing, high-rise and low-rise blocks	134	172	151	82	

Source: Renerter

Breakdown by use of energy consumption in the building

Heating accounts for 70% of the sector’s energy consumption and most of its CO_2 emissions. Hot water comes second, though consumption by electrical equipment (home appliances, electronics, etc.) is continuously growing, and now represents a significant proportion in low-consumption buildings.

“Grey energy” and the carbon footprint of buildings

The issue of GHG emissions produced during the construction of buildings should also be taken into consideration. Its relative impact varies considerably from case to case (and how it is calculated). By way of example:

A building’s carbon footprint is around (CSTB-ADEME 2010):

— 140 kg CO_2/m² (net floor area) for a wood-framed house,

— 200 kg CO_2/m² (net floor area) for an apartment in a concrete block,

— 1100 kg CO_2/m² (net floor area) for a concrete and steel glass-walled office block.

With regard to emissions arising from the use of the building, grey carbon from construction can account for between:

— 2.5 years of emissions for a class E wood-framed house (250kWh/m²/yr) heated by gas (0.220 kg CO_2/kWh)

— 250 years of emissions for a low energy consumption concrete-steel-glass building (50kWh/m²/yr) heated by electricity (0.089 kg CO_2/kWh).

In other words, this parameter should be addressed on a case-by-case basis.

Issues of energy and CO_2 emissions inside buildings

The economic issue:

The overall energy bill attributable to buildings can be evaluated in various ways. If we attribute to the sector the share of the overall external bill (€68.7 bn in 2012) corresponding to its share of total consumption, we can evaluate the impact of buildings’ energy expenditure on the external bill at nearly €30 bn.

The social issue:

The energy bill is a major factor for households’ purchasing power and well-being. The number of French people living in a situation of “energy poverty” (i.e. those who spend more than 10% of their income on energy for their home[139]) is estimated at 3.4 million in France. 87% live in private accommodation and 55% are aged over 60.

The climate issue:

At a European level, the building sector (residential and tertiary) accounts for 35% of CO_2 emissions. To attain the "20-20-20" strategic objectives of the EU "climate energy package" [140], the real estate stock is a major issue. Similarly, at a French level, since achieving the 3% per annum GHG reduction level entails cutting emissions by a factor of four between 2005 and 2050, as specified by the "POPE"[141] law of 2005, this requires a major contribution from the building sector. The various prospective exercises carried out in recent years on how to achieve this "4 factor" (De Perthuis, C. 2011, ADEME 2013) all set a rate of reduction to the building sector higher than the average reduction factor of 4 (between 6 and 8 depending on the exercise), and a more rapid rate of progress than in other sectors. These projections are based largely on the fact that from a purely technical standpoint, there is nothing to prevent almost limitless improvement in energy efficient of buildings and their equipment. We now possess highly effective insulation and energy management techniques, and it can be reasonably expected that they will be further improved in the medium term. This is not the case in other sectors such as transport or agriculture, for example.

However, we have to admit that despite the notable efforts of the public authorities in recent years, the reduction in consumption and emissions has fallen far short of what was hoped: energy consumption in the building sector increased by 17% between 1990 and 2005 and has been stable since 2005 at around 68 Mtep, with GHG emissions following a similar path. It is important therefore to understand the reasons for these trends, to find out what economic and social mechanisms are at work, to develop reliable economic forecasting instruments and to help design the most appropriate economic and legal tools for achieving the designated objectives.

139 According to ADEME, the poorest households spend 15% of their income on energy as against only 6% for the richest (ADEME & Vous, Stratégie et Études n° 3, 03/04/2008). This reference to "level of effort", most commonly used to define "energy poverty", is statistically useful, but not at an individual level: some rich households spend more than 10% of their income on energy (second homes, heated swimming pools, etc.). We can even call into question the relevance of the concept: is it legitimate to "cut" the precariousness in "fuel poverty", "food poverty", "clothing poverty" etc.?

140 The set of European laws and regulations of 23 April 2008 aiming to: raise the share of renewables in the energy mix to 20%; reduce CO_2 emissions from EU countries by 20%; increase energy efficiency by 20% by 2020.

141 Law n°2005-781 of 13 July 2005: "The fight against climate change is a priority for energy policy which aims to reduce France's greenhouse gas emissions by an average of 3% a year."

It is in this field that the Climate Economics Chairs plans to develop its sixth research initiative (RI6) with a view to complementarity and cooperation with the research teams already at work in these subjects.

2. What ways to reduce emissions in the building sector?

The issues of new construction and of the remediation of existing buildings are obviously very different.

In 2012 France had 33.2 million dwellings (18.7 million individual dwellings and 14.5 million in collective housing).

New building accounts for around 350,000 dwellings per year (ranging from 300,000 to 450,000 depending on the year) with an average area of 106 m^2, representing around 1% of the housing stock.[142] In addition, some 22,000 commercial buildings are constructed annually (around 15 million m^2)

Most European countries have adopted construction rules designed save energy. The European Union ODYSSEE -MURE[143] database has identified more than 1,000 energy saving measures affecting the building sector taken by the public authorities in the EU-28 member countries and Norway.

In 2009, the EU issued a directive on the energy efficiency of buildings, reviewed in 2012 (Energy Performance of Buildings Directive — EPBD — Directive 2002/91/EC then Directive 2012/27/UE of 25 October 2012[144]) specifying in particular transparency of performance (which in France is reflected by the DPE requirement – "Diagnosis of energy performance" – at the time of real estate transactions and the general application in the medium term of "zero energy" construction rules (in 2018 for public buildings and in 2020 for residential buildings).

New construction

In recent decades, over and beyond regulation, public and professional organizations in various countries have developed high performance energy labels linked to certification procedures, in particular:

— "Passivhaus" in Germany since 1996
— "Minergie" in Switzerland since 2000
— "Haute performance énergétique" (HPE) in France since 2005

The first thermal regulation for new construction in France dates from 1974 ("RT 1974"). It has undergone successive changes and the recent "RT 2012" sets much more stringent result requirements than hitherto.

142 http://www.logisneuf.com/statistique-immobiliere.html

143 http://www.odyssee-indicators.org/

144 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:315:0001:0056:FR:PDF

As of the beginning of 2013, new buildings must meet rules similar to those defining the HPE label. New dwellings, built to low energy consumption standards, must consume less than 50 kWh/m²(net floor area)/yr [145] in primary energy (against an average consumption in existing occupied buildings of around 240 kWh/m²/yr). This objective has been defined by the new French regulation for construction (RT 2012).

It is planned that after 2020 only "positive energy" buildings will be authorized, that produce more energy over the year than they consume.

Posted nominal performance, as calculated by the building's designers, is not generally attained in reality, according to the first published studies on operational "low consumption" buildings: shortcomings in execution, rates and types of occupation or behaviour different from that forecast (particularly temperature settings) rarely contribution to reduced consumption, and the few existing sets of measurements to date reveal real consumption in low energy consumption buildings ranging from 65 à 120 kWh/m²/yr[146]. Ways of making progress for new construction have been broadly specified for the medium term:

— Improving construction techniques and equipment

— Taking better account of real occupation conditions

— Design of types of "positive energy buildings" and their interaction with the environment and their management methods.

However, on the basis of current rates, recent buildings (constructed since 2012) will only represent a third of the total building stock in 2050. Hence the importance of renovating the existing stock.

The existing stock and thermal renovation

In the residential sector and the tertiary sector, if we confine ourselves to the technical side of things, energy savings seem readily available. This impression and prospective studies on the reduction of GHG emissions by 2050 have led to the definition of very ambitious reduction goals for 2030:

— From 37% to 53% in Europe by the European Commission (2012)

— 64% in France by the French Agency for the Environment and Energy Management (ADEME 2013).

145 In primary energy. For nuclear energy, primary energy is calculated by assuming a conversion efficiency of 33%, that is to say, one considers that the primary energy is the heat produced in the reactor by the nuclear fission reaction and that the conversion into electricity by the thermodynamic cycle, which is the same as that of conventional thermal (coal, oil, gas apart from combined cycle), has the same efficiency – about a third. Not all energy companies agree on this figure.

146 Consumption which can in many cases be reduced by reviewing the functioning of the building a few months after it comes on stream.

The "RT 2012" includes a section applicable to renovations. For major renovations, the results requirements are similar to the standards for new construction, so we can expect a gradual upgrade of the entire stock.

However, in view of the objectives mentioned above, the pace of renovation is very slow. It remains considerably below government expectations: in France, according to ADEME, it is necessary to substantially renovate about 500,000 units per year (20 million homes in 40 years) to attain a 80% reduction in GHG emissions in 2050, whereas currently the annual number of major renovations is consistently hovering between 150,000 and 200,000. Although significant efforts have been made with a view to saving energy (thermal insulation of residential and commercial buildings, improved house heating systems and equipment), the overall performance in terms of emissions remains disappointing.

Some academic studies from the 1990s suggested that the number of renovations is much lower than it should be on the basis of simple economic criteria such as return on investment. This lack of investment in energy efficiency is known as the "energy efficiency gap" (Jaffe and Stavins, 1994), since it can be explained by barriers to energy efficiency: imperfect information, conflicting interests (between owners and users), liquidity constraints, investment decisions based on other criteria, and the existence of intangible costs. It is not obvious that the phenomenon will continue in the same terms in today's economic conditions, and it may be useful to repeat the analysis afresh. Even if the barriers are real (see below), it can be currently observed that:

— For a household, the decision to invest in energy savings is rarely the result of a calculation of explicit return on the investment;

— Renovation decisions are primarily motivated more often by considerations of comfort, modernization, general value of the property and adaptation to changes in the family, since making energy savings is often done in the framework of a more general project.

— A large proportion of operations carried out in recent years to the satisfaction of developers nevertheless show very unsatisfactory performance from the standpoint of energy savings[147].

There is no doubt that clarification of the determinants of the decision to invest in energy savings (which may differ from one type of client to another) is a key issue for the orientation of public policy.

Apart from the limits of product effectiveness (heating systems or the building envelope), there is the question of consumer behaviour. On the one hand, changing the behaviour of users themselves can be an important source

147 Except if massive increases (doubling or tripling) in the price of energy in the medium term are anticipated..

of energy savings (Alcott and Mullainathan, 2010), and on the other, efficiency and consumption behaviour are closely linked by the "rebound effect" (Sorrell and Dimitropoulos, 2008; Sorrell et al., 2009). Indeed, when the energy efficiency of housing is improved, we find that the efficiency gain is distributed between energy savings and improved comfort at the cost of energy over-consumption. This behaviour, coupled with the increase in the average area per capita, increasing demand for comfort (high temperatures in winter and air-conditioning in summer) and the increase of electrical and electronic equipment, results in significantly smaller energy savings than expected.

The negative externalities generated by energy consumption in buildings and barriers to energy justify government intervention in these sectors. Up to now, the public authorities in France have not enacted binding rules for existing buildings, such as work obligations or mandatory performance thresholds, and limit themselves to policy incentives (tax credits, grants, subsidized loans, etc.) on private buildings and to renovation programmes (handicapped by the crisis of public finances) in the public sector.

Achieving substantial GHG emissions reduction targets certainly entails developing financial and/or regulatory policy initiatives. This prospect requires that strong analytical work is implemented to better evaluate different policies (subsidies, regulations, taxes) through modelling these sectors.

The Climate Economics Chair intends contributing to the study of the key factors of the construction industry in order to achieve the publicly defined targets for 2020, 2030 and 2050.

3. The general framework of the research

Some preliminaries

With regard to the preliminary work, it will be necessary to develop tools to understand what efficiency should be in newly constructed and existing buildings, by addressing the following questions:

— What proportion of energy permanently lost in domestic use? What proportion of this consumption is recoverable? Is the energy consumed a good measure from an overall management perspective?

— What typologies should be used to assess the cost-effectiveness (also considering energy uses) of each type of building? This question seems particularly critical for the tertiary sector.

— How does one evaluate the real potential for energy savings in relation to costs (taking account of all types of cost)?

— What are the economic effects of structural rigidities and other barriers (architectural constraints, legal provisions, financial capacity, relations between landlords and tenants, relations among joint owners, subdivision regulations, etc.)?

— What are the optimal strategies over time to bring a building up to a given level of performance in 2050? What might the stages of this strategy?

A wide range of publications is available on all these questions, but most of the studies concern technical improvements for energy efficiency and, by underestimating non-technical obstacles, can map out overly optimistic pathways and propose suboptimal strategies.

Carbon economy in the construction sector

An important line of research attempts to define the context of carbon economy in the building sector:

— Given the identification of rigidities (behaviour, legal forms, social norms), what might be an efficient carbon price to take into account in the building sector?

— What might be the impact of the carbon price on cost-effectiveness in terms of renovation of buildings and the strategy of owners, companies and financial operators?

— What is the effect of stakeholders' expectations in this area and how can these be taken into account in modelling?

— What would be the best ways to introduce explicit or implicit carbon pricing mechanisms into this sector?

Among these questions, it seems particularly important to understand what is meant by the concept of abatement cost for buildings. Indeed, the costs of reducing carbon emissions in the building sector have been examined in various publications (McKinsey 2009; UFE 2012), but in most cases in an aggregated form at the level of the entire sector, and they suffer from a lack of differentiation in terms of the nature of the interventions.

Most of the time, home-owners who initiate a renovation are seeking a variety of objectives, such as improved comfort and aesthetics, adaptation to new needs (especially related to people's life cycle), compliance with the most recent safety standards, financial savings or increasing the value of their assets, and to a greater or lesser extent they implicitly compare the overall assessment of these benefits with the total cost of the work and various inconveniences[148]. In the absence of value given to emissions reduction, homeowners generally ignore the collective benefit. Taking the collective benefit into account will only occur if the carbon gain exceeds the abatement cost, defined as the discounted difference between the overall discounted cost of the renovation and the total amount of individual benefits, divided by the discounted savings in terms of tonnes of CO_2 emitted. Thus, the optimal value of a tonne of carbon direct results directly from quantitative emissions reduction targets.

148 Such as the loss of living space as a result of internal insulation, the value of which often far exceeds the cost of the work.

Exploring the correlation between carbon price levels and investments can be crucial for re-assessing public policies in the sector. Indeed, several publications suggest that efforts to reduce CO_2 emissions can be seen as an increasing function of the carbon price. Most of these publications suggest that the CO_2 price level required to achieve a 80% or 90% reduction by 2050 should be significantly higher than the levels currently evoked: around €20 to €50/tCO_2 in 2010, and up to €100 to €150/tCO_2 in 2030 (Quinet, A. 2008). A recent study of SOeS (from the Res-IRF model, CIRED) for the Committee for Environmental Taxation shows, for example, that introducing a €20/tCO_2 carbon tax would, all other things being equal, increase the amount of renovation by 2030 by only about 5.6%. This type of investigation, which may call into question the idea of a single carbon price throughout the economy, merits further exploration.

The various barriers in the way of optimal strategies

The scope for materially possible interventions within the framework of existing or reasonably foreseeable medium-term technology options is extremely broad: there are few buildings where work likely to bring them up to the low energy consumption level is technically inconceivable. But much of this work is hindered by economic, legal, planning, aesthetic and informational obstacles (Koeppel, S. and Ürge-Vorsatz, D., 2007).

— Some of this work does not reach the financial breakeven point expected by the client;

— The cost of accessing information and transaction costs are often prohibitive in relation to the cost of the work itself;

— Planning, safety or heritage protection regulations prohibit certain categories of intervention (e.g. insulation from outside);

— Decision-making procedures (joint ownership, subdivision regulations, etc.) or sharing of the costs and benefits (between the owner, tenant and manager, for example) hamper investment decisions;

— The lifestyle and behaviour of occupants may be opposed to otherwise desirable changes;

— Renovation work may encounter quantitative and qualitative bottlenecks (e.g. lack of skilled labour);

— etc.

Each rigidity, barrier or asymmetry of information excludes from what is possible a set of potentially viable investments and requires an increase in the price of carbon to achieve a given emissions target. It is certainly useful to further evaluate these barriers, both to assign a price to reducing them and to estimate the impact of carbon pricing in the construction industry.

4. Helping to clarify strategies

Needless to say, the strategies that the public authorities or major economic actors can mobilize are related to the technical possibilities available and to their costs. An economic study can only take into account this data, evolving over time, but generally considered to be relatively predictable up to 2030. The Climate Economics Chair does not seek to conduct research on building technology, but it is clear that any economic research can only be based on the sector's technical and economic data. Natural complementarities emerge between the two domains and involve partnerships between their actors.

Carbon price and the carbon market in the building industry

Introducing a carbon price into the building sector is probably essential for achieving decisive emission reduction objectives in the medium and long term, but in the frame of specific characteristics of sector.

Appropriate price levels, as we have seen, can be strikingly different from what they are in other sectors of the economy

Carbon economies can be achieved in various ways, in particular:

— by taxation (a carbon tax or tax increases on fossil fuels),
— through financial aid indexed on emissions savings,
— by bonus-malus systems, combining the two previous instruments,
— by the introduction of tradable allowances in the carbon market,
— through binding regulations,
— through voluntary agreements,
— or through a combination of these instruments.

Taxation

The introduction of a climate tax in the residential sector raises the same questions as in other sectors. Apart from the design of the tax system itself (a tax on emissions? a tax on fossil fuels? how should electricity be treated? what would be the criteria for its level and evolution? etc.), the main obstacle facing taxation of fossil fuels consumed by households is social, because of the larger proportion on average of energy expenditure in the budgets of the poorest households. To take into account the social consequences of taxation, it is necessary to define at the same time possible social compensation, which may be technically complicated and politically sensitive.

In the tertiary sector, the negative effect on the competitiveness of companies can be more easily offset by a redistribution of the constant total tax levy (in particular through reducing the tax burden on the workforce).

Financial aid

Most current public subsidies allocated to building owners to encourage investment in energy savings are related to the nature and volume of the investment, and much less to the results in terms of emissions. As such, they cannot usually be seen as a form of carbon valuation. Forms of indexation of subsidies on emissions savings could also be considered, for example in the case of investments with a future performance guarantee. Similarly, bonus/malus systems could be envisaged (by funding all or part of the subsidies through revenue from sanctions).

Tradable quotas in a carbon market

A specific carbon market could be created in the building sector by allocating tradable emissions permits ("Tradable Energy Quotas" — TEQs) for building occupants on a defined basis, for example:

— on an egalitarian basis for households,

— and on the basis of recorded consumption for commercial buildings.

This form of carbon value management, whose study (over a very wide field, since it covered all household consumption) has been taken some considerable way by the UK government and Parliament[149], can present practical administrative problems and rapidly prohibitive transaction costs, but it is not impossible that future electronic banking services could make it feasible.

Its extension to overall consumption raise the difficult problem of how to determine the carbon footprint of each product, but the specificity of fossil fuels used in buildings would allow, if desired, a much simpler system to be designed if it were limited to the building sector.

Its main advantages over tax schemes are firstly that it is consistent with social equity, even if one wants to include a redistributive element, and secondly that the annual emissions reduction (determined by an independent authority within the framework of a long-term plan) becomes a variable for controlling the system.

The economic effects of stringent regulations and obligations to act

Rules, norms and obligations introduced to reduce emissions in fact implicitly produce a carbon valuation. These may, for example, be:

— mandatory rules applying to construction and equipment, in new buildings and the existing stock,

149 The Domestic Tradable Quotas Bill, introduced in July 2004 by the Labour MP Challen Collin, led to a debate in the House of Commons. Quotas would apply to the entire energy consumption of households and not just housing. Parliament has continued examining and supporting the idea: see in particular "A Policy Framework for Peak Oil and Climate Change", House of Commons, All Party Parliamentary Group on Peak Oil & The Lean Economy Connection, David Fleming and Shaun Chamberlin, January 2011.

— requirements to renovate the least energy efficient buildings in the event of a change of ownership, or periodically,

— etc.

When such rules require the owner to spend a specific amount of money to reduce emissions, this entails a type of CO_2 valuation, even if the implicit price of a tonne of CO_2 may differ in two different operations. Establishing implicit prices for different obligations possibilities is useful for guiding policy.

One particular form of these obligations is the French system of "energy saving certificates": major energy suppliers ("the obligated") are required every year to obtain from their customers a defined amount of energy savings. This amount is set by the government for a three-year period. The certificates can be traded and a genuine market is emerging. This form of obligation opens up an interesting prospect for:

— developing a carbon market, particularly in the building sector

— enhancing the effectiveness of action: the major energy suppliers are, more so than individuals, in a position in the future to offer a service directed at property owners, facilitating the execution of work and providing guarantees of energy savings. It can be an interesting field for research (see below, the SOFITREBAT 2 project).

Combinations of these systems

The most likely form of public policy in the future will be to combine different systems, for example obligations with, in return, aid to comply with them or take them further.

5. First lines of research

Measurement of lost energy

The energy consumed in buildings is generally measured by the energy consumption of the building's users. This type of measure accounts poorly for the building's relations with its environment. For a building can collect energy from the environment (through heat pumps) and also provide its environment with usable energy (through waste heat, for example). It therefore seems that the most relevant measure of final energy loss would be better represented by the exergy variation of the system concerned than the nominal energy used.

This type of perspective can provide a common measure for the analysis of a set of buildings as a system managed as a whole, taking into account long-term local energy production, storage (particularly in the batteries of electric vehicles) and some neighbourhood urban functions.

Modelling the tertiary sector

The tertiary sector, which in France represents a third of the total building stock in terms of energy consumption and CO2 emissions (and perhaps more in terms of potential savings), has to date been subject to much less research and fewer studies than housing. The reasons are understandable: great heterogeneity of building types, uses and owners, difficulties in collecting data, etc. The Chair wishes to invest in knowledge and modelling of the sector's energy consumption and GHG emissions, in cooperation with other teams interested in the subject. A prerequisite is to move towards an agreed nomenclature for commercial buildings.

Legal measures likely to lower barriers

A good many obstacles to investment in thermal renovation can probably be mitigated through appropriate legal measures, some of which have already been mentioned. RI6, in cooperation with RI4 (law and climate economics), is planning to invest in this area of research, bringing an economic point of view to it and modelling effects.

Modelling the evolution of systems

The various measures, mentioned above, for the introduction of a building-related carbon market call for an exploration of their medium to long-term effect by taking into account, as much as possible, actors' behaviour, decision-making processes and expectations.

Participation in the "SOFITREBAT 2" project

The "SOFITREBAT 2" project has been initiated by a consortium of 13 partners – medium and large companies, design and architectural firms, financial and insurance institutions, and research organizations (including the Chair) – with a view to develop an overall offering to renovate buildings from the initial analyses of the situation through to the signing of a energy-saving contract with a performance guarantee. It is led by the Strasbourg competitiveness cluster "Energivie" and the Paris "Financial innovation" cluster.

The project raises a wide range of issues around the assessment of opportunities, cost and effectiveness of emissions reduction, and the best legal and financial framework for the development of large-scale investments.

This project has been presented to the financing of the "competitiveness clusters structuring projects" (PSPC) third request for proposals. It would offer a prime field of research in relation to the questions raised above.

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Author's bios

Ayong Le Kama, Alain is Professor of Economics at the University of Paris West Nanterre la Défense and Head of the "Mobility in a low-carbon society" Research Initiative (IR3) at the Climate Economics Chair.

Bonnet, Clément holds an MSc in Environment and Energy Economics from Paris West Nanterre la Défense and Agro Paristech. He is a researcher at the Climate Economics Chair, his works focus on policies' design and implementation supporting green innovation.

Baudry, Marc is currently professor of economics at the University of Paris West Nanterre la Defense. His research was initially in the field of environmental and resource economics with a special emphasis on the real option analysis of innovation in less polluting technologies and technological change induced by environmental policies. He gradually expanded his work to the study of patents and innovation economics. He has published articles in international peer-reviewed journals both in the field of environmental and resource economics and in the field of industrial economics. He heads the "Ecological transition" Research Initiative (IR5) at the Climate Economics Chair.

Bertrand, Vincent holds a PhD in economics, whose the topic is the interaction between energy markets and the EU ETS. He is research fellow at the Climate Economics Chair and associate researcher at the *Centre de Recherches sur les Stratégies* Économiques (CRESE) of University of Franche-Comté. His research interests are in the areas of energy and environmental economics, and his current work focuses on the use of biomass for power generation and the interactions with agricultural and forestry sectors.

Boiteau, Claudie is Professor of Public Law at Paris Dauphine University and Head of the "Law, Regulation, Climate" Research Initiative (IR4) at the Climate Economics Chair

Brunetière, Jean-René is a civil engineer graduate of the French

École polytechnique, of the *École nationale des Ponts et chaussées* and of the *Institut d'études politiques of Paris*. He made a career partly in the administration for environment, town-planning an infrastructure and partly in the ministry of Social affairs and health. He was until 2012 in charge of the special commission for sustainable development in the French ministry of environment.

De Perthuis, Christian is Professor of Economics at Paris-Dauphine University and Head of the Climate Economics Chair. He started his career in the agricultural sector, went on to work in leading French research and forecasting institutes and headed the Mission Climat of Caisse des Dépots between 2004 and 2008. His research focuses on the economics of climate change and ecological transition. Author of several articles and books, he is co-author of « Le Capital Vert », published on September 26, 2013 by Odile Jacob editions. Since December 2012, he chairs the « Green Tax Commission » implemented jointly by the French Ministry of economics and finance, and the French Ministry of ecology, sustainable development and energy.

Delacote, Philippe is a researcher in environmental economics at the Laboratory of Forest Economics (INRA) and Head of the "Agriculture, Food, Forest" Research Initiative (IR2) at the Climate Economics Chair. His work focuses on the economics of climate change in forests, avoided deforestation policies and forest sector analysis.

Dequiedt, Benjamin is a PhD student at the Climate Economics Chair in the "Agriculture Food and Forestry" research initiative. His research focuses on greenhouse gas emission abatement cost in the sector of crops.

Derbali, Vincent is a PhD student at Paris Dauphine University and advisor for the French Financial Markets Authority. His research interests for the "Law, Regulation and Climate" research initiative of the Climate Economics Chair include the energy derivatives markets regulation.

Edwige, Pierre-Franck is an intern and research fellow in the "Mobility in a low-carbon society" Research Initiative (IR3) of the Climate Economics.

El Beze, Jeremy graduated in economics and management at the École Normale Supérieure in Cachan. He is a researcher at the Climate Economics Chair. His research is mostly concerned with carbon taxation and combustion sector.

Geoffron, Patrice is Professor of Economics at Paris-Dauphine University and formerly Vice-president of International Relations. He is now Director on the CGEMP (Centre de Géopolitique de l'Énergie et des Matières Premières) and Head of the Climate Economics Chair steering committee.

Jouvet, Pierre-André is Professor and Vice President of the Board of Directors at Paris West Nanterre - La Defense University, where he is Director of the Master of Economics in Sustainable Development, Environment and Energy (EDDEE). He is the scientific Director of the Climate Economics Chair. His research areas mainly encompass Environmental Economics (environmental policy, regulatory instruments, innovation, etc.), the effects of risks on investor and consumer behavior, and more generally on public economics. Author of several articles and books, he is co-author of « Le Capital Vert », published on September 26, 2013 by Odile Jacob editions

Le Cadre, Elodie is an economist at the Strategy Division of GDF SUEZ and associate researcher at the Climate Economics Chair since 2012. Her research focuses on modeling of energy demand forecast and the analysis of climate policies, as well as business plan of bioenergies. Trained as an engineer in Agronomy, she holds a MSc in Sustainable Development, Environmental and Energy Economics from IFP School. After a first experience in agricultural economics in the USA (FAPRI-Missouri), she holds a PhD in Economics from University of Paris Ouest-Nanterre and AgroParisTech on the modeling of the bioenergies development. Her PhD has been funded by the French company Sofiprotéol where she was economist specializing in the renewable energies for transportation.

Le Roy, Maxime is an intern and research fellow in the "Mobility in a low-carbon society" Research Initiative (IR3) of the Climate Economics Chair.

Lecourt, Stephen is an economist at Direction Générale des Statistiques Monétaires et Financières of Banque de France. Before joining Banque de France, he was a researcher at the Climate Economics Chair where his area of research focused on modeling CO2 emissions of non-power industries in the EU ETS. Lecourt holds a Master's degree in Energy and Environmental Economics from ParisTech and a Master's degree in Aerospace Engineering from ISAE – SUPAÉRO. While pursuing his studies Lecourt was also a visiting independent advisor, specializing in modeling at NASA Jet Propulsion Laboratory. He is currently pursuing a PhD in Economics at Paris-Dauphine University.

Madelenat, Jill holds a MSc in Management for Energy and Environment from *Ecole Nationale Supérieure de Techniques Avancées ParisTech* and a MSc in Energy and Environment Economics from *Ecole des Ponts ParisTech*. Her work focuses on energy efficiency in buildings at Climate Economics Chair.

Meurisse, Bénédicte is a research fellow at the University of Paris Ouest Nanterre la Défense and is an associate at the Climate Economics Chair, in the "Mobility in a low-carbon society" Research Initiative (IR3).

Papaix, Claire is a research fellow at IFSTTAR, the French Institute of Science and Technology for Transport, Development and Networks and is an associate at the Climate Economics Chair, in the "Mobility in a low-carbon society" Research Initiative (IR3).

Quemin, Simon holds a MSc in Management for Energy and Environment from *Ecole Nationale Supérieure de Techniques Avancées ParisTech* and a MSc in Energy and Environment Economics from *Ecole des Ponts ParisTech*. His work at the Climate Economics Chair focuses on international carbon markets and linkages among them.

Renner, Marie is economist, she holds a Master's degree in Economics of Sustainable Development, Environment and Energy granted by the French Institute of Petroleum (IFP) and the CEA (Atomic Energy Agency), Paris. She currently undertakes a PhD in economics, on Carbon Capture and Storage Technologies (CCS).

Simonet, Gabriela is an agronomic engineer from AgroParisTech (Paris Institute of Technology for Life, Food and Environmental Sciences) and holds a Master 2 in Economics of Sustainable Development, Energy and Environment. She is a PhD student and researcher at Climate Economics Chair and at French Agricultural Research Centre for International Development (CIRAD). Her research focuses on REDD+ policies and projects, and their impacts on local populations. She is currently developing a database of REDD+ projects around the world and will then conduct socio-economic impact evaluation on two REDD+ projects.

Solier, Boris is an economist from the Universities of Montpellier I and Paris-Dauphine and a researcher at the Climate Economics Chair. His research focuses on the interaction between carbon markets and the electricity sector. He teaches energy and environment economics to master students at Paris-dauphine University.

Trotignon, **Raphael** head of the "Carbon Markets and Prices" Research Initiative (IR1) at the Climate Economics Chair, is an energy and environment engineer from *École des Mines de Nantes* and Doctor in Economics from Paris-Dauphine University. His research focuses mainly on the EU Emission Trading System and the relationship between carbon and energy markets.

Wang, Wen is a Chinese PhD Candidate working on the Chinese climate politics and particularly economic potential of Chinese agriculture in mitigating climate change. She is also working with the Chinese Academy of Agricultural Sciences (CAAS). She completed her MSc in environmental economics at AgroParisTech after graduation from Nanjing University in China.

Wolfersberger, Julien is PhD student and researcher at Climate Economics Chair and Forest Economics Laboratory of INRA (Nancy). His research field is natural resource economics, especially the issue of long-term deforestation under development. He worked on the empirical determinants of the cumulative nature of deforestation and the role of agroforestry in green growth. His current work includes modeling the long-term dynamics of land uses and highlighting the impact of trade openness on land conversion. He has been visiting PhD student at Virginia Tech Polytechnic Institute (USA).

Climate Economics in Progress 2013 offers a global overview of the present status of action on climate change and on the efforts devoted to develop innovative economic tools. Drawing on the most recent data, this collective book analyzes the development of carbon markets in Europe and worldwide and assesses the involvement of major sectors such as agriculture, forestry, transport and housing in the fight against global warming.

Created in 2010, the Climate Economics Chair is a joint initiative of CDC Climat and Paris-Dauphine University, with the objective to stimulate innovation in the field of climate change economics, by linking academic and empirical approaches with political decision-making. The content is indebted to the cooperation of highly committed European corporate partners.

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