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Resource-efficient green economy and EU policies

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European Environment Agency

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Executive summary

Green economy as a strategy

Originally seen as a useful policy approach to tackle the economic and financial crisis that began in 2008, the green economy is, today, seen as a strategic way of delivering a fairer society living in a better environment. Three objectives underly the green economy approach: improving resource efficiency, ensuring ecosystem resilience, and enhancing social equity. This report addresses the first of these objectives from a primarily macro-economic perspective.

Within the EU, acceptance of the concept of a resource-efficient green economy is gaining momentum. Policy initiatives can be found across the EU's Research and Innovation programme — in the Innovation Union Initiative together with the Eco-innovation Action Plan, the EU's Seventh Framework Programme for Research (FP7) and Horizon 2020. It is also articulated across major EU strategies, including the Europe 2020 Strategy and its Resource Efficiency initiative, the 7th Environment Action Programme as well as a large number of specific environmental, energy, and resource policies.

Further, policy recommendations on environmental fiscal reforms ([3]) to foster the resource-efficient green economy are articulated in fiscal and budgetary policies of the EU, in the European Semester process of the Europe 2020 strategy, and explicitly in the Country Specific Recommendations of the Annual Growth Survey. Green orientation is also emerging in EU strategies for international cooperation for development, in particular through the role of the EU and individual Member States in the fast growing area of 'climate finance'.

This report highlights the major forces fostering the shift to a resource-efficient green economy in Europe, including the role of EU policies. It examines trends in major environment and climate areas, which show that the underlying economic and technological changes leading towards green economy objectives are weak, slow, or, in many cases, have ground to a halt.

Current trends

Changes in resource efficiency, often in the form of 'relative decoupling', indicate significant environmental improvements but such decoupling of resource use from economic growth will not guarantee long-term sustainability. The slow pace of change observed means that the major EU environment and climate objectives and targets for 2020 and beyond are unlikely to be met without additional effort and more radical re-orientation of the European economic system. Trends also suggest that the global economic and financial crisis have not resulted in improvements in resource efficiency; in some areas it has led to a decrease in efficiency.

The change in the sectoral composition of the EU economy, in particular the growth of services, has not lowered its impact on resources as was expected, belying optimistic evaluations. Instead, it is more associated with changing trading patterns and 'trade-embodied emissions', as well as an increase of the global consumption footprint above that of the EU.

Recent EU strategies to effect an 'industrial renaissance', include the policy objective of 're-manufacturing', accomplishing a 20 % share of manufacturing industry in the EU's GDP by 2020. Given the present state of resource efficiency in manufacturing, 're-manufacturing' is unlikely to improve the resource efficiency of the EU economy, and major objectives, including those for climate, unless innovative and selective green

([3]) Environmental fiscal reform is here understood as a policy tool of shifting taxes away from labour towards environmental factors that are less detrimental to growth. This concept was recommended in the 2013 country-specific recommendations of 11 EU Member States as part of the European Semester process under the Europe 2020 Strategy as an area for improving the economic performance of the relevant EU Member States.

re-manufacturing are pursued; EU funding of research and development of new materials including nano- and bio-based applications shows some promise in this regard.

Currently, though, change in resource efficiency across the EU economy is proceeding too slowly; what is required is a much bigger, deeper, and more permanent change in the EU economy and society to create both new opportunities and substitution processes across the economic structure. To bring this about, it is important to study and understand enabling factors and mechanisms at the crossroads of policies and real economy dynamics that could accelerate and direct the transformation.

Enabling factors and policies

Green or ***eco-innovation*** should be considered as a primary enabling factor especially as the policy framework for green innovation is already in place (mainly through the Europe 2020 strategy, the Innovation Union Initiative, the Eco-Innovation Action Plan, and Horizon 2020). While it is not the only element in creating a green economy, innovation can be a fundamental lever in guiding the EU energy and material-use systems towards a radical transformation of practices.

Adoption and diffusion of eco-innovation are extremely important, even more so than invention, for the resource efficiency benefits of innovation to reach a macro-level. Indeed, technology-related changes have been, quantitatively, the main factor behind the resource efficiency gains recorded in the EU in the last two decades.

Adoption and diffusion are driven by the decisions of companies and other economic actors, and there is a correlation between eco-innovation adoption by firms and the resource efficiency performance of the countries in which they operate. Structural differences exist for this correlation across Member States, and there is room for greater eco-innovation adoption and diffusion in both the EU's leading and laggard countries.

However, adoption and diffusion face a range of barriers — finance, knowledge, costs, markets, etc. — which can be particularly severe for small- and medium-sized enterprises (SMEs). The way companies react to these barriers should be a focus of eco-innovation strategies.

The open circulation of ***green knowledge*** is a second factor that can open new opportunities for commercial transactions and economic pay-offs while encouraging the international community, as a whole, along the path to a resource-efficient green economy. A global role of the EU is its capacity to spread green knowledge internationally while interacting with other countries to diffuse green technologies.

The EU leads some sectors of global trade in which there are great opportunities for green technologies. Further, domestic EU environmental policies have been important drivers of both outgoing and incoming green knowledge flows. Indeed, environmental policies are having a range of direct impacts on environmental standards and regulation in non-EU countries e.g. road vehicle engine emission standards. Even international green patents — a form of 'disembodied' green knowledge largely driven by energy and environmental policies — demonstrate the dynamic and two-way role of EU economic actors in contributing to green economic growth and jobs.

Fiscal reforms, too, are important enabling factors. Economic instruments, such as environmental taxes and emission trading schemes, are policy tools that can change pricing systems, which is essential for triggering the resource-efficient green economy transformation process. Closely linked, and a pre-condition of environmental taxation, is the reform and phasing-out of environmentally harmful subsidies. Implementing resource-efficient technologies is often not economically viable under current economic conditions. Higher energy prices, for example — brought about by economic instruments — could trigger the more widespread creation and diffusion of green technologies. However, achieving the benefits expected from economic instruments and environmental fiscal reforms depends crucially on the design of environmental taxation, which otherwise could have adverse effects.

To avoid a loss of competitiveness of domestic industries and negative distribution impacts, this requires a more general policy setting, with the environmental fiscal reform framework integrating demands particularly from economic and industry policies, thereby potentially delivering 'double dividends'. Policymakers, of course, need to consider the risk of adverse impacts but experience shows that they can be dealt with.

The availability of ***financial resources*** is arguably the most important enabling condition for the long-term transition to a resource-efficient green economy. Estimated financial needs for the necessary investment in green technologies, infrastructure, and innovation at the European and global scale are huge. There are, nonetheless, opportunities for directing financial resources towards improving resource efficiency through a number of channels.

Some channels are publicly driven, including specific initiatives undertaken by EU financial institutions, while others, for example pension funds, are to be found in the private sector. Instruments implemented by hybrid players, such as sovereign wealth funds, and hybrid instruments, including green bonds and Project Bond Initiatives, also have potential. Selectivity in funding based on sustainability criteria, such as from socially responsible investments, can also be a powerful mechanism in a competitive financial market for re-directing resources.

Among the international opportunities, financial resources mobilised to fund climate-related projects and the diffusion of green knowledge in developing countries could act as fast-growing support for a global-scale shift to a green economy, as envisaged by Rio+20.

Financing the shift to a resource-efficient green economy is a process of a macro-economic scale that may require public policy initiatives to act as catalysts. Both to turn these opportunities into reality, and to avoid conventional allocations and strategies being adopted by the financial system in times of crisis, a high level of commitment and persistence, as well as risk-reducing strategies, are needed.

Further reflections

The potential for the EU to embark on the shift to a resource-efficient green economy is great, but a variety of constraints are emerging. The major policy implication is the need for stronger interaction and greater coherence between, on the one hand, environmental and climate policies and, on the other, major EU policies, including fiscal and financial, innovation and industrial policies. Changing the industry mix, industrial dynamics and innovation are major forces that can drive the EU economy towards a green economy. The major sectoral policies that are most relevant to integration are industrial ones, in particular for the recent strategy to 're-manufacture', and those for innovation because of the absolute structural link emerging between eco-innovation and resource efficiency. Fiscal policies, too, are central to enhanced integration and coherence, especially through environmental fiscal reforms.

The on-going economic crisis, however, has shortened political outlooks and emphasised immediate pay-offs, resulting in a weakening of aspiration and confidence in a strong Europe and its international role. Initial reactions to tackling the crisis were primarily guided by economic thinking, but with clear attempts of integrating environmental aspects via fiscal recovery strategies. This process soon lost momentum, however, given the difficulties of extending fiscal stimulus packages. Environment and climate objectives have not managed to gain an equal standing compared to other policy areas, in particular economic, industry, social and financial policies.

Furthermore, the economic crisis has exacerbated divergences in economic and environmental performance of EU Member States, fragmenting both EU economic systems and individual country pathways to a resource-efficient green economy. As a result, benchmarks and good practices risk becoming unachievable by many countries.

One of the challenges for environment and climate policies is their long-term perspective as compared with the relatively short-term challenges and requirements of economic and social policies. For instance, the creation of new jobs or dealing with social inequalities has a short-term perspective as immediate action and results are expected by society. This short-term thinking is not only found in politics but also regularly in business as well as in society more broadly.

To be successful, the green economy transformation process requires acknowledgment of the multiple persistent problems (or systemic risks) faced by Europe and the rest of the world that require fundamental solutions. In this regard, regular policies offer no immediate solutions; market creation and commodification in itself is not a solution; nor is incremental institutionalism; and while resource efficiency gains are necessary, they are not sufficient for ensuring ecosystem, economic and societal resilience. Achieving a green economy requires long-term thinking and actions, the widespread application of a coherent framework that drives profound changes in dominant structures and thinking, and includes the promotion of innovation, extensive recalibration of fiscal instruments and innovative financing initiatives. Coherent integration of objectives across all policy areas is required, treating economic, social and environmental performance objectives as equal.

Introduction

In the wake of the 2008 financial crisis the green economy emerged as a policy approach to help solve two problems: the economic slowdown and consequent loss of jobs, and the continuing deterioration of the natural environment, most visible in terms of climate change and ecosystem degradation. This potential double dividend led many European countries to adopt recovery policies in 2008 and 2009 that had a green economy focus. However, as policy focus shifted to the fiscal consolidation and sovereign debt crises in Europe, the concept of the green economy began to lose appeal within short-term macro-economic policies.

At the same time, the green economy became a pillar of major European and international strategies: most notably within the Europe 2020 strategy adopted in 2010 by the EU to drive sustainable growth, and in the Rio+20 outcome *The future we want* (UN, 2012) as a tool for achieving sustainable development. The green economy can now be seen as an approach that can achieve a structural and permanent transformation of the economy.

This report is guided by the definition of a green economy as: *…. combining enhanced resource efficiency with environmental resilience, while boosting prosperity and equity in society* ([4]). Specifically, it analyses macro-level trends in Europe since the 1990s and addresses those economic factors, drivers, and outcomes that could support a stable shift to a resource-efficient green economy (hereafter called simply green economy): green innovation, green finance, environmental fiscal reforms and the changing sectoral mix of the economy.

A specific focus is the link between the shift to a green economy and the EU policy framework. As illustrated in *Towards a green economy in Europe — EU environmental policy targets and objectives 2010–2050* (EEA, 2013), a wide range of specific policies is already in place to support change. However, this report also considers the links between the green economy and policies outside the environmental sector, such as manufacturing and competitiveness policies.

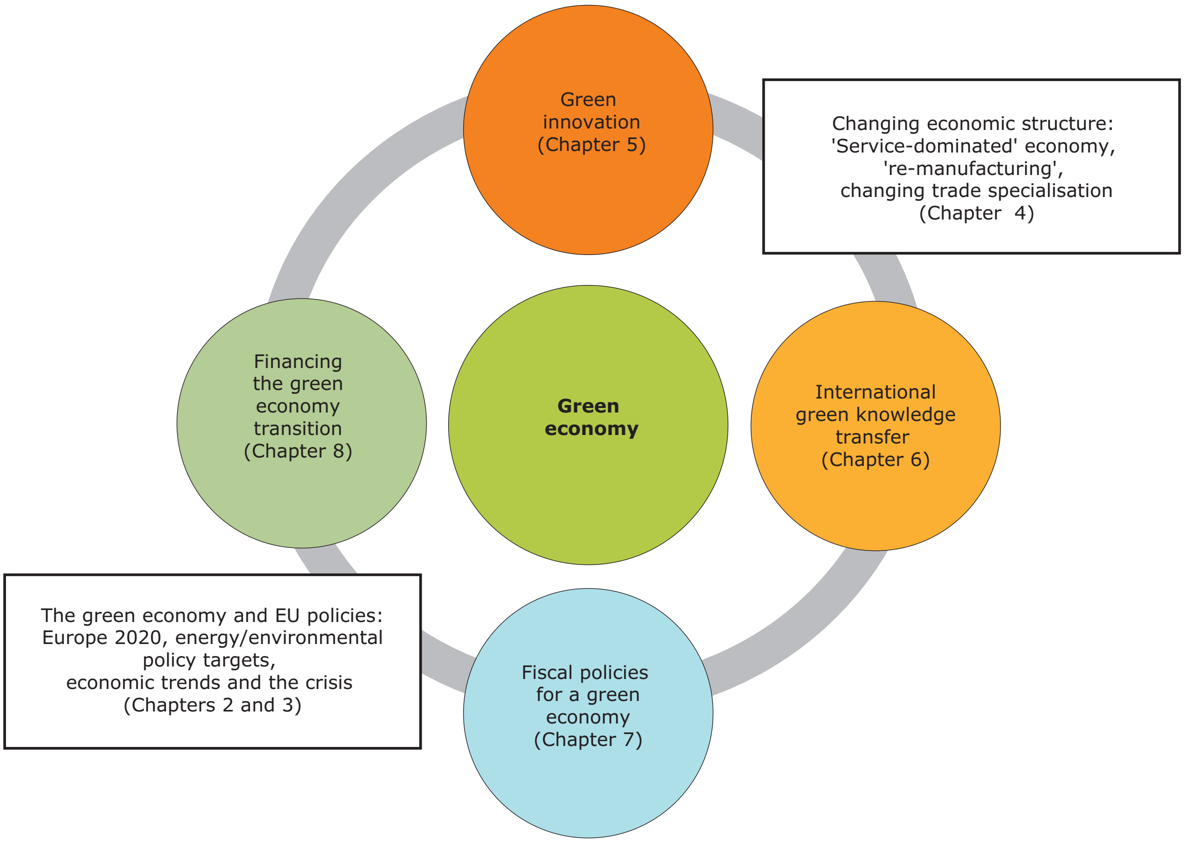
The logic of the report's approach and structure is presented in the figure on the following page. Chapters 1–4 highlight the macro-level trends towards a green economy emerging from the policy framework and the major transformation of the EU economy over recent decades. In Chapter 1, different concepts and definitions of the green economy are discussed. In addition, a brief history of the emergence of the concept of a green economy in the wake of the financial crisis is given. The EU policy landscape, focusing on different EU policy initiatives that promote the green economy, is addressed in Chapter 2. In Chapter 3, recent developments and progress in achieving environmental policy targets are studied. The changing structure of the EU's economy in terms of environmental pressures, and the extent to which manufacturing, services, and trade can play a role, are analysed in Chapter 4.

Given the combination of policy pushes and macro-level transformations of the economy, Chapters 5–8 address key enabling factors that can help to promote or hasten the development of a green economy (Figure I.1). Chapter 5 focuses on the role of eco-innovation diffusion as an established enabling condition in Europe. The role of the international transfer of green knowledge, another enabling factor, is presented in Chapter 6. The role of environmental fiscal reforms and economic instruments are analysed in Chapter 7. Finally, the role of finance, and particularly of innovative green finance as an enabling condition of the green economy, is analysed in Chapter 8.

In short, eco-innovation, green knowledge transfer, environmental fiscal reform and green finance

([4]) http://www.eea.europa.eu/themes/economy/about-green-economy.

A green economy transformation process



Note: Macro trends (boxes) and enabling factors (circles).

Source: EEA.

(Chapters 5–8) are seen as levers for effecting a shift within the framework of favourable and unfavourable macro trends emerging from EU policies and the transformation of its economic structure (Chapters 1–4). With this logic, the report seeks to contribute to an understanding of the major forces that promote or hinder progress in Europe, and of the policies needed to guide it.

1 Green economy: concepts and actions

1.1 The scope of green economy

The definitions by different international organisations of the green economy (Box 1.1) are broadly characterised by the following three objectives:

- improving resource-use efficiency: a green economy is one that is efficient in its use of energy, water and other material inputs;
- ensuring ecosystem resilience: it also protects the natural environment, its ecosystems' structures and flows of ecosystem services; and
- enhancing social equity: it promotes human well-being and fair burden sharing across societies.

Green economy thinking can be highly relevant to the political debate through providing a coherent framework to guide policy and planning with the aim of achieving ambitious, closely interlinked, though not necessarily similar, objectives. So, for example, resource efficiency will not guarantee steady or declining impacts on natural systems; therefore it is essential to focus on efficiency and resilience together to achieve environmental sustainability (EEA, 2012 and 2013).

Besides the twin challenge of boosting resource efficiency and maintaining ecosystem resilience, the integration of the social aspect or human well-being is fundamental given the importance of basic resources — food, water, energy, and materials — as well as ecosystems services for people's subsistence needs (Figure 1.1). Enhanced social equity and fair burden-sharing with respect to present and future generations can be seen as highly relevant to the long-term view of the green economy.

International organisations place different emphases on the three dimensions. For example, the Organisation for Economic Co-operation and Development (OECD) focuses, like this report, on efficiency in the use of resources, whereas the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP) focus on the inclusion of environmentally sensitive approaches in development strategies. The World Bank, the EEA and UNEP also focus on natural systems and the biosphere, in particular the importance of respecting environmental limits — respecting resource constraints and planetary boundaries. The social dimension of the green economy plays a large role in the definitions of UNDP, UNEP and the World Bank, which concludes that *this [green] growth needs to be inclusive* (World Bank, 2012). 'Green growth' is a term that is often used alongside or interchangeably with green economy.

The concept of green economy does not replace that of sustainable development, but can instead be understood as a way to achieve sustainable development ([5]) (Bowen, 2012). *A green economy is a means to sustainable development … essentially, the concept postulates that the transformation of the economy is a precondition for sustainable development* (Eurostat, 2013).

Circular economy is another concept that is connected to the green economy; it is narrower in scope as it refers mainly to physical and material resource aspects of the economy — fuel, minerals, water, biomass, etc. It does not place emphasis on human well-being or social inclusion rather it focuses on recycling, limiting and re-using the physical inputs to the economy, and using waste as a resource ([6]), leading to reduced primary resource consumption. As such, the circular economy concept

([5]) A major policy attractor was the concept of sustainable development as originated by the work of World Commission on Environment and Development (WCED) in 1987. The WCED report — also known as the Brundtland report — made the case for designing strategies that would simultaneously preserve or improve the quality of the environment and ensure economic growth, and also expanded the definition of growth by speaking both of 'reviving growth' and 'changing the quality of growth' (WCED, 1987).

([6]) See for example the report published by the Ellen MacArthur Foundation: http://www.ellenmacarthurfoundation.org/circular-economy/circular-economy/the-circular-model-an-overview.

Box 1.1: Definitions of green economy and green growth ([7])

European Environment Agency: 'A green economy is one in which policies and innovations enable society to use resources efficiently, enhancing human well-being in an inclusive manner, while maintaining the natural systems that sustain us' (http://www.eea.europa.eu/themes/economy/about-green-economy and EEA, 2012).

OECD: 'Green growth means fostering economic growth and development, while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies. To do this, it must catalyse investment and innovation which will underpin sustained growth and give rise to new economic opportunities' (http://www.oecd.org/greengrowth/48012345.pdf).

UNDP: '[…] new growth poles that can potentially contribute to economic recovery, decent job creation, and reduced threats of food, water, energy, ecosystem and climate crises, which have disproportionate impacts on the poor' (http://content.undp.org/go/newsroom/2009/june/green-economy-a-transformation-to-address-multiple-crises.en).

UNEP: '[…] a green economy is one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one which is low carbon, resource efficient and socially inclusive. Practically speaking, a green economy is one whose growth in income and employment is driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services' (www.unep.org/greeneconomy).

World Bank: '[…] green growth — that is, growth that is efficient in its use of natural resources, clean in that it minimizes pollution and environmental impacts, and resilient in that it accounts for natural hazards and the role of environmental management and natural capital in preventing physical disasters. And this growth needs to be inclusive' (http://siteresources.worldbank.org/EXTSDNET/Resources/Inclusive_Green_Growth_May_2012.pdf).

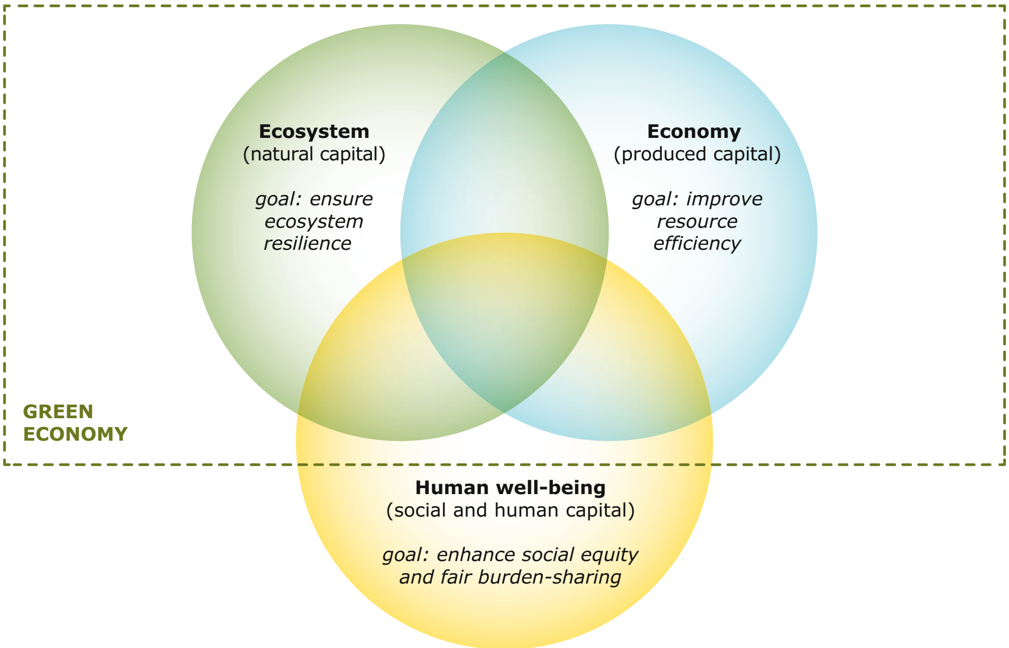
supports directly the resource-efficiency dimensions of green economy objectives.

The green economy approach marks a shift away from the short-term understanding of environmental considerations as a cost factor that constrains economic growth and impairs competitiveness, and instead views those considerations as fundamental to the long-term sustainability of economic output. It emphasises economic development that is within environmental limits (Sachverständigenrat für Umweltfragen (SRU), 2012) and that economic development of this nature will require a long-term shift of many aspects of economic activity. This shift would be sufficiently large so that it would also involve a cultural transition in terms of the things that societies value.

This perspective is discussed in more detail in recent UNEP studies (Fedrigo-Fazio and ten Brink, 2012; Mazza and ten Brink, 2012). In these, UNEP envisions the green economy as a final set of economic and social objectives, which are achieved by starting from present conditions, and assembling a series of building blocks. These include environmental compliance, new infrastructure, risk management, investment in natural capital, resource efficiency, and innovation.

([7]) See also for further information: AtKisson (2013), UNDESA (2012) and Fedrigo-Fazio and ten Brink (2012). The concept of the green economy only elicited minor policy interest in the late 1980s and early 1990s, in spite of works by economists that proposed this concept (see Pearce et al., 1989, and Jacobs, 1991).

Figure 1.1 The green economy according to the EEA



Source: EEA, 2012.

1.2 The financial crisis as a catalyst

In 2008, the onset of the financial and economic crisis presented policymakers and the public with a complex series of challenges. The array of interconnected problems included: a reduction in economic activity in most EU Member States; severe challenges of liquidity and solvency in the banking sector; an increase in unemployment and reduction in government tax revenues. Moreover, EU Member States themselves became increasingly indebted as they borrowed and spent to deal with these problems, breaching of one of obligations of the Maastricht Treaty ([8]) of keeping sound fiscal policies, with debt limited to 60 % of gross domestic product (GDP) and annual deficits no greater than 3 % of GDP. The wake of the crisis was also accompanied by the re-emergence of social inequality as a political issue of pressing importance, amid growing disparities in income and wealth between and within many European countries and globally. For example, data published by Eurostat ([9]) indicated an increase in the number of Europeans (EU-27) at risk of poverty or social exclusion from 114 million in 2009 to almost 123 million in 2012. This, in turn, led to the emergence of new political actors as well as *a weakening of democratic institutions and legitimacy of governance systems and political parties* (Vergragt, 2013).

The relationship between the economy and the environment emerges more clearly at times of perceived environmental stress and economic slowdown (Ekins and Speck, 2011). This crisis was no different, and its complexity arguably made the concept of a green economy more compelling. The very interconnectedness of the financial, political, and social problems occasioned by the crisis helped to promote an understanding of systemic challenges that also included environmental challenges such as climate change, biodiversity loss and ecosystem degradation (EEA, 2010).

In practical terms, this new focus on the green economy was most evident in the stimulus packages adopted across much of the developed world in 2008–2009. Initially many countries tried to tackle the economic crisis by using fiscal packages aimed at recovering the fall in economic growth through green economy measures (DB Climate Change

([8]) The Treaty on European Union (TEU) signed in 1992 by the members of the European Community.
([9]) http://epp.eurostat.ec.europa.eu/portal/page/portal/europe_2020_indicators/headline_indicators accessed 20 March 2014.

Advisors, 2009). The European Economy Recovery Plan (EREP) of the European Commission, launched at the end of 2008, asked EU Member States to invest funds amounting to EUR 200 billion (1.5 % of GDP) to boosting demand, while also respecting the Stability and Growth Pact with its restrictions on deficit spending (EC, 2008) — the overall estimated amount of fiscal stimulus packages amounted to 5 % of GDP (EC, 2009). One of the priorities for the investments funded by these programmes was given to energy, the environment, and eco-innovation — a broad term encompassing technology that reduces environmental damage or improves resource efficiency. These investments were also consistent with EU environmental and climate policy targets, such as the target to reduce greenhouse gas emissions by 20 % compared to 1990 levels, that is part of the EU's 20-20-20 strategy ([10]).

Fiscal stimulus packages with a green economy emphasis were also implemented in other regions of the world. Bowen et al. (2009) estimated that green measures accounted for 20 % of the value of stimulus packages globally, although EU Member States allocated just 14 % of their stimulus packages to green economy measures (Edenhofer and Stern, 2009 and Geels, 2013). Other sources estimated that the green economy components of the Member States' stimulus packages amounted to 10 % (HSBC, 2010) but this figure differs widely between EU Member States. For example, the share of green economy measures in Germany's stimulus is estimated at 13.2 % for the years 2009 and 2010, whereas the share allotted by the United Kingdom is comparatively smaller at 6.9 % for the period 2009–2012 (Edenhofer and Stern, 2009). Overall these percentages are small compared to Asian countries; for example, South Korea is estimated to have allocated 95 % of its stimulus packages to green investments, a sum that corresponded to about 3 % of its GDP (Barbier, 2010).

After 2009, fiscal recovery strategies centred on green economy objectives began to lose momentum. This slowdown in national-level political enthusiasm for stimulus in general (and the green economy in particular) was widespread by 2012 (Geels, 2013). The cause for this change was the growing pressure for fiscal consolidation and debt-reducing macro-economic policies.

However, the decline in popularity of green economy stimulus policies was also partly due to disappointments around their macro-economic impacts. Some of these disappointments may have been the result of exaggerated expectations on the income-multiplier effects of green economy investments. At the macro-economic level, the green economy was also unable on its own to address the crisis, which had many causes and was deeply-rooted in the overall unsustainable structure of our economies.

1.3 International initiatives

The crisis prompted many international-level initiatives to re-appraise long-established positions on certain aspects of economic growth and development. The belief in GDP and GDP growth as suitable indicators for measuring development and well-being came in for particular attention (UNECE, 2013).

The Commission on the Measurement of Economic Performance and Social Progress (Stiglitz, Sen and Fitoussi, 2009) reprised a long-standing tradition of critical thinking on GDP, and concluded [….] *the time is ripe for our measurement system to shift emphasis from measuring economic production to measuring people's well-being* [...] *measures of well-being should be put in a context of sustainability* [...] *measures of wealth are central to measuring sustainability. What is carried over into the future necessarily has to be expressed as stocks of physical, natural, human and social capital* (Stiglitz, Sen and Fitoussi, 2009).

Taking a similar line, the European Commission led the Beyond GDP Initiative (www.beyond-gdp.eu), and various statistical offices launched initiatives on revising national accounting in line with a well-being approach (EEA, 2013). In this work, statistical offices made use of the framework of environmental accounting provided by the *Revised Handbook of National Accounting: Integrated Environmental and Economic Accounting, Rev. 1* (SEEA 2003). This handbook was later revised to become the *SEEA Central Framework* of 2011 (UNSD, 2012), adopted by the United Nations Statistical Commission in 2012 as the first international standard for environmental economic accounting ([11]).

This conceptual debate within international organisations also focused on practical green economy measures that would reconcile economic development and environmental limits. One

([10]) See also: Cambridge Econometrics and Ecorys, 2011.
([11]) See http://unstats.un.org/unsd/envaccounting/seearev.

example is the increased visibility in policy circles of environmental taxation. Its advocates recognise that environmental taxes can be used to discourage environmentally damaging activities and behaviour, and promote these taxes as being the least distortive and most growth-enhancing that can be levied (OECD, 2010).

In 2011, the OECD published a strategy to help governments to seize opportunities for green growth (OECD, 2011). According to the strategy, green growth means fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which human well-being relies. It clarifies that greening the growth path of an economy depends on policy and institutional settings, levels of development, resource endowments and particular environmental pressure points. This means that there is no one-size-fits-all prescription for implementation. However, innovation plays a key role, as it can help to decouple growth from natural capital depletion. Existing production technology and consumer behaviour can only be expected to produce positive outcomes to a certain point, as there are limits beyond which depleting natural capital has negative consequences for overall growth. That frontier can be pushed outwards by innovation.

This more comprehensive view of growth and green economy was quickly embraced by international organisations and different policy fora, including UNEP's Green Economy Initiative (UNEP, 2011), which lists a set of enabling conditions. These include employing taxes and market-based instruments to shift consumer preference and promote green investment and innovation. The various initiatives culminated in the central role assigned to the green economy within the 2012 Rio+20 conference on sustainable development as *green economy in the context of sustainable development and poverty eradication* was one of pillars of the conference.

More recently, the World Economic Forum (WEF) conducted a survey in order to compile its 2014 Global Risks report (WEF, 2014). The survey points to the enduring relevance of the green economy. Respondents said that the areas they were most concerned about were financial crises in key economies, high unemployment, income disparities and environmental crises. This list shows that the green economy debate is still as important as it was five years ago. Moreover, the failure of global governance and the decline in trust in institutions were also identified in the 2014 Global Risk report as areas that must be taken seriously as they may be hindering the shift to a green economy.

2 The EU policy landscape

The EU is increasingly formulating its policies, including those for environment and climate, with reference to two time frames: 2020/2030 specific objectives and targets consistent with comprehensive policies such as the Europe 2020 strategy; and 2050 long-term visions and targets, mostly with a societal transition perspective (Box 2.1).

This chapter looks at this policy context and its relevance to the green economy, focusing primarily on major strategies, their objectives to 2020, and discusses the role of the green economy in each of them. The strategies all share the overall objectives underpinning the green economy as discussed in Chapter 1: combining enhanced resource efficiency with environmental resilience, while boosting prosperity and equity in society. These EU policy initiatives — the EU 2020 Strategy, the Roadmap to a Resource Efficient Europe, the Roadmap to a Low Carbon Economy, and the 7th Environment Action Programme — should also be seen in the context of the recent financial crisis and the urgent necessity to increase employment and return economies to growth.

2.1 The EU 2020 strategy

The Europe 2020 strategy (EC, 2010a) is a ten-year growth strategy that aims *to create the conditions for a more competitive economy with higher employment* ([12]). More specifically, it aims to deliver *growth that is: smart, through more effective investments in education, research and innovation; sustainable, thanks to a decisive move towards a low-carbon economy; and inclusive, with a strong emphasis on job creation and poverty reduction* ([13]).

Concretely, the Europe 2020 strategy established a set of ambitious targets (headline indicators) to be reached by 2020 in five key policy areas:

- employment: 75 % of the population aged 20–64 should be employed;
- research and development (R&D): 3 % of the EU's GDP should be invested in R&D;
- climate change and energy sustainability: the 20/20/20 climate and energy targets ([14]) should be met. These are: a 20 % reduction in total EU greenhouse gas emissions from 1990 levels; a 20 % increase in energy efficiency by 2020 from 1990 levels; and an increase in the share of EU energy consumption from renewable resources to 20 %;
- education: the share of early school leavers should be less than 10 %, and at least 40 % of the younger generation should have a tertiary degree;
- fighting poverty and social exclusion: 20 million fewer people should be at risk of poverty.

The 2020 strategy sees these targets as vital, stating as they do the long-term direction for making Europe's future sustainable as well as serving as benchmarks. Furthermore, they are closely related and self-reinforcing, and the EU foresees them being pursued through a mix of its own and national action.

The European Commission has also launched a number of flagship initiatives to catalyse progress in these areas. Two are particularly relevant to the green economy:

- The Flagship Initiative for a Resource-Efficient Europe (EC, 2011a) aims to decouple economic growth from the use of material resources — achieving growth using fewer resources than has historically been necessary to produce the same

([12]) See http://ec.europa.eu/europe2020/europe-2020-in-a-nutshell/priorities/index_en.htm.
([13]) See http://ec.europa.eu/europe2020/europe-2020-in-a-nutshell/priorities/index_en.htm.
([14]) The 20/20/20 targets were adopted by the European Council in March 2007. It foresees the possibility of raising the 20 % emissions reduction target to 30 %, if the conditions are right.

rate of growth; supports the shift towards a low carbon economy; increases the use of renewable energy sources; modernises the transport sector and promotes energy efficiency.

- Industrial policy for the globalisation era (EC, 2010b) '*sets out a strategy that aims to boost growth and jobs by maintaining and supporting a strong, diversified and competitive industrial base in Europe offering well-paid jobs while becoming more resource efficient*' ([15]). The economic importance of the industrial sectors is obvious considering that they account for 80 % of Europe's exports and each job in the manufacturing industry creates 0.5–2 jobs in other sectors (EC, 2014).

Relevant to this combination of industrial and environmental objectives, is the European Commission's aspiration of increasing the share of manufacturing to as much of 20 % of EU GDP by 2020 — an objective that can contribute to an 'industrial renaissance' in Europe (EC, 2014).

Increasing the share of the economy devoted to a sector that is typically seen as environmentally damaging may seem odd at first glance. But reversing the structural changes to the European economy of recent decades — by augmenting the manufacturing sector's share in economic output — could sustain the transition to a green economy. This is because the manufacturing sector is more dynamic than the service sectors, with a greater capacity for increasing labour productivity and resource efficiency. Moreover, when viewed from a 'consumption footprint' perspective, that is by considering all the emissions and environmental damage caused by the products we consume (Box 4.1) by including the import-export development of EU economies, industry as a whole is not more resource intensive than service sectors (Chapter 4).

The European Commission's objective of increasing manufacturing to account for 20 % of economic output in 2020 could, therefore, bring multiple benefits. In the short term, however, it also poses important risks, particularly in terms of achieving the EU's greenhouse gas emissions reduction targets. Reconciling the EU's manufacturing and climate targets for 2020 will necessitate a major increase in the resource efficiency of industry, a fact reflected in the EU's 2020 innovation policy (Chapter 5).

2.2 The Roadmaps to a Resource Efficient Europe and to a Low-Carbon Economy

The Flagship Initiative for a Resource Efficient Europe, included in Europe 2020, led to two major roadmaps.

The Roadmap to a Resource Efficient Europe (EC, 2011b), launched in 2011, sets objectives for 2020 in a wide range of areas — sustainable consumption and production, waste, research and innovation, the elimination of environmentally harmful subsidies, ecosystem services, biodiversity, minerals and metals, water, air, land and soil, marine resources, food and drink, buildings, and mobility. Each objective indicates action to be taken at all levels of society by Member States and at EU level ([16]).

The second, also released by the Commission in 2011, is the Roadmap for moving to a Competitive Low-Carbon Economy (EC, 2011c). This stipulates that, by 2050, the EU should cut its greenhouse gas emissions to 80 % below 1990 levels through domestic reductions alone and hence enable the EU to deliver reductions in line with the agreed 80–95 % target. It sets out incremental targets along what it argues is a cost-effective pathway to this goal. For example, it envisions reductions of the order of 40 % by 2030 and 60 % by 2040. The Roadmap for moving to a Competitive Low-Carbon Economy also shows how the main sectors responsible for Europe's emissions — power generation, industry, transport, buildings and construction, and agriculture — can make the transition to a low-carbon economy in a cost-effective way ([17]).

2.3 The 7th Environment Action Programme

A green economy perspective can also be found in the 7th Environment Action Programme (7th EAP), which has the subtitle *Living well, within the limits of*

([15]) See http://ec.europa.eu/enterprise/policies/industrial-competitiveness/industrial-policy/index_en.htm.
([16]) The Roadmap to a Resource Efficient Europe illustrates the concept of green economy through reference to the EEA diagram (Figure 1.1).
([17]) The Energy Roadmap 2050 (EC, 2011d) is also relevant in the context of the EU's greenhouse gas emissions-reduction commitment. The roadmap investigates the implications of the emissions-reduction objective while safeguarding security of energy supply and competitiveness.

our planet (EC, 2013). The 7th EAP was adopted by the Council of the European Union and the European Parliament in November 2013 and seeks to guide environment policy up to 2020. It aims to enhance Europe's ecological resilience and transform the EU into an inclusive and sustainable green economy. To this end, the 7th EAP recognises nine priority objectives with the first three as thematic objectives and the others as establishing an enabling framework supporting effective action:

1. to protect, conserve and enhance the European Union's natural capital;

2. to turn the European Union into a resource-efficient, green and competitive low-carbon economy;

3. to safeguard the European Union's citizens from environment-related pressures and risks to health and well-being;

4. to maximise the benefits of the European Union environment legislation by improving implementation;

5. to increase knowledge and evidence base for the European Union environment policy;

6. to secure investment for environment and climate policy and account for the environmental externalities;

7. to improve environmental integration and policy coherence;

8. to enhance the sustainability of the European Union's cities;

9. to increase the European Union's effectiveness in addressing international environmental and climate-related challenges.

The 7th EAP, thus, speaks of *an inclusive green economy that secures growth and development, safeguards human health and well-being, provides decent job, reduces inequalities and invests in, and preserves biodiversity, including ecosystem services it provides (natural capital), for its intrinsic value and for its essential contribution to human well-being and economic prosperity* (EC, 2013).

Recognising the importance of policy integration discussed earlier, the 7th EAP speaks of the necessity of integrating environmental issues into other policy areas, such as energy, transport, trade, economy and industry and employment (EC, 2013).

In order to make the nine goals more concrete and measurable, the 7th EAP has also formulated specific objectives so that by 2020:

1. the EU will have met its 2020 climate and energy targets and will be working towards reducing 2050 greenhouse gas emissions by 80–95 % compared to 1990 levels, as part of a global effort to limit the average global temperature increase to less than 2 °C;

2. the overall environmental impact of EU industry in all major industrial sectors will have been significantly reduced, and resource efficiency increased;

3. the overall environmental impact of production and consumption will have been reduced, in particular in the food, housing and mobility sectors;

4. waste will be safely managed as a resource, waste generated per person will be in absolute decline, energy recovery from waste limited to non-recyclable materials, and landfilling of recyclable and compostable materials effectively eradicated;

5. water stress in the EU will have been eradicated or significantly reduced.

The long-term visions described in several EU policies in recent years represent a major innovation in thinking and sets challenges for how policy action is developed in the coming decades. Almost all of the established activities in the EU are focused on short- and medium-term (2020) targets and objectives. Whilst many of these will have continued relevance for 2050 visions, there is a desire to avoid a lock-in to 2020 and instead put in place a balanced approach to policy actions 2015-2020-2030-2050.

A key element of European policy is the principle of environmental integration as it is a general principle of EU policy pursuant to Article 11 of the Consolidated Version of the Treaty on the Functioning of the European Union ([18]). The challenge of connecting different policy areas to achieve a particular goal is not unique to

([18]) See http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:12012E/TXT.

Box 2.1 Selected visions to 2050

*'Europe faces a **moment of transformation**. The crisis has wiped out years of economic and social progress and exposed structural weaknesses in Europe's economy. In the meantime, the world is moving fast and long-term challenges — globalisation, pressure on resources, ageing — intensify. The EU must now take charge of its future. 'Europe can succeed if it acts collectively, as a Union. We need a strategy to help us come out stronger from the crisis and turn the EU into **a smart, sustainable and inclusive economy** delivering high levels of employment, productivity and social cohesion. Europe 2020 sets out a vision of Europe's social market economy for the 21st century.'*

Europe 2020 Strategy

*'In 2050, **we live well, within the planet's ecological limits**. Our prosperity and healthy environment stem from an innovative, circular economy where nothing is wasted and where natural resources are managed sustainably, and biodiversity is protected, valued and restored in ways that enhance our society's resilience. Our low-carbon growth has long been decoupled from resource use, setting the pace for a global safe and sustainable society.'*

EU 7th Environment Action Programme

*'By 2050 the EU's economy has grown in a way that **respects resource constraints** and planetary boundaries, thus contributing to global economic transformation. Our economy is competitive, inclusive and provides a high standard of living with much lower environmental impacts. All resources are sustainably managed, from raw materials to energy, water, air, land and soil. Climate change milestones have been reached, while biodiversity and the ecosystem services it underpins have been protected, valued and substantially restored.'*

EU Roadmap to a Resource Efficient Europe

*'People's well-being, industrial competitiveness and the overall functioning of society are dependent on **safe, secure, sustainable and affordable energy**. The energy infrastructure which will power homes, industry and services in 2050, as well as the buildings which people will use, are being designed and built now. The pattern of energy production and use in 2050 is already being set. The EU is committed to reducing greenhouse gas emissions to 80–95 % below 1990 levels by 2050 in the context of reductions by developed countries as a group. [….]. The EU policies and measures to achieve the Energy 2020 goals and the Energy 2020 strategy are ambitious. They will continue to deliver beyond 2020 helping to reduce emissions by about 40 % by 2050. They will however still be insufficient…as only less than half of the de-carbonisation goal will be achieved in 2050. […]'*

EU Energy Roadmap 2050

*'The **transition towards a competitive low carbon economy** means that the EU should prepare for reductions in its domestic emissions by 80 % by 2050 compared to 1990.'*

EU Roadmap for moving to a Competitive Low-Carbon Economy

*'Still, the **transport system** is not sustainable. Looking 40 years ahead, it is clear that transport cannot develop along the same path. If we stick to the business as usual approach, the oil dependence of transport might still be little below 90 %, with renewable energy sources only marginally exceeding the 10 % target set for 2020. CO_2 emissions from transport would remain one third higher than their 1990 level by 2050. Congestion costs will increase by about 50 % by 2050.'*

Box 2.1 Selected visions to 2050 (cont.)

'The challenge is to ***break the transport system's dependence on oil*** *without sacrificing its efficiency and compromising mobility […] In practice, transport has to use less and cleaner energy, better exploit a modern infrastructure and reduce its negative impact on the environment and key natural assets like water, land and ecosystems.'*

'Action cannot be delayed. Infrastructure takes many years to plan, build and equip — and trains, planes and ships last for decades — the ***choices we make today will determine transport in 2050****. We need to act on a European level to ensure the transformation of transport is defined together with our partners rather than determined elsewhere in the world.'*

EU Roadmap to a Single European Transport Area —
Towards a competitive and resource efficient transport system (White Paper)

'By 2050, European Union ***biodiversity*** *and the* ***ecosystem services*** *it provides — its natural capital — are protected, valued and appropriately restored for biodiversity's intrinsic value and for their essential contribution to human wellbeing and economic prosperity, and so that catastrophic changes caused by the loss of biodiversity are avoided.'*

Our life insurance, our natural capital — an EU biodiversity strategy to 2020

'We, the heads of State and Government and high level representatives, having met at Rio de Janeiro, Brazil, from 20–22 June 2012, with full participation of civil society, renew our commitment to sustainable development, and to ensure the promotion of ***economically, socially and environmentally sustainable future*** *for our planet and for present and future generations.'*

UN Resolution — The Future We Want

environmental policy. Many social and political challenges are multi-faceted and cover different policy areas. This makes it difficult to effectively address a problem using a single sector policy. For this reason, the European Union and Member States are increasingly focusing on policy integration: making sure that all sectoral policies are aligned and working towards a common goal. The three policy initiatives above all promote this goal of policy integration at the European level.

3 Environment and climate policies: are we on track?

3.1 Specific policy targets and the green economy

The green economy concept may also be linked to more immediate, concrete and specific sectoral policies and EU legislation ([19]). There is already an extensive set of policies for the environment and major sectors of economic activity, including objectives for resource efficiency and ecosystem resilience ([20]). In particular, by mid-2013, a total of 63 legally binding targets and 68 nonbinding objectives had been identified across nine broad environmental policy areas (EEA, 2013a). Many of the binding targets in the areas of energy, air pollution, transport emissions and waste are set for 2015 and 2020. The great majority of non-binding objectives are set for 2020, mainly in the areas of resource efficiency and sustainable consumption and production (SCP). Biodiversity and land use are also included in these objectives. The process of achieving these targets and objectives can be seen as a pathway to a green economy in Europe (see ETC/SCP, 2013).

Is the EU on track to meet these targets? Although improvements can be seen in resource use and resource efficiency in the EU (ETC/SCP, 2013), the pace of change is slow compared to the demanding targets and objectives set by EU policies. Indicators of resource efficiency show a steady but slow improvement during the 2000s. This is in contrast to the developments in the early 1980s or the 1990s when there were structural breaks or step-changes in the trend of efficiency improvements. Most recent developments show a continuation of the well-established trends that started many years ago. In some cases, the slowdown in economic activity caused by the global crisis has had an effect on trends, bringing them closer to long-term targets/objectives than they had been before the crisis (Section 3.3).

3.2 The trends before the crisis

In order to better characterise current trends, structural-break analysis ([21])— econometric techniques for detecting a stable change in the trend line of an indicator (Annex 1) — have been applied to selected indicators of resource use and resource efficiency in major energy and environmental areas: energy consumption, greenhouse gas emissions, air pollution, material flows, and waste. Looking at data for the period before the financial crisis, prior to 2008, many indicators showed structural breaks in the early 1980s or during the 1990s. Few indicators showed breaks in their trend lines during the 2000s (Table 3.1).The lack of recent structural breaks in trend lines, whether positive or less positive, simply suggests that desirable changes are taking place too slowly.

In the case of energy, for example, a challenging gap has emerged between the projected level of primary energy consumption in 2020 and the EU target of a decrease of 20 % by the same year. For greenhouse gas emissions, the EU-27 will meet the 2020 target, but the strategic targets for 2030 and 2050 are likely to be difficult to achieve (EEA, 2013b) and will require a radical change in efficiency trends.

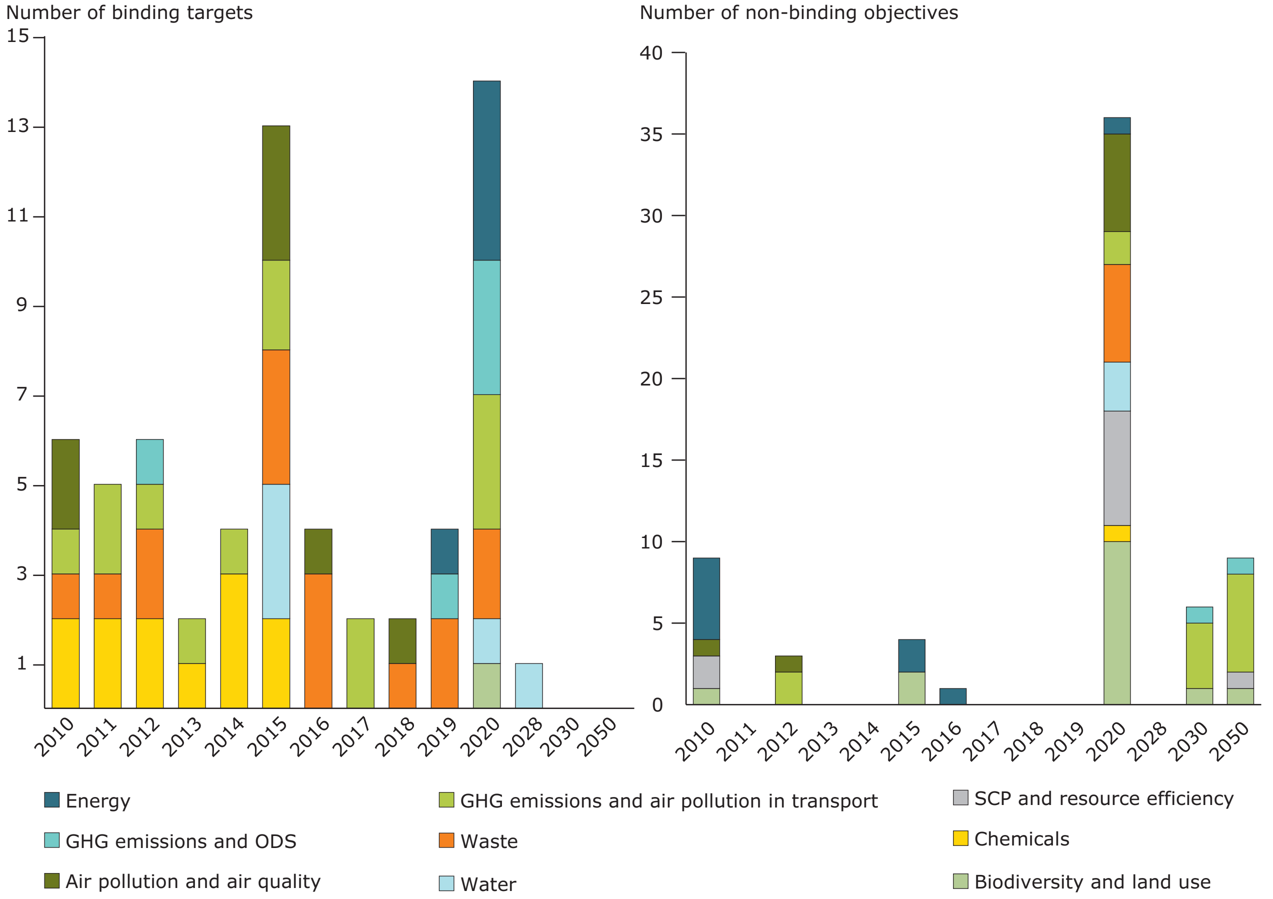
Emissions of air pollutants have been decreasing steadily for decades, but a further acceleration of the downward trend is needed to achieve the targets set by EU policies (EEA, 2013c).

([19]) These include the Energy Performance of Buildings Directive, 2002/91/EC; the Directive on Renewable Energy, 2009/28/EC; the EU Forest Action Plan adopted in 2006; the White Paper on EU transport policy from now to 2050, COM/2011/144 final; and the waste streams directives, in particular Directive 2006/66/EC on batteries and accumulators; Directive 2000/53/EC on end-of-life vehicles (ELV); Directive 2002/96/EC on waste electrical and electronic equipment (WEEE); Directive 2002/95/EC restricting the use of hazardous substances in electrical and electronic equipment (EEE); Directive 94/62/EC, as amended by Directive 2004/12/EC, on packaging and packaging waste, which can be quoted as examples of relevant sectoral tools; see Mazza and ten Brink, 2012.

([20]) The nine areas considered in EEA (2013a) are: energy; greenhouse gas (GHG) emissions and ozone-depleting substances; air quality and air pollution; transport sector emissions of greenhouse gases and air pollutants; waste; water; sustainable consumption and production (SCP); chemicals; biodiversity and land use.

([21]) The methodology of structural break analysis is described in Annex 1.

Figure 3.1 Objectives and targets of EU environmental policies



Source: EEA, 2013a.

Projections show a continuation of the present trend of increasing volumes of municipal solid waste (MSW) generation, but decreasing amounts being sent to landfills, as ever more waste is incinerated or recycled (EEA, 2013d). The policy target of having a deceasing trend of waste generation per person by 2020 seems difficult to achieve due to the limitations of waste-prevention policies. The policy target of having zero landfill in 2020 also seem very challenging given the projected gap between the target and the projected trend of waste going to landfill.

The lack of radical changes in trends can have implications for the shift to a green economy. Considering the projections based on trends before the crisis (Annex 1), the main policy objectives and targets are likely to be very difficult to achieve.

Table 3.1 Summary of structural breaks in the indicator trend prior to 2008

Series	Time frame of data	Years of break (change in pattern/slope)
Total primary energy supply EU-27	1960–2008	1967–1971; 1974
Net import of primary energy EU-27	1960–2008	1971
Share of fossil fuel in energy consumption EU-27	1960–2007	1972–1991
GDP productivity of energy use EU-27	1980–2007	1997
Total CO_2 emissions EU-27	1970–2008	1980–1981; 1986–1990
CO_2 emission intensity of energy use Euro Area	1990–2007	1995–1996
CO_2 emission intensity of GDP Euro Area	1980–2007	1993–1994; 1996–1997
Tropospheric ozone potential EU-27	1990–2007	None
Acidifying potential EU-27	1990–2008	None
Particulate matter EU-27	1990–2007	2001
Domestic material consumption EU-15	1970–2008	1994; 1997–2000
Domestic material consumption EU-12	1992–2007	2001
Material productivity (on GDP) EU-15	1970–2008	None
Material productivity (on GDP) EU-12	1992–2007	None
MSW generation per capita EU-27	1995–2008	None
MSW landfilling per capita EU-27	1995–2008	2001
MSW incineration per capita EU-27	1995–2008	None

Source: Adapted from ETC/SCP, 2011.

3.3 The effect of the crisis on trends

Has the global economic crisis changed the projections for any of these trends? To answer this, projections using data from before the crisis, up to 2007 or 2008, can be compared with those using data that include 2009–2011, two mid-crisis years.

For most of indicators in the sectors considered, projections using data including the economic crisis years show that the corresponding EU policy targets for 2020 may still be difficult to achieve without new policy initiatives. The exceptions to this are:

1. greenhouse gas emissions, for which the projection, including the 2009–2011 figures, places the EU in a position of meeting and even surpassing the targets for 2020; and

2. non-methane volatile organic compounds (NMVOC), for which the projection, including the 2009–2011 data, foresees the EU meeting the policy target for 2020 — a change from the projections made before the crisis, which suggested that the EU would miss the target.

However, in four cases — sulphur oxides (SO_X), particulates ($PM_{2.5}$), MSW recycling and MSW land-filling — the difference between the projection including the two crisis years and the 2020 target is larger than the difference between the projection based only on data before the crisis and that target. These results suggest that although the crisis, by depressing the economic drivers of resource use and emissions, pushed energy and some environmental indicators to approach the 2020 policy targets, the 'economic crisis effect' was not enough to achieve the targets in most cases, and in other cases has even increased the distance to 2020 policy targets.

For the same parameters, intensity indicators have been elaborated that show the amounts of energy, emissions, and waste per unit of GDP. These represent efficiency (gains) at the macro level and allow us to see whether resource efficiency improved or worsened in the two mid-crisis years (2009–2011). For the totality of sectors considered, the indicators of resource intensity (efficiency) did not further improve their long-term trends during the mid-crisis years and slightly worsened in some cases — waste land-filling and recycling and some air pollutants). Boxes 3.2 and 3.3 present the results of the analysis for energy consumption and waste landfilling.

Therefore, the crisis did not result in real and long-lasting resource efficiency improvements in the EU economic and technological system. During the height of the crisis there was a decline in environmental pollution and a reduction in resource use in absolute terms, but this was, at least in part, the consequence of reduced economic activity. More important is whether there was a change in intensity (efficiency), which was not influenced by the collapse in GDP. The energy and waste intensities of the EU-27 (Figures 3.3 and 3.5) suggest that the long-term trend of intensity did not change during the crisis.

Box 3.2 Energy efficiency

Figure 3.2 shows projections for primary energy consumption (PEC) in the EU-27 to 2030. In order to meet the target of a 20 % improvement in energy efficiency by 2020 PEC would have to be 1 474 million tonnes of oil equivalent (Mtoe), which is 20 % below the business as usual (BAU) level for 2020 according to the European Commission's calculations based on the PRIMES model (baseline 2007) ([22]).

Based only on data from before the economic crisis, up to 2008, the projection for energy consumption by the European economy in 2020 (1 699 Mtoe) is 15 % above the target. Adding the data from two mid-crisis years, 2009–2011, the projection for 2020 is around 1 637 Mtoe, still above the 2020 target, but with a reduction from 15 % to 11.1 %. The expectation, therefore, is that, under the assumptions underpinning the ETC/SCP methodology (i.e. future policy effect similar to that observed ex post in the data), the target will not be achieved. This result is consistent with the results of model-based forecasts from both PRIMES-baseline 2007 and PRIMES–baseline 2009 (EEA, 2013).

Figure 3.2 Projections for primary energy consumption in the EU-27

Note: MA: moving average.

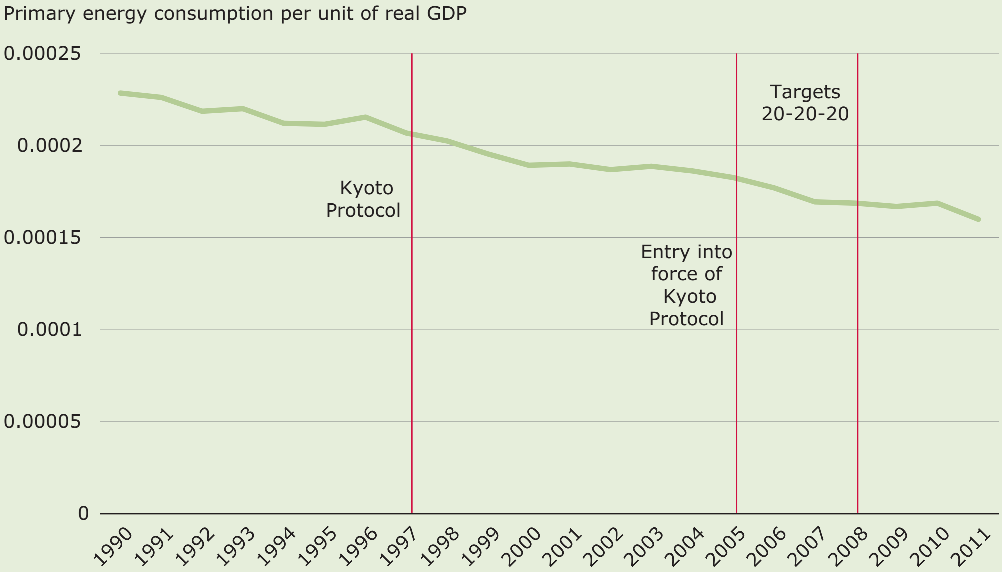
Source: ETC/SCP elaborations on Eurostat data.

Figure 3.3 shows energy intensity (PEC) per unit of real GDP) in the EU-27 for 1990–2011 ([23]). The crisis seems not to have affected the long-term falling trend: the decline slowed in 2007–2010 and then recovered in 2011. As a consequence, the crisis did not worsen energy efficiency on the macro scale but neither did it improve it. Therefore, the strong decrease of PEC in 2009–2011 (Figure 3.2) was due not to energy efficiency improvements but mainly to decreasing economic activity.

([22]) For further details on the official calculation of the target see ETC/SCP (2011) and EEA (2013a).
([23]) To have a consistent series for GDP in real terms from 1990, the World Bank data on GDP at 2000 dollars for EU-27 are used as the denominator for this and other intensity indicators in this section.

Box 3.2 Energy efficiency (cont.)

Figure 3.3 Energy intensity (PEC per unit of real GDP; constant 2000 prices) in the EU-27



Source: ETC/SCP elaboration on Eurostat and World Bank data.

The challenging picture for EU environmental and energy policy implementation, as emerging from ETC/SCP (2011) and EEA (2013a), therefore seems to have been unaffected by the crisis.

Important new targets for climate change and renewable energy have recently been proposed by the European Commission. These proposals aim to reduce greenhouse gas emissions by 40 % by 2030, and to increase the share of renewable energy in final consumption to 27 % by 2030 ([24]). Both of these targets call for stronger action for faster improvement in trends ([25]).

Scenarios created by other European institutions ([26]) use different modelling approaches, in particular macro-econometric models. These model-based scenarios include assumptions on the possible positive effects of policies and technologies in the coming years that are not taken into account in our analysis. However, these same models also highlight difficulties in achieving the EU environmental policy targets and therefore offer interesting insights.

([24]) The reduction of GHG emissions by 40 % by 2030 had already been discussed as a non-binding target by the European Commission in 2011 (EC, 2011). In the document 'A policy framework for climate and energy in the period from 2020 to 2030' (EC, 2014a) the EC invites the Council and the European Parliament to endorse the proposed targets. In particular, the Commission invites the Council and the European Parliament to agree by the end of 2014, that the EU should pledge a greenhouse gas emissions reduction of 40 % by early 2015. EU leaders agreed at the European Council meeting on 20–21 March 2014 to take a final decision on the framework in October 2014 at the latest. See http://ec.europa.eu/clima/policies/2030/index_en.htm.

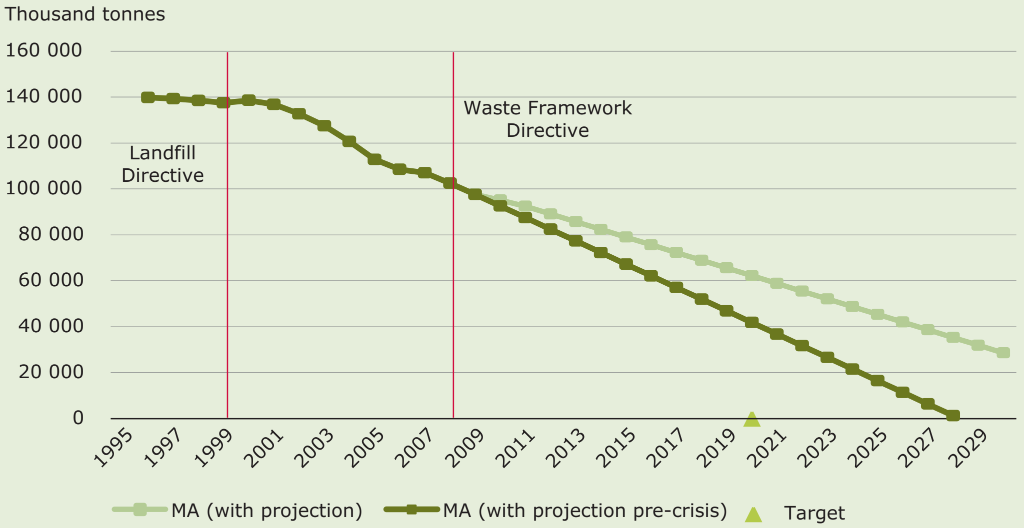
([25]) The main conclusions from EEA (2013b) are: 'Looking beyond 2020, the aggregation of national projections indicates that EU GHG emissions are expected to continue to decrease, although at a slower rate. With the current existing measures, GHG emissions would decrease by only one percentage point between 2020 and 2030 (reaching a level 22 % below 1990). Implementing the additional measures currently planned by Member States would reduce emissions in the period 2020 to 2030 to 28 % below 1990 levels. These anticipated reductions between 2020 and 2030 are largely insufficient when compared to the cost effective 2030 milestone of reducing EU emissions by 40 % indicated by the European Commission in March 2013. The EU's commitment to achieving a reduction of emissions by 80 % to 95 % by 2050 compared to 1990, as agreed by European heads of state and government, will require enhanced efforts from Member States'.

([26]) For example, the models used in EU Energy, Transport and GHG Emissions Trends to 2050 reference scenario 2013 published by DG Energy in 2014 (EC, 2014b).

Box 3.3 Waste sent to landfill

Figure 3.4 shows the projections for municipal solid waste (MSW) disposed in landfill for the EU-27 up to 2030. The non-binding target of near zero landfill, i.e. virtually eliminated, by 2020 was adopted in the Roadmap to a Resource Efficient Europe. The projection based on data from before the economic crisis is that 42 million tonnes of municipal solid waste will be land-filled in 2020. When the data for 2009–2011 are included, the projected amount is more than 62 million tonnes. The increase of the gap is due to the production of MSW not falling as fast during the economic crisis as it did before.

Figure 3.4 Projections for municipal solid waste (MSW) to landfill in the EU-27

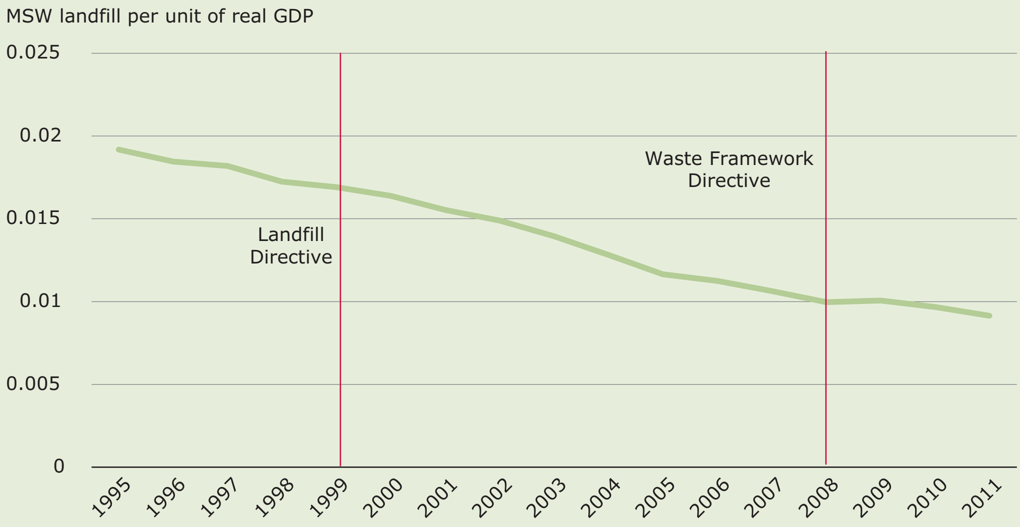


Note: MA: moving average.

Source: ETC/SCP elaboration on Eurostat data.

The graph of total MSW to landfill per unit of GDP in the EU-27 for 1995–2011 (Figure 3.5) shows that the trend of the efficiency indicator, although following its positive longer term trend, worsened slightly for 2009–2011, slowing the rate of decrease.

Figure 3.5 Municipal solid waste (MSW) to landfill per unit of real GDP (constant 2000 prices) in the EU-27



Source: ETC/SCP elaboration of Eurostat and World Bank data.

3.4 Main conclusions

- There is a policy push in Europe to foster a shift to a green economy. This is embodied in the main growth and development strategies of the EU, such as the Europe 2020 strategy, as well as in a large set of specific environment, climate and sectoral policies.

- However, the slow pace of change observed means that the major objectives and targets for 2020 and beyond are unlikely to be met without additional effort and more radical re-orientation of the European economic system.

- Observed incremental changes in resource efficiency indicate significant environmental improvements, often in the form of 'relative decoupling', but the crucial reversal of the trend has not occurred. Relative decoupling of resource use from economic growth will not guarantee long-term sustainability (EEA, 2012).

- Indicator trends suggest that the global economic and financial crisis have not resulted in improvements in resource efficiency; in some areas it has led to a decrease in efficiency.

- Projections based on past trends show that transformation to a green economy requires a departure from the business-as-usual economic paradigm, which is socially, environmentally and economically unsustainable. The process requires long-term vision and targets that include the societal transition perspective (EEA, 2014).

4 The changing structure of the EU economy: from manufacturing to services

While economic activity in general — as represented by such indicators as GDP — puts pressure on resources and the environment, economies with equal GDPs can place dramatically different demands on ecosystems because of the way they are structured. The structure of an economy is defined by factors such as the mix of industries, the level of technological development and the way the economy trades with other countries. Changes in structure, while slow, are resilient to normal business cycles and even crises. While GDP trends are important in driving most environmental indicators, structural change of the economy is a more powerful force for steadily improving environmental performance and resource efficiency. The green economy itself can be seen a structural transformation of the economic (and social) system. The macro-level trends underpinning the shift to a green economy can therefore first be examined at the level of the economic structure and its change.

4.1 The contribution of services to a green economy

The share of services in the European economy has been increasing steadily. In 2012, service sectors accounted for 73.6 % of gross value added (VA) in the EU-27, up from 69.8 % 2000 ([27]). The economic and financial crisis hit manufacturing more severely than service industries (EC, 2013), its share falling from 18.5 % in 2000 to 14.5 % in 2009, but it has subsequently increased slightly, to 15.1 % in 2013.

The shift towards an ever-increasing share of services in the economy is often seen as favourable to the environment since services generally create lower direct pressures on natural resources. However, this positive service effect cannot be taken for granted and there are a number of uncertainties about the real meaning of the transition to services for a green economy transition.

The first stems from the evidence that there are usually fewer opportunities for innovation and efficiency gains in service than in industrial sectors. This can be linked to the 'cost disease' theory (Baumol, 1967; Schettkat and Yocarini, 2006), according to which there is a systematic difference between productivity gains in services (lower) and industry (higher). Thus, although services have lower direct environmental pressures than industry, there may be little room for strong innovation or eco-innovation in many service sectors. In this case, given that services already account for 73.6 % of EU VA, a large burden of further significant efficiency gains, as demanded by the green economy, will fall on the remaining small industrial share of the economy.

A second uncertainty stems from the fact that many services require large amounts of industrial inputs. Therefore, while the direct pressure of services may be low, their overall pressure may be higher when the industrial inputs incorporated in their provision are taken into account. Thus a further shift to a service economy may be less green when seen from an integrated macro-level perspective.

A third problem is that the change in the production structure towards services has not been accompanied by a similar change in the structure of final demand (consumption), which is changing more slowly. Industrial goods formerly produced in the EU are increasingly produced elsewhere, imported and consumed in the EU. The further shift to a service economy therefore increasingly highlights a possible divergence between the footprint of domestic production within the EU and that of EU consumption at the global scale through trade-embodied pollution.

Changes in the economic structure can also have social and employment implications, an area of increasing relevance in current economic discussions. Data show that a shift of employment

([27]) Eurostat data (National Accounts by 10 branches — aggregates at current prices (nama_nace10_c)).

from the higher-paid manufacturing sector towards the lower-paid service sector results in a reduction in earnings, as reported for the United Kingdom (Taylor et al., 2014).

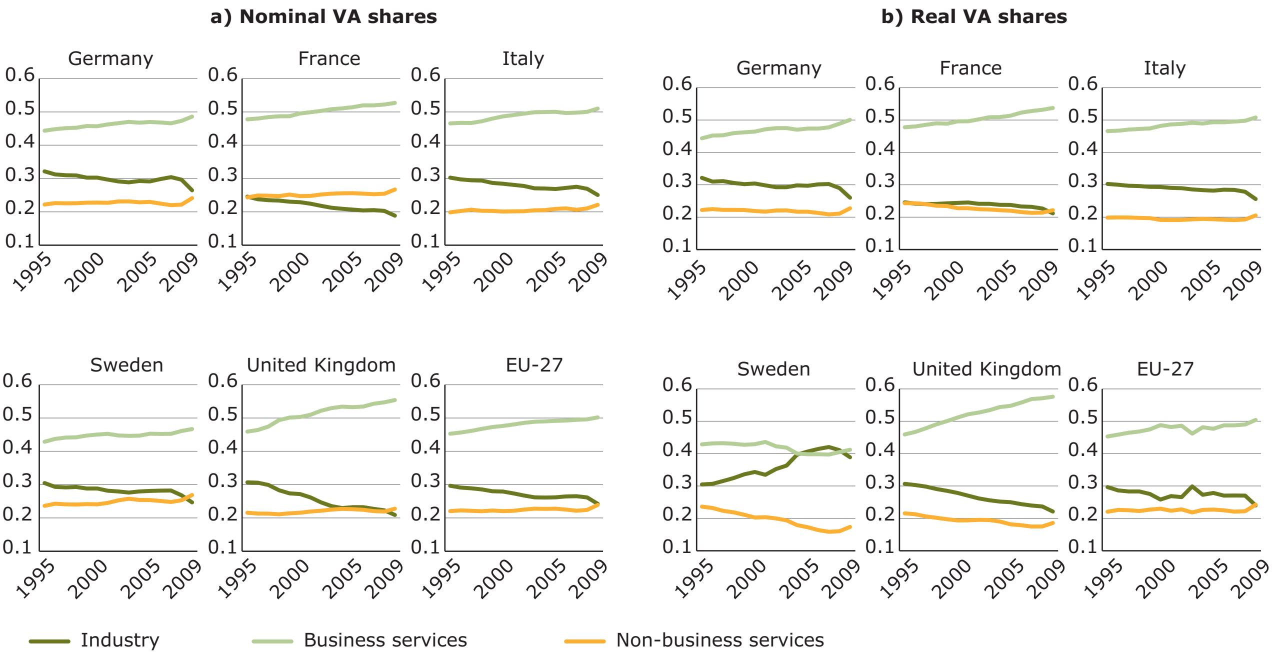
4.1.1 *Structural change and 'cost disease' of services*

The environmental implications of structural change towards services can be explored within an environmentally extended input-output (EEIO) framework, using carbon dioxide (CO_2) emissions as the environmental extension (Annex 2). The focus is on five EU Member States — France, Germany, Italy, Sweden and the United Kingdom — and on the EU-27 as a whole ([28]).

The contribution of industry, business services and non-business services to aggregate VA, in nominal and real terms is shown in Figure 4.1 (base year for price deflation is 1995) ([29]). In France, the United Kingdom and Italy there has been a smooth and continuous decline in the contribution of industrial sectors to nominal VA. In these countries, there has been an increasing contribution to VA by business service sectors while the trend of non-business service sectors has been generally flat. In contrast, the nominal contribution of industrial sectors to VA in Germany, Sweden and the EU-27 as a whole fell up to the early 2000s before bottoming out, and then fell again with the beginning of the economic crisis ([30]).

However, when looking at shares of VA in *real* terms, deflating for sector-specific price indices, the picture changes. The contribution of non-business services fell markedly in France, the United Kingdom and Sweden. The fall in the contribution of industry sectors in France is now much less clear, and there

Figure 4.1 Nominal and real value added shares (share of total)



Source: Authors based on the WIOD database.

([28]) The database of reference is WIOD (World Input Output Database), which reports single country and worldwide input-output tables for 40 countries for the period 1995–2009 together with other economic and environmental accounts. More information about WIOD is available on http://www.wiod.org. See also Annex 2.

([29]) Based on the Nace 1.1 classification, industry (Indus) includes Mining and quarrying (C), Manufacturing (D), Electricity, gas and water supply (E) and Construction (F). Business services (B Serv) include Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods (G), Hotels and restaurants (H), Transport, storage and communication (I), Financial intermediation (J) and Real estate, renting and business activities (K). Non-business services (NB Serv) include Public administration and defence; compulsory social security (L), Education (M), Health and social work (N), Other community, social and personal service activities (O) and Activities of households (P).

([30]) In this analysis the main focus is on the evolution of industry and services without a specific focus on agriculture, forestry, and fishery. This very important sector of the green economy has a very small and stable share of employment and value added and its changes do not significantly influence major structural changes of the EU economy.

has been a strong increase in the contribution by industry sectors in Sweden. The real share of VA accounted for by industry sectors in the EU-27 as a whole remained somewhat stable.

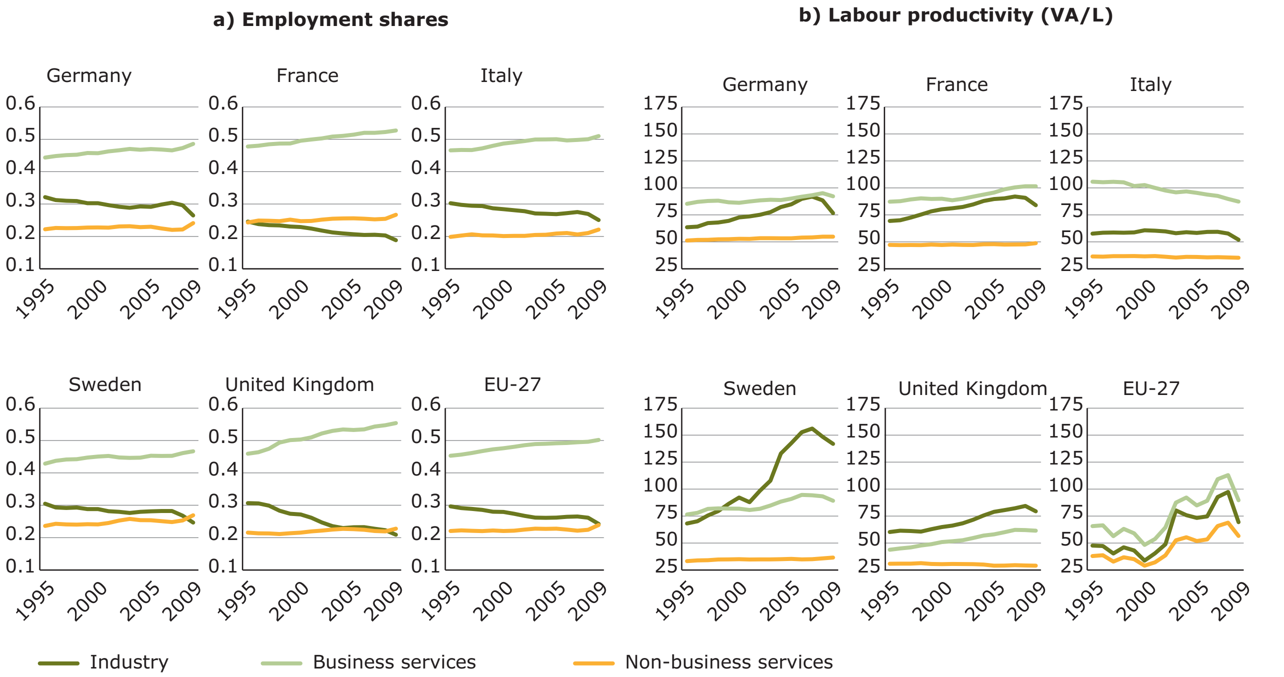
The reason for the difference between nominal and real figures is the different dynamics of prices in industry and services. In all five countries, price growth was faster than average in non-business services while, other than in Germany and the United Kingdom, inflation in industry was the lowest.

Figure 4.2 shows employment share by macro sector and real labour productivity (real VA per employee) between 1995 and 2009. In all countries employment shifted away from industrial to service sectors, particularly in Germany and the United Kingdom.

Over the period, labour productivity grew far faster in industry than in business services in the EU-27 and the countries considered, except in the United Kingdom. A reduction of real labour productivity in business services was seen in Italy. In all countries, labour productivity in non-business services has been stagnating.

The evolution of domestic final demand [31] in nominal and real terms by macro-sector is shown in Figure 4.3. No significant change occurred in France, Germany, Italy, Sweden or the EU-27 as a whole for 1995–2007, the years preceding the crisis. The apparent rapid shift away from industrial goods in the United Kingdom in nominal terms was less pronounced when considering real figures, that is when consideration the fact that there was very little inflation in industrial goods in this period is taken into account. In the year of the crisis (2008–2009) there was a strong reduction in the share of final demand for industrial goods, both in real and nominal terms, in all countries except France.

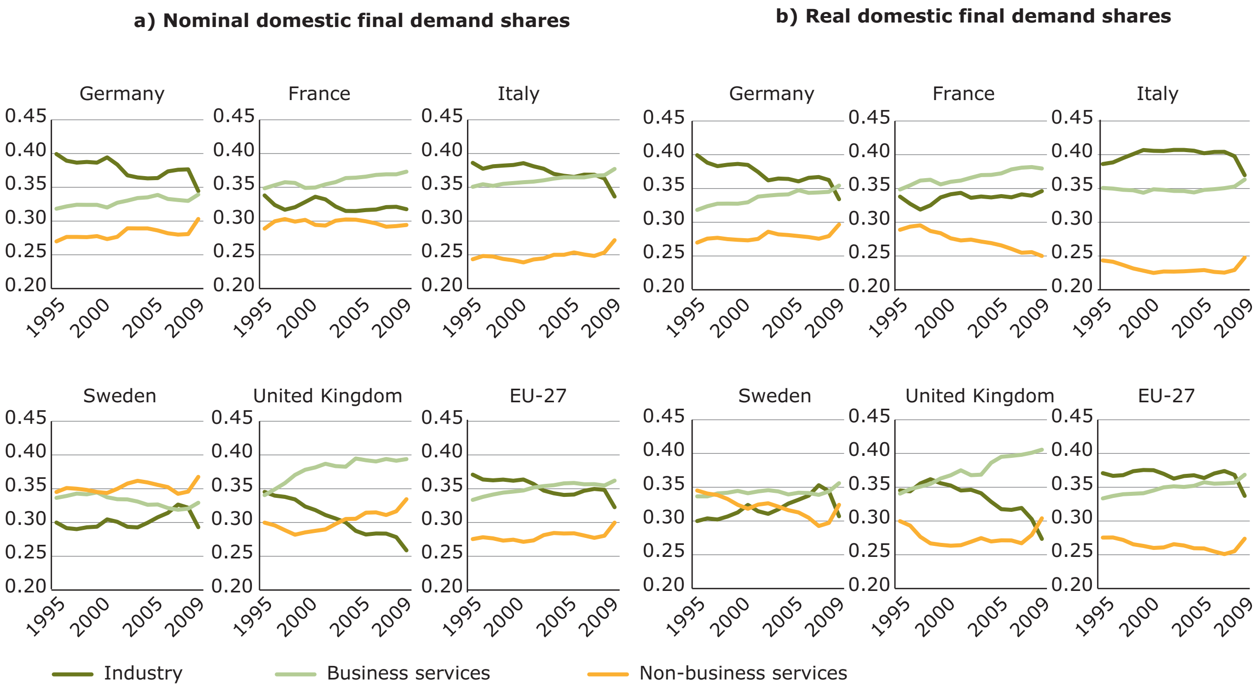
Figure 4.2 Shares of total employment shares and labour productivity (VA per employee, thousands of real USD (base year 1995) per employee)



Source: Authors based on the WIOD database.

[31] For domestic overall final demand we consider the expenditure in final demand by resident units, either of domestically produced or imported commodities. Domestic overall final demand thus includes all import of commodities destined to satisfy final demand together with the part of commodities destined to final demand that is consumed in the country (the export of final commodities is excluded).

Figure 4.3 Nominal and real domestic final demand shares (share of total)



Source: Authors based on the WIOD database.

This evidence on changing shares, relative prices, and productivity in services and industry, and final demand, is in line with the 'unbalanced growth' or 'cost disease' theory proposed by Baumol (1967), which had two main arguments. The first is that to ensure a constant share of final demand or final output between two (or more) sectors, production inputs — labour, capital, natural resources, energy, intermediates, etc. — need to shift towards the so-called stagnant, less productive, sectors ([32]).

The second argument is that the shift to a service economy is more nominal than real due to cross-sectoral differences in terms of productivity growth rates and prices. Due to the differences in productivity growth, and consequently the relative costs of production between stagnant and progressive sectors, prices in stagnant sectors should increase relatively faster than prices in other sectors. This means that to maintain the same proportion of final consumption in real terms, net of relative price changes, the share of monetary resources (i.e. nominal) directed to buying goods or services from the stagnant sectors needs to increase.

In addition, these results highlight the divergence between changes in production structures and the generally stable structures of final demand. This divergence implies that also the international trade composition and specialisation of these countries has also changed (Section 4.2).

4.1.2 Environmental performance implications

What are the environmental implications of the shift to services? Taking CO_2 emissions as a well-documented environmental pressure, and a useful proxy for environmental pressures in general, Figure 4.4 shows the CO_2 emission intensity of real VA by country and macro-sectors for 1995 and 2009. In addition to it being a well-documented pressure, there are other reasons to use CO_2. While other emissions and pollutants have been reduced by the adoption of end-of-pipe

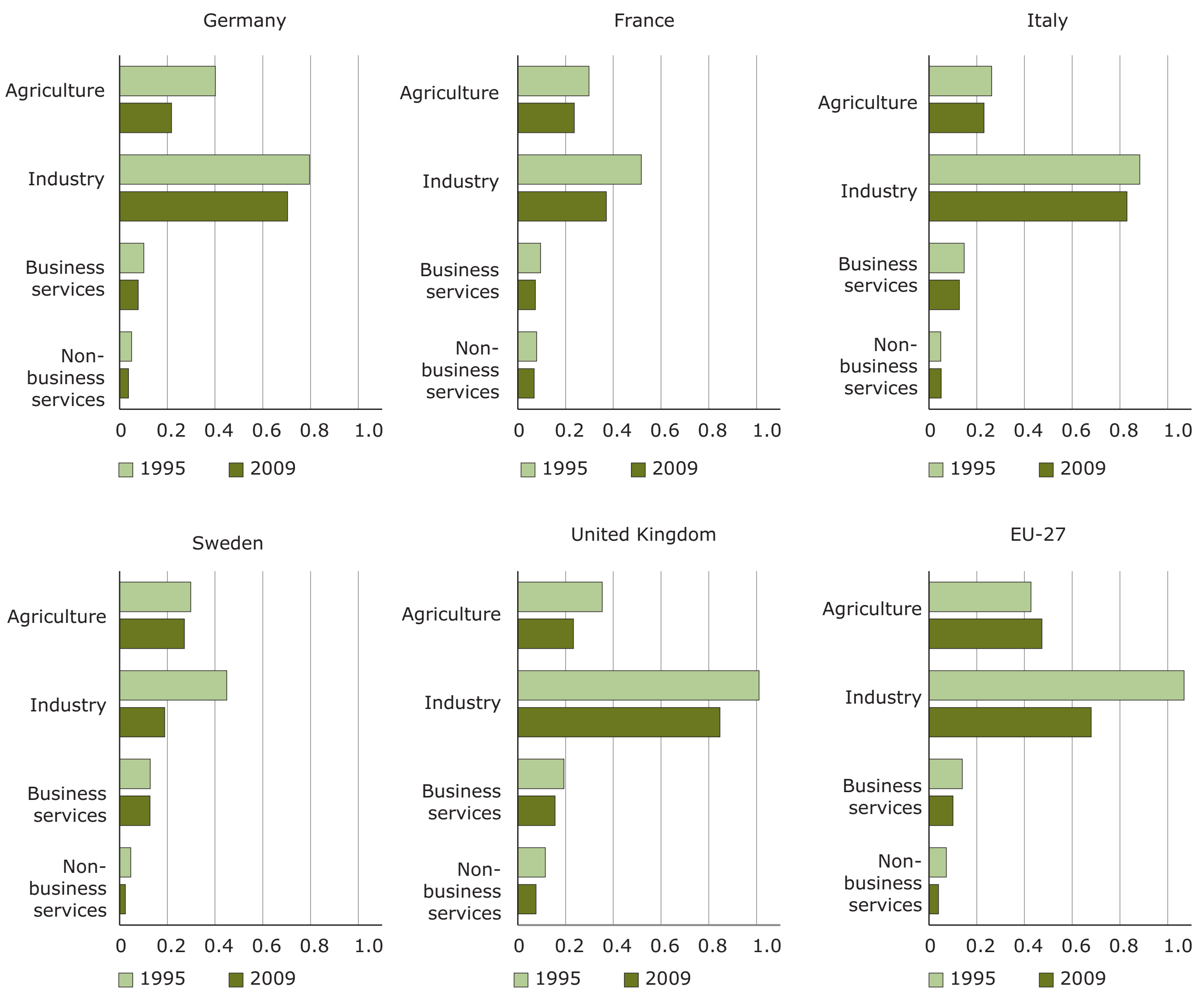
([32]) Stagnant sectors are defined as those for which, due to their particular nature, little improvement in the productivity of inputs is possible. In contrast, progressive sectors tend to be characterised by sustained improvements in productivity.

technologies, CO_2 emissions remain one of the most challenging areas and a limited degree decoupling has occurred in EU Member States and industrial sectors. Industry sectors are, as expected, the most emission-intensive ones, and non-business sectors the least emission-intensive.

Figure 4.4 shows that improvements in emission efficiency in industry, in absolute terms, has been greater than the improvements in services in all countries except Italy, and is especially evident in Sweden and the EU-27 as a whole. This is particularly important because of the high relative emission intensity of industrial sectors. In relative terms, however (Figure 4.5), the reduction in emission intensity of real VA was larger in business services than in industry, except in Sweden and the EU-27 as a whole, while the performance of non-business sectors is more mixed. In France, Sweden and the EU-27 there has been a very large reduction in the emission intensity of industry sectors — by 28 %, 58 % and 36 % respectively relative to 1995 levels — accompanied by a small improvement in the emission efficiency of business services, including transport.

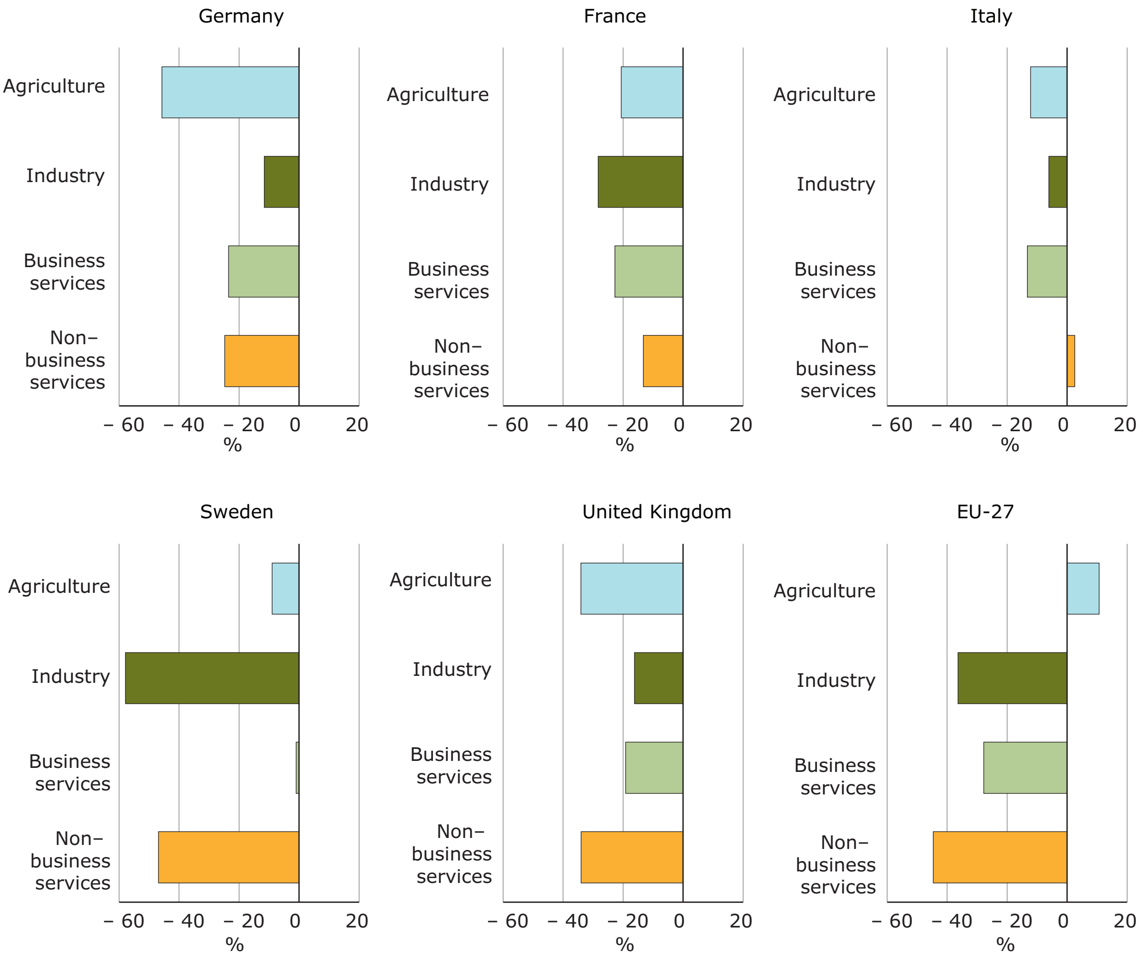
This suggests that, in term of direct emissions, industry is not the only sector that can improve its emission efficiency, even though great improvements from industry in absolute terms are likely to contribute substantially to aggregate improvements. Service sectors also have the potential to improve their emission efficiency, albeit in a non-uniform way across countries.

Figure 4.4 Direct emission intensity (CO_2/VA, measured in kg CO_2 per real USD of VA, 1995 prices)



Source: Authors based on the WIOD database.

Figure 4.5 Percentage change in emission intensity (CO_2/VA), 1995–2009



Source: Authors based on the WIOD database.

These results are valid only for direct emissions, the so-called production perspective or production footprint, and must be reconsidered when looking at the environmental implications of the final consumption of services consumption perspective or consumption footprint, in which emission efficiency is evaluated for final demand of good and services, and by comparison between the two (see Box 4.1 and Annex 2).

4.1.3 The consumption footprint of services

The environmental impacts of a country's activities are commonly assessed by measuring pressures within its borders, for example emissions from cars or factories, or pollution of freshwater systems. However, measurements of this nature often obscure important information for which it is necessary to separate production- and consumption-footprint emissions.

Production footprint emissions include only those environmental pressures that arise directly from the production and consumption of goods and services (direct emissions). Consumption-footprint emissions include environmental pressures all along the supply chain that satisfies the final demand for a good or service. Thus the production footprint considers only direct emissions, while the consumption footprint also considers indirect emissions. This is also relevant when considering domestic emissions only, because emissions in the two perspectives are allocated to sectors according to different criteria (see Box 4.1 and Annex 2).

Figure 4.6 and 4.7 illustrate the differences between the production and consumption footprints. They show the relative contribution of four macro-sectors to overall production and consumption-footprint CO_2 emissions for the EU-27 in 1995–2009 (see ETC/SCP, 2012). Industry is the main contributor

Box 4.1 Direct versus induced emissions, or production versus consumption footprint ([33])

Environmental pressures are generally recorded by tracking all pressures directly exerted by economic units residing in a country — the environmental accounting approach — or by considering all environmental pressures exerted within a specific territory — the territorial approach. There is no consideration of environmental pressures occurring along the supply chain in either of these accounting methods.

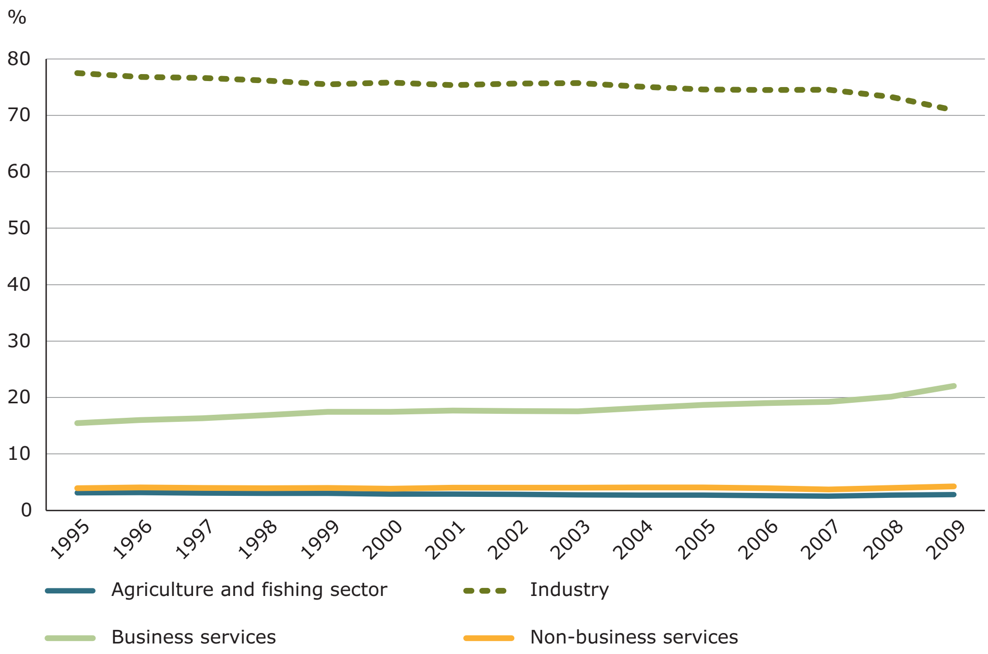
The production footprint considers environmental pressures arising directly from the production of goods and from their consumption — direct emissions.

The consumption footprint considers environmental pressures associated with meeting the final demand of the population of a country or region, irrespective of where the pressures arise. Consumption footprint figures aim to track all emissions from the entire supply chain to final consumption — direct and induced emissions, net of emissions associated to goods/services used as intermediate inputs in other sectors.

While production footprint figures are widely available from environmental statistics or environmental accounts, consumption-footprint figures need to be estimated. A widely-used method is environmentally extended input-output (EEIO) modelling. These allow the tracking of all environmental pressures along the supply chain, excluding pressures arising from the production of exported goods ([34]).

The domestic technology assumption (DTA) is often used to analyse the consumption footprint figures. According to the DTA, imported goods are produced with the same technology as domestically produced goods, and the emission intensity of imported goods (environmental technology) is the same as that of domestically produced goods ([35]).

Figure 4.6 Direct CO_2 emissions (production footprint) for EU-27 by macro-sector (% share of total emissions)



Source: Authors based on the WIOD database.

([33]) See for a detailed review of the development of footprint-type indicators for materials, water, land and carbon: Giljum et al., 2013 and for an analysis of the material flow of 186 countries: Wiedmann et al., 2013.

([34]) For a detailed discussion of the concepts and methodologies behind different accounting perspectives — territorial, production and consumption, see EEA, 2013a.

([35]) Footprint/perspective-based environmental statistics and accounts are increasingly produced by Eurostat, see http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-DK-12-001/EN/KS-DK-12-001-EN.PDF; http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/documents/RME%20project%20-%20Introduction.pdf; http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-DK-12-001/EN/KS-DK-12-001-EN.PDF.

to total emissions from both consumption and production perspectives, despite a slow but continuous reduction. However, Figure 4.6 shows a slow and continuous increase in the contribution from business services. The contributions of the agriculture and fishing sector and of the non-business services sector does not show any significant change over time.

Figure 4.7 shows that the overall contribution from industry is lower, and of non-business services higher, using a consumption rather than production perspective.

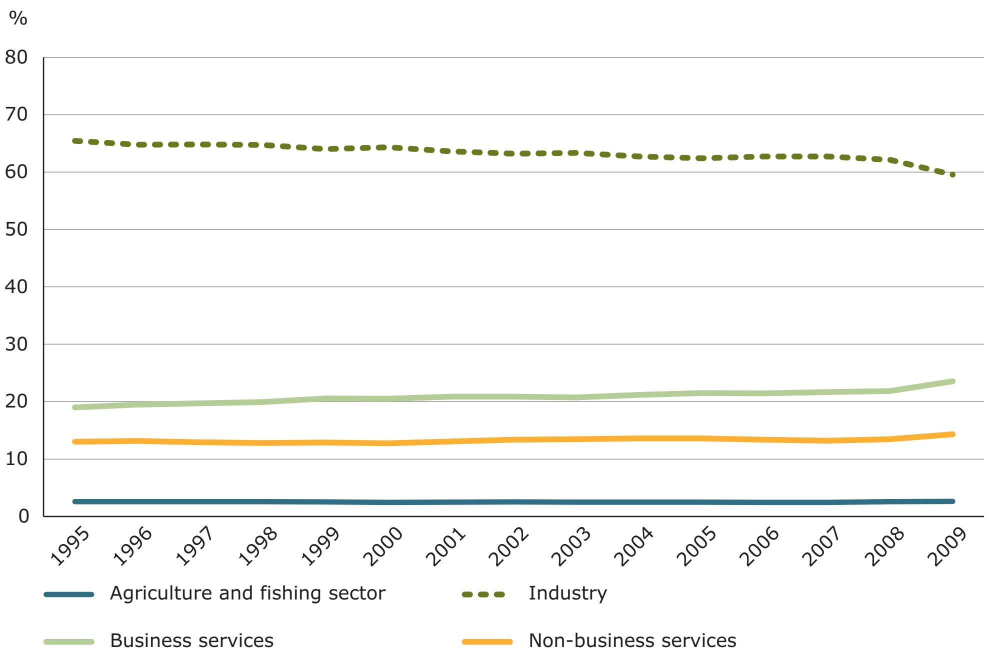
Combining the production and consumption footprint data reveals interesting findings. Figure 4.8 shows the ratios between the consumption and production footprint figures for each macro-sector. Macro-sectors with a ratio above 1 release more emissions to satisfy final demand than those released directly in production: their consumption footprint is greater than their production footprint.

Figure 4.8 shows that, while industry has a ratio below 1 — they deliver a large part of their products and the associated emissions to other sectors, business and non-business services both have ratios above 1: their consumption footprint is larger than their production footprint. The ratio is particularly large, more than 3, for non-business services. This suggests that a shift to a service-based economy, and especially certain services, is likely to lead to a significant increase in the demand for intermediate inputs, both from industry and other services, and in the associated emissions, wherever they are generated.

Services have a much greater consumption than production footprint while for industry the reverse is true. This can also be seen in Figure 4.9, which shows the ratio between the CO_2 emission intensities of domestic final demand — the consumption footprint — and of VA — the production footprint — for five countries and for the EU-27 as a whole. The ratio between these two measures is greater for both business and non-business services than for industry, the only exception being Sweden in 2009.

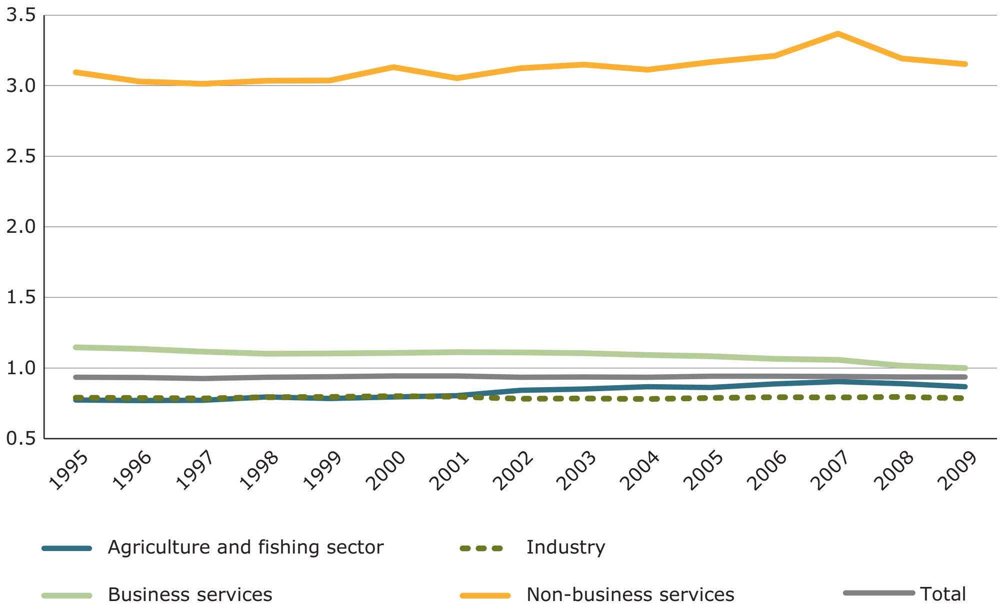
One final issue to consider is the change in emission intensity of the consumption footprint between 1995 and 2009 (Figure 4.10). There is evidence of a decline in the emission intensity this in all countries and macro-sectors, the only exception being business services in Sweden and the United Kingdom. The emission intensity for industrial goods fell more than the corresponding figure for business services in all countries except Germany, while non-business services performed better than

Figure 4.7 Direct and induced CO_2 emissions (consumption footprint) for EU-27 by macro-sector (% share of total)



Source: Authors based on the WIOD database.

Figure 4.8 Ratio between consumption and production footprint for CO_2 emissions by macro-sector, EU-27

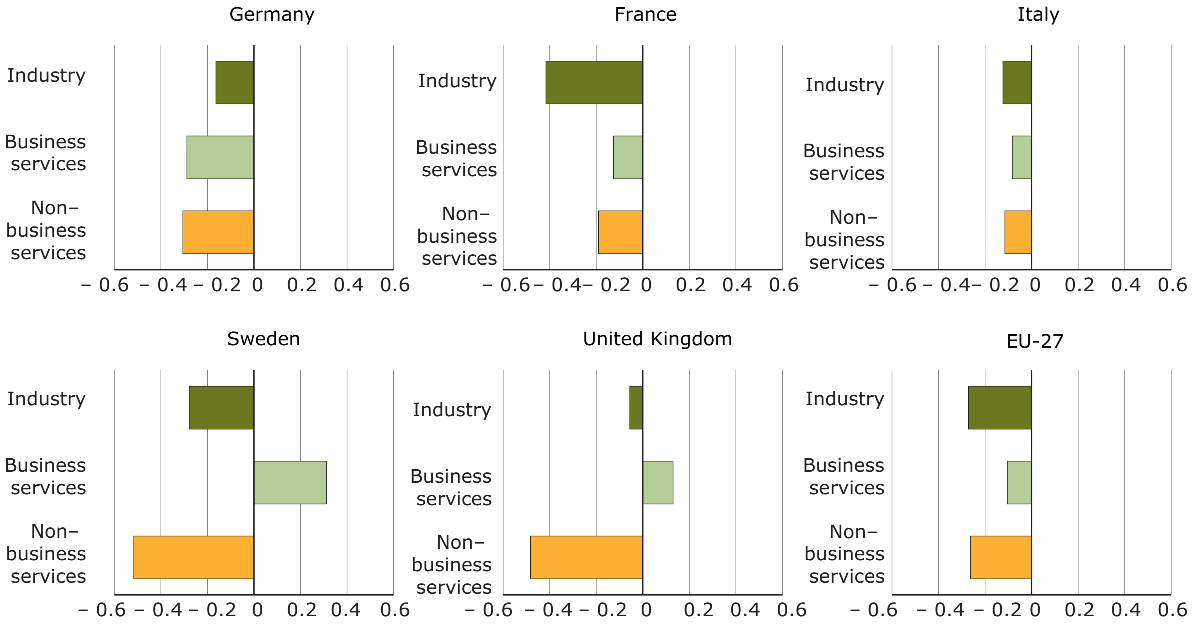


Source: Authors based on the WIOD database.

Figure 4.9 Ratio between the consumption footprint of real final demand and the production footprint of real VA (emission intensity indicator in kg CO_2 per real USD, 1995 prices)

Source: Authors based on the WIOD database.

Figure 4.10 Percentage change in consumption footprint emission intensity (kg CO_2 per real USD, 1995 prices) of real final demand, 1995 and 2009



Source: Authors based on the WIOD database.

average in all countries other than France and Italy. This suggests that business services, characterised by significant indirect emissions, also tend to show a worse dynamic performance than industry when considering their overall consumption footprint emission intensity.

The conclusion is that the production footprint of industry is larger than that of services, and in this respect a transition to a service-based economy will result in a shift to a green economy. However, the consumption footprint of services can be higher or much higher depending on the sector and in this respect the further shift to a service-dominated economy cannot be expected to deliver strong net progress towards a green economy.

4.2 Structural change and the international footprint of the EU

As a result of structural changes in EU economies, the domestic production mix increasingly differs from the final demand mix. This necessarily implies changes in the international trade in goods and services. This changing production and trade specialisation in the EU has many implications from the economic point of view, including a weakening of the global industrial role of the EU and a redistribution of international employment in different sectors. It also has environmental implications, including the possible shift of environmental pressures to different parts of the world.

Analysing the environmental effects of the changing economic specialisation of countries is difficult. Many empirical studies on trade-embodied pollution or the international environmental footprint of nations focus on just one effect of the change in international specialisation — the re-location of international emissions — while generally excluding the broader set of effects and in particular international employment effects (Box 4.2). Thus they do not highlight the full set of gains and losses for all the countries involved. Moreover, this type of analysis often fails to account for the role of trade as a channel for the diffusion of more efficient and greener technologies, because it implicitly assumes that technologies are different but unchanging across countries (Chapter 6).

The conclusion that can be drawn from these studies is that the environmental pressures embodied in imports to industrialised countries are generally greater than those embodied in their total exports. Although the evidence is quite robust when considering the set of industrialised countries as a single region, quantitative assessments at the

Box 4.2 Trade-embodied pollution

Studies on trade-embodied pollution use different assumptions: some use the domestic technology assumption (DTA; Box 4.1). In others, imported goods are modelled differently from domestic goods in terms of production technology and/or environmental efficiency, and multi-regional input-output models (MRIO) are also used.

A recent EEA report (EEA, 2013b) used an EEIO model with pure DTA, environmental accounts (NAMEA ([36])) and input-output tables, to estimate emissions to the air and material flows embodied in trade flows for nine EU-27 countries. The results are varied, with some countries emerging as net exporters of emissions and some as net importers. Arto et al. (2014) assume that direct emissions are proportional to the weight of imported goods (produced with the same set of intermediate inputs as domestic goods) and not to the monetary value of the goods, as assumed by classical DTA. Results show that the estimated trade imbalance — emissions embodied in imports higher than emissions embodied in exports — of Spain is greater for the physical DTA than for the monetary DTA, which significantly underestimates emissions embodied in imports. Another set of studies uses alternative assumptions, with the DTA taken as a benchmark. Li and Hewitt (2008) estimate that the DTA underestimates emissions embodied in imports for UK-China bilateral flows by 63 % compared to an input-output model that accounts for bilateral trade.

Another set of studies uses *ad hoc* multi-regional input-output (MRIO) models. Ahmad and Wyckoff (2003) use a MRIO model based on OECD data for 24 countries/regions with specific assumptions made for the rest of the world. Nakano et al. (2009) also use an MRIO model based on OECD and International Energy Agency (IEA) data for 41 regions with specific assumptions made for the rest of the world. The results of both studies show a general tendency for carbon leakage in western European countries. Kratena and Meyer (2010) focus on Austria and describe the rest of the world with the EU-27 input-output matrix and environmental coefficients, finding significant, though decreasing in time, carbon leakage for Austria. Peters and Hertwich (2008) built a MRIO model for Norway, including its seven most important trade partners, and find that Norway is a net emissions importer. A study on Switzerland by Jungbluth et al. (2011) using a combination of life cycle assessment (LCA) and input-output models (IO) concludes that 60 % of the impacts of final demand occur abroad as a result of trade in goods and services.

Wiedmann (2009) compares results from a MRIO for the United Kingdom with those obtained by applying LCA coefficients to physical quantities of imported and exported goods. The two approaches differ substantially as regards sector-level results although these are quite similar for the two approaches. These differences in methodologies and limitations in data lead to a complex picture.

Eurostat also publishes data on the trend of greenhouse gas emissions from a consumption perspective (Eurostat, 2011 and 2012).

country level vary substantially depending on the methodological approach, the level of aggregation of raw data, and the specific year or period considered.

However, the re-location of emissions outside Europe resulting from structural change and new trade specialisations must be kept in mind when looking at macro-level resource efficiency indicators, such as the emission intensity of the EU economy. While this is a useful indicator, it generally accounts only for domestic emissions and cannot provide a measure of the overall resource efficiency profile of an economy from a global perspective.

Furthermore, the global social benefits of changing trade specialisation need to be considered together with the environmental costs. An analysis based on the MRIO approach concludes that in 2008 24 % of global greenhouse gas emissions were linked to international trade but also that 20 % of global employment is linked to trade (Arto et al., 2014). For China, one of the countries with which the EU has a greenhouse gas trade deficit, with emissions caused by European imports from China being greater than those caused by European exports to China, 29 % of Chinese employment and 34 % of national greenhouse gas emissions are linked to the production of goods exported to other countries (Arto et al., 2014).

([36]) NAMEA is the National Accounts Matrix with Environmental Accounts, which is part of official environmental accounting including Regulation (EU) 691/2011 on European environmental economic accounts which is the response of the EU to developing a system of environmental and economic accounts (SEEA).

The analysis of trade-embodied emissions as part of policy discussion should therefore not focus only on environmental pressures induced by international trade but should also include the economic and employment gains resulting from such trade. The green economy concept seeks to assess economic and environmental performance together, while also considering social inclusion and employment.

Attempting to discriminate against imported products based on their embodied pollution can be problematic. Not only does it neglect the social benefits of international trade for exporting countries, it may also not be in accordance with World Trade Organization (WTO) rules ([37]) (Yungfeng et al., 2011). For this reason, international 'embodied pollution' may better be discussed in combination with 'green' technology transfer (see Chapter 6) ([38]).

4.3 Can re-manufacturing strategies support the shift to a green economy?

The implications of a shift towards a service economy, and the associated changes in the patterns of trade, suggest that manufacturing can have an important role in the shift towards a green economy. Recent EU industrial policy calls for re-manufacturing in the EU economy as a lever for innovation and competitiveness. It explicitly calls for manufacturing to achieve a 20 % share of GDP in the EU by 2020, from about 16 % in 2011.

The *Industrial Policy Communication Update — A Stronger European Industry for Growth and Economic Recovery* (EC, 2012) states that:

With the renewed industrial strategy outlined in this Communication, the Commission seeks to reverse the declining role of industry in Europe from its current level of around 16 % of GDP [year 2011] to as much as 20 % by 2020. This should be driven by substantial recovery in investment levels (gross capital formation and investment in equipment), an expansion of the trade in goods in the Internal Market (to reach 25 % of GDP in 2020) and a significant increase in the number of SMEs exporting to third countries ([39]).

What are the implications of this strategy for the EU's environment? Can re-manufacturing deliver an economy that is resource-efficient as well as competitive?

Different simulations have been run to provide a preliminary answer to these questions. They have considered scenarios with a 2020 target of a 20 % share of manufacturing in GDP and a 20 % reduction in greenhouse gas emissions compared to 1990. They have been formulated using an EEIO-based what-if scenarios simulation tool (ETC/SCP, 2013; Annex 3).

A first scenario of pure re-manufacturing assumes meeting the 20 % manufacturing objective by 2020 without constraining greenhouse gas emissions to meet the EU target of a 20 % reduction. This scenario requires growth of final manufacturing demand of 49 % in the 12 years from 2008 to 2020, 3.4 % per year, and would result in an increase in economy-wide greenhouse gas emissions of 1.1 % per year, together with an increase of greenhouse gas intensity of VA. Such an outcome would mean that the EU's greenhouse gas emissions in 2020 would be 28 % above the 1990 level, greatly exceeding the current target (Table 4.1).

A second scenario assumes carbon neutral re-manufacturing, in which the greenhouse gas emission consequences of re-manufacturing are neutralised by decreasing emission intensity of output in the manufacturing sectors. In this scenario, the increase in final EU manufacturing share is the same, but the decrease of 50 % in greenhouse gas emission intensity in manufacturing in 12 years (by 5.6 % per year) is challenging.

A third scenario assumes that the re-manufacturing demanded by industrial policy is achieved through a growth in final demand of certain manufacturing sectors only, without increasing greenhouse gas emissions. The chosen sectors are those that combine already low emission intensity for greenhouse gas with a high- or medium-technology standard, thus better representing an innovative green economy. For example, in its Communication on industrial renaissance (EC, 2014), the Commission identifies the following priorities: advanced manufacturing;

([37]) One of the often referred policies in this context is Border Tax Adjustments (BTA), meaning that, for example, a tax is levied on imports by carbon-taxing countries on goods and products originating from non-carbon taxing countries and goods and products from carbon-taxing countries will be exempt from the carbon tax when exported to non-carbon taxing countries, thereby guaranteeing a level playing field. There is an on-going debate whether WTO rules are preventing the introduction of carbon taxes. For a detailed discussion see Hillman, 2013.

([38]) As Yungfeng et al. (2011) state: *This [consumption footprint] approach is not meant to fuel a meaningless blame-game of political rhetoric. Rather, it is meant to help inform climate change mitigation efforts by promoting greater accountability among nations and economic blocs*.

([39]) In the Communication, the 20 % target refers to manufacturing, see EC (2012), page 4.

Box 4.3 What-if scenarios

The simulation tool for *ex ante* what-if scenarios is based on Eurostat IO tables for the EU-27 as a whole, using data from the National Accounts Matrix with Environmental Accounts (NAMEA) as the environmental extensions. Data are for 2008, the last available year (ETC/SCP, 2013; Annex 3).

An IO framework with environmental extensions allows exploration of the consequences of changes in economic and environmental variables up to the disaggregation level of NACE Rev. 2 sectors and, through the IO inter-industry linkages, of both direct and indirect effects. The features of the EEIO models — fixed coefficients, no behavioural modelling, etc. — allow exploration of only a limited set of simple scenarios after changes of some variables decided by the user.

In the present analysis (ETC/SCP, 2013), scenarios are created by imposing, separately and together, the achievement of two main policy targets on the model: a 20 % share of manufacturing in EU-27 VA, the re-manufacturing target and a 20 % reduction in greenhouse gas emissions from the whole EU-27 economy, both by 2020. The question is 'what if the target should be achieved?' in terms of economic and environmental outcomes as well as the required adaptations of certain key variables.

In the scenarios presented here, the achievement of a 20 % share of manufacturing in EU-27 VA by 2020 assumes that the level of demand for manufacturing will increase, for a given the level of demand for services and agriculture, so that the share of these macro-sectors will be redistributed at 2020 compared with the reference year, 2008. The results of the simulations include the consequences for a set of economic and environmental variables at the EU-27 aggregate level: VA, employment, both imported and domestic intermediate inputs, greenhouse gas emissions, greenhouse gas intensity of VA, share of final demand in initial VA and labour productivity. Some of these variables are presented in Table 4.1; more detailed results are presented in ETC/SCP 2013.

The outcomes of simulations should be seen as speculative because of the limitations of the modelling framework, including the underlying assumptions and the reference year of the data, 2008. However, the results provide some indications of the challenges of achieving different policy objectives together.

key enabling technologies; bio-based products; clean vehicles and vessels; sustainable construction and raw materials; smart grid and digital infrastructure.

The results indicate a target for final demand growth of these sectors of 101 % in 12 years, or 6.0 % per year, and a compensatory reduction in the greenhouse gas intensity of manufacturing as a whole of 29 %, or 2.1 % per year.

A fourth scenario addresses the so-called brown manufacturing sectors — the 20 sectors with the highest greenhouse gas emission intensity. If re-manufacturing is based on these sectors, the final demand for them would need to grow by an unrealistic 180 % in 12 years, or 9.0 % per year, to achieve the re-manufacturing target, with a compensatory decrease of greenhouse gas intensity for manufacturing as a whole of 88 % in 12 years, or 5.4 % per year.

These results suggest that the sectoral composition of re-manufacturing can be critical in terms of both its economic *and* environmental consequences.

The scenarios of re-manufacturing with no increase of greenhouse gas emissions from increasing manufacturing output leave unchanged, by definition, the path the EU economy is presently on of meeting the greenhouse gas emissions reduction target. A fifth scenario therefore explores the implications of achieving *both* the industrial policy and the climate policy targets. The required increase in final manufacturing demand is again 49 % in 12 years, or 3.4 % per year, and the decrease in greenhouse gas emission intensity of the economy as a whole is 22 %, or 2.1 % per year. This necessary gain in emission efficiency is ambitious and challenging but not completely unfeasible compared to the rate of decrease of greenhouse gas emission intensity in the past 12 years in the EU. Based on Eurostat figures, the average rate of reduction of greenhouse gas intensity of GDP — the ratio between emissions and real GDP — for the EU-27 was about 1.4 % per year in 2000–2010, substantially worse than the average rate of 3.2 % per year in 1995–2000. As this latter rate of reduction is higher that the 2.1 % per year required by the scenario, its outcome cannot be ruled out.

Table 4.1 Scenarios for re-manufacturing: economic and environmental implications

	Change in final demand for manu-factured goods	Change in sector emission intensity (GHG/output)	Distance from target GHG	Share of manu-facturing in value added	Change in GHG emissions	Total VA growth	Imported intermediate inputs growth
First scenario Achieving 20 % manufacturing in total value added: increase of final demand in manufacturing	49 % (3.4 % p.a.)	0 % (0 % p.a.)	28 %	20 %	14 % (1.1 % p.a.)	11 % (0.9 % p.a.)	23 % (1.8 % p.a.)
Second scenario Carbon-neutral re-manufacturing: Increase in final manufacturing demand and 'compensatory' decrease of carbon intensity (GHG/output) in manufacturing	49 % (3.4 % p.a.)	– 12 % (– 1.1 % p.a.) [*only manu-facturing sectors*]	13 %	20 %	0 % (0 % p.a.)	11 % (0.9 % p.a.)	23 % (1.8 % p.a.)
Third scenario 'Selective re-manufacturing' (high/medium tech and low emission sectors, C26 to C30) with 'carbon-neutrality' through decrease of carbon intensity (GHG/output) in all manufacturing sectors	101 % (6.0 % p.a.) [*only sectors C26-to-C30*]	– 29 % (– 2.8 % p.a.) [*all manu-facturing sectors*]	13 %	20 %	0 % (0 % p.a.)	9.2 % (0.7 % p.a.)	38 % (2.7 % p.a.)
Fourth scenario 'Selective re-manufacturing' (brown sectors, C10–C12, C17, C19–C24) with 'carbon-neutrality' through decrease of carbon intensity (GHG/output) in all manufacturing sectors	180 % (9.0 % p.a.) [*only sectors C10–C12, C17, C19–C24*]	– 88 % (– 5.4 % p.a.) [*all manu-facturing sectors*]	13 %	20 %	0 % (0 % p.a.)	14 % (1.1 % p.a.)	38 % (2.7 % p.a.)
Fifth scenario Re-manufacturing coherent with the climate policy target (– 20 % GHG emissions at 2020): Increase in final manufacturing demand and 'compensatory' decrease of carbon intensity (GHG/output) of the economy	49 % (3.4 % p.a.)	– 22 % (– 2.1 % p.a.)	0 %	20 %	– 11 % (– 1 % p.a.)	11 % (0.9 % p.a.)	23 % (1.8 % p.a.)
Sixth scenario Re-manufacturing (20 % share) with increasing demand for services (1 % per year) and coherence with the climate policy target (– 20 % emissions at 2020) through 'compensatory' decrease of carbon intensity (GHG/output) of the economy	76 % (4.8 % p.a.)	– 37 % (– 3.7 % p.a.)	0 %	20 %	– 11 % (– 1 % p.a.)	34 % (2.5 % p.a.)	51 % (3.5 % p.a.)
Seventh scenario Re-manufacturing by 2020 coherent with the 2030 climate policy target (– 40 % emissions at 2030): Increase in final manufacturing demand and 'compensatory' decrease of carbon intensity (GHG/output) of the economy	49 % (3.4 % p.a.)	– 42 % (– 2.4 % p.a.) [*by 2030*]	0 % [*target of – 40 % with regards to 1990 levels by 2030*]	20 %	– 34 % (– 1.8 % p.a.) [*by 2030*]	11 % (0.9 % p.a.)	23 % (1.88 % p.a.)

Source: Authors based on Eurostat data.

A sixth scenario removes the unrealistic assumption that re-manufacturing up to a 20 % share of VA can take place without increasing final demand for services — an assumption made by the previous five scenarios. Therefore, an annual increase of 1 % in final demand for services is assumed, together with the achievement of the re-manufacturing and emissions reduction targets. Compensating for this growth in services, the results require an increase in final manufacturing demand of 76 %, or 4.8 % per year, and a decrease of the greenhouse gas emission intensity of 37 %, or 3.7 % per year.

A final scenario looks at the re-manufacturing target of 20 % share by 2020 together with a 40 % reduction in greenhouse gas emissions by 2030 recently proposed by the EU. The results indicate, as in other scenarios, a required increase in final manufacturing demand of 49 % by 2020, or 3.4 % per year, combined with a decrease of the greenhouse gas emission intensity of the economy as a whole of 42 %, or 2.9 % per year, by 2030.

Although the scenario results are based on different hypotheses, and should be seen within the limitation of the simulation tool used, including the adoption of 2008 as the base year, all the scenarios show that to achieve re-manufacturing together with the climate objectives requires substantial improvements in emission efficiency by manufacturing and the economy as a whole. This is consistent with the need both for greater and faster changes in environmental efficiency and for greater policy coherence in support of the green economy shift, as highlighted in Chapter 3.

4.4 Main conclusions

- The slow but structural shift towards services cannot be expected *per se* to lead to substantial changes in the resource efficiency of EU economies. Services have less direct pressures than manufacturing, but when considering both direct and indirect pressures associated with the final consumption of services along the supply-chain, services require significant amounts of resources. Many services are generally less innovative than manufacturing, and this is especially relevant in the context of green innovation.

- The green economy does not mean de-industrialisation; there is a role for innovative manufacturing in a green economy transition. Recent EU-level strategies for re-manufacturing of Europe, to a 20 % share of GDP in 2020, are expected to result in greater international competitiveness and a reduction in the productivity slowdown effects associated with a service-based economy. However, the impact of this change, with the present level of resource efficiency in manufacturing, for example in terms of greenhouse gas emissions, implies increasing direct pressures.

- Re-manufacturing should at least be carbon neutral but this may be not sufficient to achieve the major environmental and resource efficiency objectives of the EU, in particular climate policy objectives. Policy coherence requires a further significant improvement in resource efficiency, and therefore a green innovative push, in manufacturing.

- The gradual shift to services and the corresponding reduction of the manufacturing share in the EU economy has implications for the specialisation of the EU economy, as well as for the level, structure and geographical patterns of the EU's international trade. To a certain extent, gains in direct resource efficiency in Europe depend on changing international production systems to shift some production away from the EU, reducing some domestic impacts while, actually, shifting them abroad.

- The consumption structure of the EU is changing slowly, however, and some of the emissions shifted abroad are embodied in goods imported into Europe as intermediate inputs or for final demand: from a global perspective, the total resource footprint of the EU is probably larger than the footprint of its domestic production. This does not apply to all countries, and models vary in what they show. However, growing global interdependence cannot be disregarded and examining only domestic resource efficiency indicators may be misleading from a global green economy perspective.

- From a resource-efficiency perspective, the shift to a service-dominated economy, even re-balanced by re-manufacturing strategies, and the changing international trade patterns of the EU, appear to be producing a set of partial and somewhat contradictory pushes towards a green economy. This conclusion is consistent with the observations of weak and slowly-changing trends for resource-efficiency indicators (Chapter 3) which should be seen in the context of the policy push for a green economy in Europe.

5 The role of innovation: an untapped potential?

The remaining chapters of this report discuss several enabling factors that can help to promote or hasten the development of the green economy. This chapter focuses on the role of eco-innovation diffusion, Chapter 6 on the international transfer of green knowledge, Chapter 7 on environmental fiscal reforms and economic instruments, and Chapter 8 on finance, particularly innovative green finance.

Technological innovation can play a critical role in the shift to a green economy. Although some types of technological innovation lead to an increased use of resources, green or eco-innovation can be a powerful lever for achieving resource efficiency ([40]).

Research shows that in the past few decades, from a quantitative point of view, changing technology has been the main factor behind resource efficiency gains in Europe, well ahead of other factors such as structural change and behavioural change. EU policies recognise this role of green innovation through, for example, the Eco-Innovation Action Plan of 2011. Green technologies have a role in broader innovation and R&D strategies, for example the Innovation Union flagship initiative of Europe 2020, the EU's Seventh Framework Programme for Research (FP7), and Horizon 2020, the new EU research and technology programme. Environmental policies can also stimulate green innovation through binding targets, which can help create a potential market for green innovation, accompanied by technical standards and environmental taxation.

All three phases of the innovation process are important: invention of useful new technologies, its adoption in production/consumption systems, and the diffusion of novel technologies so that they become widespread. However, it is the last two phases, adoption and diffusion, that have the greatest effects at the level of the economic system. Adoption and diffusion can be hindered by a number of barriers including the resilience of the current technological, and social system, lack of knowledge in application, lack of finance, insufficient incentives for the substitution of old technology by the new, high costs and insufficient market demand.

The result is that the great potential for green innovation in Europe is partially untapped. Understanding the adoption and diffusion of green innovation within the technological systems of the economy, together with reducing the barriers faced by firms in adopting them, is therefore an important requirement for a transition to a green economy. In addition, as with all types of innovation, green technologies interact with organisations and individuals. Green innovation therefore requires some degree of social innovation if it is to facilitate a green economy.

5.1 The policy setting

The EU has recognised the importance of stimulating green innovation. Innovation Union (EC, 2010a) is one of the seven Flagship Initiatives launched by the European Commission under the Europe 2020 strategy; it provides an overarching support for green innovation within general innovation processes. This flagship initiative suggests the key European, national and regional initiatives needed to create the Innovation Union by 2020 ([41]). According to the Communication on the state of the Innovation Union 2012 (EC, 2013a), more than 80 % of the initiatives were on track.

([40]) According to the EU FP7 'Measuring Eco-innovation project', eco- or environmentally-friendly or green innovations are defined as '*The production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation (developing or adopting it) and which results, throughout its life-cycle, in a reduction of environmental risks, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives*' (UNU-MERIT et al., 2008; see also Europe Innova (2008) and CML et al. (2008)). The definition of eco-innovation is not limited to specific technologies; it includes new organisational methods, products, services and knowledge-oriented innovation.

([41]) For a complete list of the action points, see EC, 2010a or visit the Innovation Union website: http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=action-points.

The Commission's Horizon 2020, the new multi-annual European research and innovation programme, includes a significant share of resources devoted to research areas linked to green innovation. Horizon 2020 marks a clear break with the past by covering the entire creation value chain in one single programme. The principle of smart consolidation, protecting, or if possible increasing, growth-friendly expenditure such as R&D, is widely accepted.

The Commission recognises that the on-going economic crisis has exposed structural weaknesses in Europe's innovation performance. In 2011, for the first time since the beginning of the crisis, the total public R&D budget of the 27 EU Member States decreased slightly, while the 2013 Innovation Union Scoreboard ([42]) shows that the process of convergence in the innovation performance of Member States has come to a halt. As convergence has been the dominant pattern since the introduction of the European Innovation Scoreboard in 2001, this signals a risk that a gap may re-appear in the innovation performance of different countries.

The European Commission's Eco-innovation Action Plan (EcoAP), launched in 2011 (EC, 2011), is a comprehensive set of initiatives to improve the market's uptake of eco-innovation. It focuses on specific bottlenecks, challenges and opportunities for achieving environmental objectives through innovation, building on the Innovation Union Flagship Initiative, and on EU eco-innovation activities and experience gained over the past decade, especially under the Environmental Technologies Action Plan (ETAP) (EC, 2004).

The EcoAP includes targeted action to stimulate both demand for and supply of green technology. It focuses on research and industry but also on policy and financial instruments. It commits the Commission to foster the market uptake of eco-innovation by:

- using environmental policy and legislation as a driver to promote eco-innovation (Action 1);
- supporting demonstration projects and partnering to bring promising, smart, and ambitious operational technologies that have been suffering from low uptake to the market (Action 2);
- developing new environmental standards to boost eco-innovation (Action 3);
- mobilising financial instruments and support services for SMEs (Action 4);
- promoting international cooperation (Action 5);
- supporting the development of skills, jobs and training related to the needs of the green technology industry (Action 6);
- promoting eco-innovation through the European Innovation Partnerships foreseen under the Innovation Union (Action 7).

On the operational side, EU funding of climate change-related research is estimated at EUR 9 billion across the different themes of the 7th Framework Programme (FP7) for the period 2007–2013, compared to around EUR 3.2 billion in the 6th FP. By 2013, the EU's Environmental Technologies Action Plan (ETAP) is expected to have channelled more than EUR 12 billion towards eco-innovation projects through FP6, FP7 and other EU funding programmes. Eco-innovation has been included among the missions of the European Agency on Competitiveness and Innovation (EACI). Companies are, of course, the main actors targeted by these strategies.

([42]) A European Innovation Scoreboard has been in place since 2001. Its main purpose has been to offer a comparative assessment of the innovation performance of Member States and to inform innovation policy discussions at the national and European levels. The measurement framework used in the Scoreboard distinguishes between three main types of indicators and eight innovation dimensions, capturing in total 25 different indicators (European Commission, 2013b).

Box 5.1 Socio-economic research on eco-innovation

A large amount of socio-economic research on eco-innovation has been published in journals by academics and international organisations over the past two decades.

Technological progress has long been recognised by economic research as a decisive driver of long-term growth in income per person ([43]), and eco-innovation is a subset of technological progress (Kemp, 1997; Rennings, 2000; Brock and Taylor, 2010). Eco-innovation is the point where sustainability and competitiveness meet (Jaffe et al., 1995; 2003; Fankhauser et al., 2011; EEA, 2013), making it a critical element of the green economy. Innovation can both reduce costs by increasing resource and emission efficiency at process level, and/or increase the final value of products (green products).

The role of eco-innovation and green inventions in the development of a greener and more competitive economy is seen in recent work by international institutions, such as the OECD (OECD, 2008, 2010a,b, 2011, 2012, 2013), UNEP ([44]) and the EU (Montalvo et al., 2011, *Europe Innovation watch* ([45])). The Community Innovation Survey (CIS) implemented in 2009 and published by Eurostat is, together with ancillary Eurobarometer surveys on EU SMEs, the first attempt to widely assess the adoption of eco-innovation by firms. The British government's *Review on the Economics of Climate Change* (Stern, 2007) also acknowledged the role of technological change, calling it one of the three pillars of climate-change mitigation — the others are policy change and behavioural change. This was a keystone recognition of the multifaceted role that innovation should play in driving societies towards sustainability in the medium-term.

Innovation of the technological, organisational and behavioural kind has increasingly been recognised in research studies of the determinants of environmental and economic performance as a key factor for improving sustainability in general terms, with impacts on emissions, waste and energy (van den Bergh, 2007; Mazzanti and Montini, 2010; Costantini and Mazzanti, 2013), and in particular on decarbonising the economy (Edenhofer et al., 2012). Innovation is one of the main factors that, as long as the energy mix and the economic structure also changes, can compensate for the ever-increasing size of economies.

Researchers have focused mainly on the drivers of eco-innovation and invention, with a particular interest in market and policy factors: firms may react innovatively on the green side when policy stimuli are well designed and stringent (Jaffe and Palmer, 1997; Brunnermeier and Cohen, 2003), or when more extended corporate green strategies are adopted, well beyond the role of policies (Horbach 2008; Johnstone et al., 2010), even depending upon external conditions related to environmental pressures and knowledge spill-overs (Ghisetti and Quatraro, 2013; Montresor et al., 2013). Such reactions to policy may be evident at a macro-economic scale (Popp et al., 2010; Dechezlepretre et al., 2011; OECD, 2011), where it has been difficult in some cases to ascertain the different effects of temporally-related market and policy shocks, such as oil prices peaks or the establishment of the Kyoto Protocol.

Innovations and eco-innovations are not adopted as isolated entities within organisations. Starting from a broad definition of eco-innovation (Kemp and Pontoglio, 2011), recent evidence has pointed to the potential value of innovation complementarity: doing more of one innovation, such as technological eco-innovation, increases the attractiveness of doing more on others, for example organisational or human resources activities. Systemic effects might arise, '*with the whole being more than the sum of the parts*' (Roberts, 2006). This complementarity, a real investment in reorganising firms (Mohnen and Roller, 2005), may become a factor that supports emission efficiency both in specific regional systems (Antonioli et al., 2013) and in the EU as a whole (Gilli et al., 2014).

A conclusion, from most if not all studies, is that the economic benefits of eco-innovation, though not always achievable as low-hanging fruit, should be included in decision-making on environmental policy. The costs of environmental policy, for firms and sectors, are overestimated if the economic benefits

([43]) The Europe 2020 strategy includes a target of 3 % of EU's GDP to be invested in R&D. The data show that the R&D share of GDP in 2012 was only 2.1 % (http://epp.eurostat.ec.europa.eu/portal/page/portal/europe_2020_indicators/headline_indicators accessed 18 May 2014).

([44]) UNEP states that *Eco-innovation is the development and application of a business model, inspired by a new business strategy, that will lead to a company's enhanced sustainability performance through a combination of a significantly improved or new product (good/service), processes, market approach and organizational structure. Eco-innovation operates at the level of a company strategy, mainstreaming a holistic life-cycle approach throughout all the company's operations (including associated activities that take place beyond company gates and influence/involve its supply chain) and is centred on enhancing its positive sustainability impacts, gaining reputational benefits and access to new markets. In sum, eco-innovation provides a win-win solution to improving economic competitiveness and sustainability* (http://www.unep.org/ecoinnovationproject).

([45]) See http://ec.europa.eu/enterprise/policies/innovation/support/europe-innova/index_en.htm.

Box 5.1 Socio-economic research on eco-innovation (cont.)

of eco-innovation are not recognised (UCL, 2014). For this reason, researchers have coined the term 'innovation offset' to describe the way that environmental policies, regulations and economic instruments can help to promote profitable innovation and thus offset the costs incurred in developing new technologies.

Some recent studies have moved along different tracks and provide evidence and conceptual insights on the effects of innovation on emission performances, with emphasis on sectoral and regional features (Carrion-Flores and Innes, 2010; Marin and Mazzanti, 2013; Gilli et al., 2014). These studies show that innovation can counterbalance the increased emissions caused by the scale of the economy and other technological developments. Some insights on the relatively overlooked issue of innovation effects are given in Section 5.2.

5.2 Emission performance of countries: the contribution of innovation

The role of technology and innovation in changing environmental pressures at the macro level can be identified through structural decomposition analysis (SDA) within an EEIO approach (Annex 2).

Looking at CO_2 emissions as a well-documented pressure within EU official data, SDA can identify the contribution to total CO_2 emissions of:

1. changes in emission intensity — the ratio between CO_2 emissions and real gross output;

2. changes in the structure of intermediate inputs in production — defined as technical change;

3. changes in the composition in terms of mix of final goods and services of real final demand that leave its real level unchanged; and

4. changes in the overall level of real final demand.

The results of a SDA based on the production footprint ([46]) are shown in Figure 5.1.

Total CO_2 emissions from production increased slightly in the Italy, Sweden, United Kingdom and the EU-27 as a whole between 1995 and 2007, while decreasing slightly in France and Germany. Carbon dioxide emissions from production then dropped sharply in 2008–2009 as a consequence of the economic crisis. Although the aggregate level of final demand is important for emission volumes, changes in the real composition of final demand — which sectors are increasing or reducing their share of final demand — tend to be much less important in terms of emission magnitude ([47]). The effect of changes in the composition of real final demand has tended to increase emissions in Germany because the composition has changed to favour re-industrialisation, and increases in exports, and reduce them in all other countries. The contribution to emission volumes resulting from changes in the mix of domestic intermediate inputs has been generally insignificant, with a visible, but nonetheless small, reduction only in Sweden.

Finally, the reduction in emission intensity has been a crucial factor in reducing emissions, compensating for the increase in emissions that would have resulted from the increase in final demand. Reduction in emission intensity of production accounted for a very large reduction of CO_2 emissions in France, – 36 %, Germany, – 32 % and the EU-27 as a whole, – 25.5 %. The contribution of emission intensity to the reduction of CO_2 emissions was also significant, but substantially smaller, in the other countries.

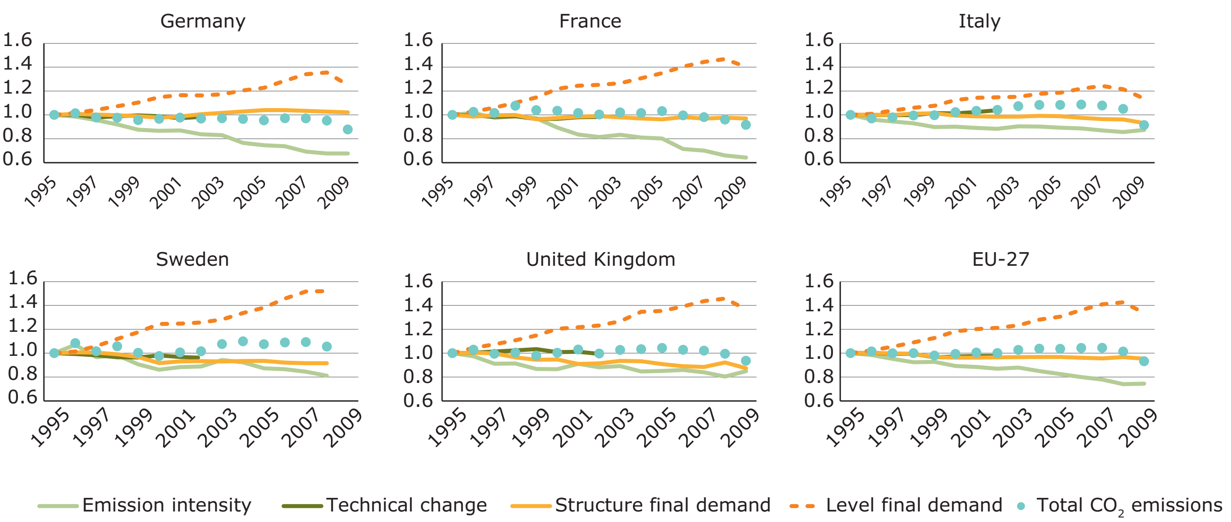
Figure 5.2 shows the decomposition of consumption footprint emissions for the same years, 1995–2009 ([48]). In the model used in this analysis, final demand of resident units (domestic and imported final goods only, exports are not considered) drives CO_2 emissions through a so-called Leontief matrix (Annex 2).

([46]) Here only the direct and indirect emissions from the domestic economy are considered, without considering trade-embodied pollution; see also Chapter 4 for the distinction between production and consumption footprint perspectives.
([47]) The final demand vector used in this decomposition includes only domestically-produced final demand, demanded either by local units or by foreign units (export). See Annex 2.
([48]) Here the emissions from the domestic economy as well as those embodied in trade are considered; see also Chapter 4 for the distinction between the production and consumption perspectives. Data for Sweden are available up to 2008.

Between 1995 and 2009, consumption footprint CO_2 emissions increased rapidly and steadily by more than 25 % in Italy and the United Kingdom, substantially in Sweden, remained basically stable in France, fell by more than 20 %in Germany and increased by 28 % in the EU-27 as a whole, with a sharp decrease in 2009. Therefore, increase in final demand also had a significant emission-increasing effect in the consumption footprint. The composition of final demand by domestic units was quite stable in the period considered, which explains the absence of significance of final demand composition for total emissions.

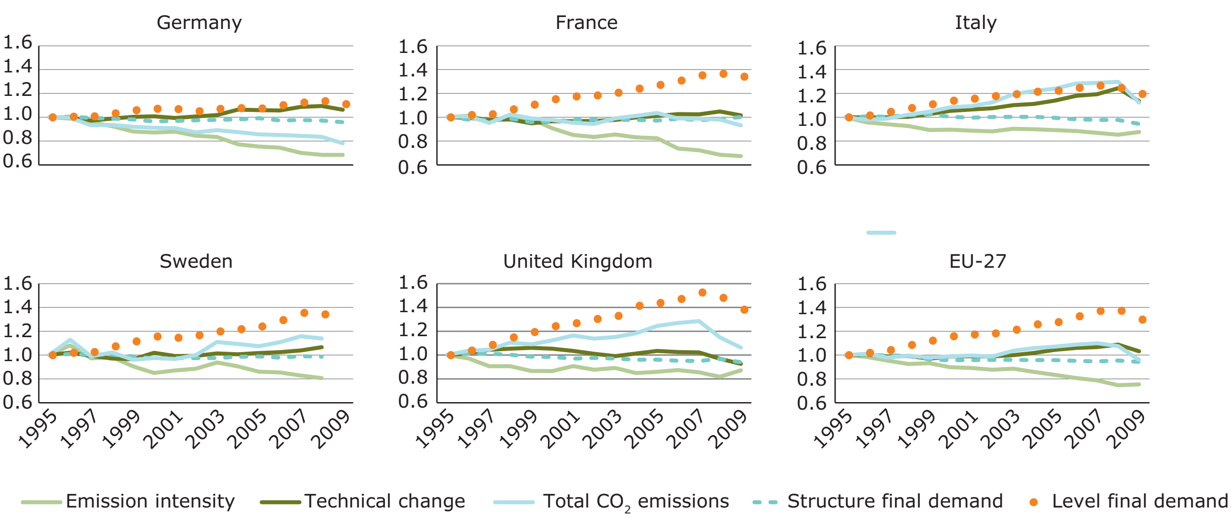
Technical change — the mix of intermediate inputs used in production — had a greater effect on consumption footprint emissions than on production ones. Technical change increased emissions in Italy because production sectors relied increasingly on imported intermediates to produce goods and services for the domestic market, thus increasing overall emissions to satisfy final demand. A similar

Figure 5.1 Structural decomposition analysis for the production footprint of CO_2 emissions (index, 1995 = 1)



Source: Authors based on the WIOD database.

Figure 5.2 Structural decomposition analysis for consumption footprint CO_2 emissions (index, 1995 = 1)



Source: Authors based on the WIOD database.

effect, though smaller, can be seen from 2002 onwards in Germany and in the EU-27 as a whole.

Finally, improved emission efficiency was the main factor mitigating the increase in consumption footprint CO_2 emissions, in line with the evidence found for the production footprint.

These results from SDA show that emission intensity, the indicator closest to being a proxy for environmental innovation, plays a crucial role in controlling environmental pressures. Emission intensity has a larger role in controlling environmental pressures than other factors such as the level of demand and the changing industrial mix. After emission intensity, the second most important factor is technical change as represented in SDA by the coefficients of supply and demand linking the different sectors, which represents the technology of production of the economy.

5.3 Linking company innovation performance to the emission efficiency of countries

The above results suggest that emission efficiency is quantitatively the most important factor in compensating for the increase in total emissions resulting from increasing final demand. Adoption of more emission-efficient technologies is the key to spreading the benefits of these technologies across entire production systems. This section presents evidence on the correlation between the adoption of eco-innovations and the CO_2 emission-efficiency performance of countries.

Large datasets are available for patents, but they do not generally give much indication of the adoption and diffusion of eco-innovation within economic systems ([49]). The EU's Community Innovation Survey (CIS) is the only source that currently offers data on eco-innovation adoption at country and sectoral levels for a large area such as the EU. The CIS data cover the EU-27, with gaps due to each country exercising their choice as to whether to respond to the eco-innovation section of the survey ([50]). The CIS data are then merged with environmental-economic data at the sectoral level by using Eurostat data. The focus here is on the correlation between eco-innovation adoption and CO_2 /value added indicators in 2006–2008 ([51]).

Maps 5.1, 5.2 and 5.3 present the spatial differences of eco-innovation and CO_2/VA indicators in the EU ([52]).

Emission efficiency, which depends on the efficiency of processes and on industrial and economic structure, for example the manufacturing and services shares, varies within the EU (Mazzanti and Montini, 2010; Costantini et al., 2011; Gilli et al., 2013). The structural composition of the economies of the eastern EU, when looked at from a production perspective, appears to be particularly environmentally negative, with high CO_2-emission intensity of value added. The industrial core of Western Europe — Germany, Italy, Belgium, and the Netherlands — follows with medium intensity, while more services-oriented countries (e.g. France) have lower CO_2/VA indicators.

CIS data show the geographical distribution of eco-innovation adoption. This is to some extent characterised, as expected, by some north-south and east-west divides. Maps 5.2 and 5.3 show that just before the 2008–2009 economic downturn, the level of eco-innovation adoption for CO_2 and energy across the EU was quite varied. Germany was an expected leader in terms of the percentage of companies that introduced at least one green innovation in the field of energy efficiency between 2006 and 2008 (Horbach 2008; Dechezlepretre et al., 2011; Gilli et al., 2013). Two of the more surprising top adopters in this period were Ireland and Portugal. The EU as a whole shows a reasonably significant number of companies adopting eco-innovation. Innovations that aim at reducing carbon footprints and those oriented to energy efficiency are also relatively, albeit not fully, correlated phenomena.

Scatter analysis captures the relationship between eco-innovation for energy efficiency (ECOEN) and

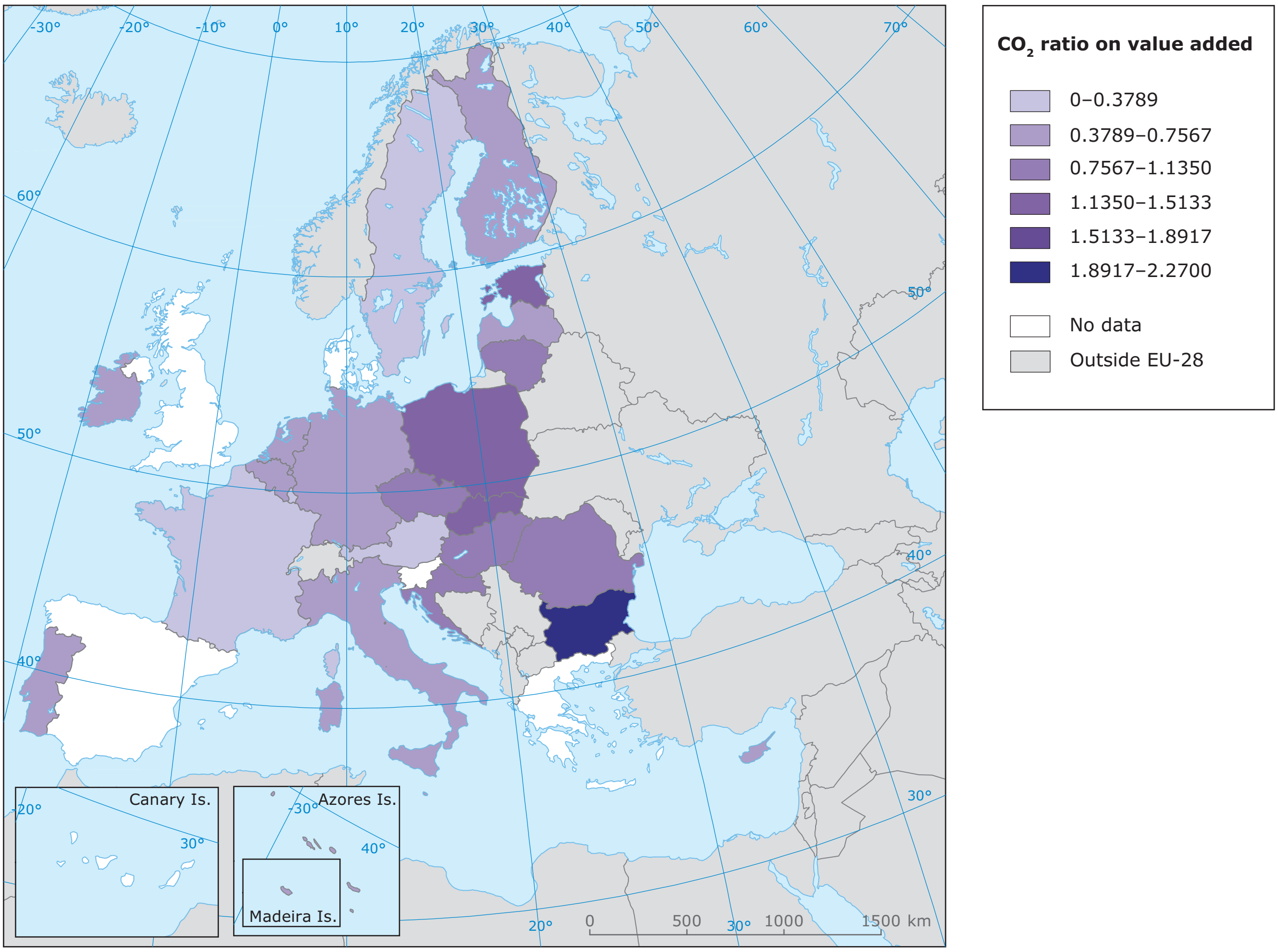
([49]) The relationships between innovation diffusion and innovation adoption are discussed in Lissoni and Metcalfe (1993). Adoption is the correct term when referring to the introduction of innovation by firms; diffusion refers to large-scale penetration as a result of barriers, drivers, networking at sectoral and geographical scales. We here analyse innovation and not invention (patent) data. One reason is that though patents are in some ways a good proxy of innovation capacity (UCL, 2014), only a fraction of inventions are marketed and diffused as innovations (Johnstone, 2007; OECD, 2011).

([50]) Some countries, such as Spain and the United Kingdom, do not present data on innovation adoption since national agencies did not implement the eco-innovation section of the CIS survey 2006–2008. Previously the CIS presented data for some 'environmental motivation' behind innovation adoption, but not for specific eco-innovation introduction. For details on the CIS see http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/cis.

([51]) This exploits eco-innovation (EI) adoption in the two areas of CO_2 abatement and energy efficiency (acronyms ECOCO and ECOEN).

([52]) Ratio of CO_2 to value added is a consolidated indicator of economic/environmental efficiency (Map 5.1). Maps 5.2 and 5.3 show the share of firms that adopted eco-innovations over 2006–2008 (services and manufacturing together).

Map 5.1 **CO_2/VA intensity of EU Member States (thousand tonnes CO_2 per EUR 1 million VA, 2008)**



Source: Authors based on Eurostat data.

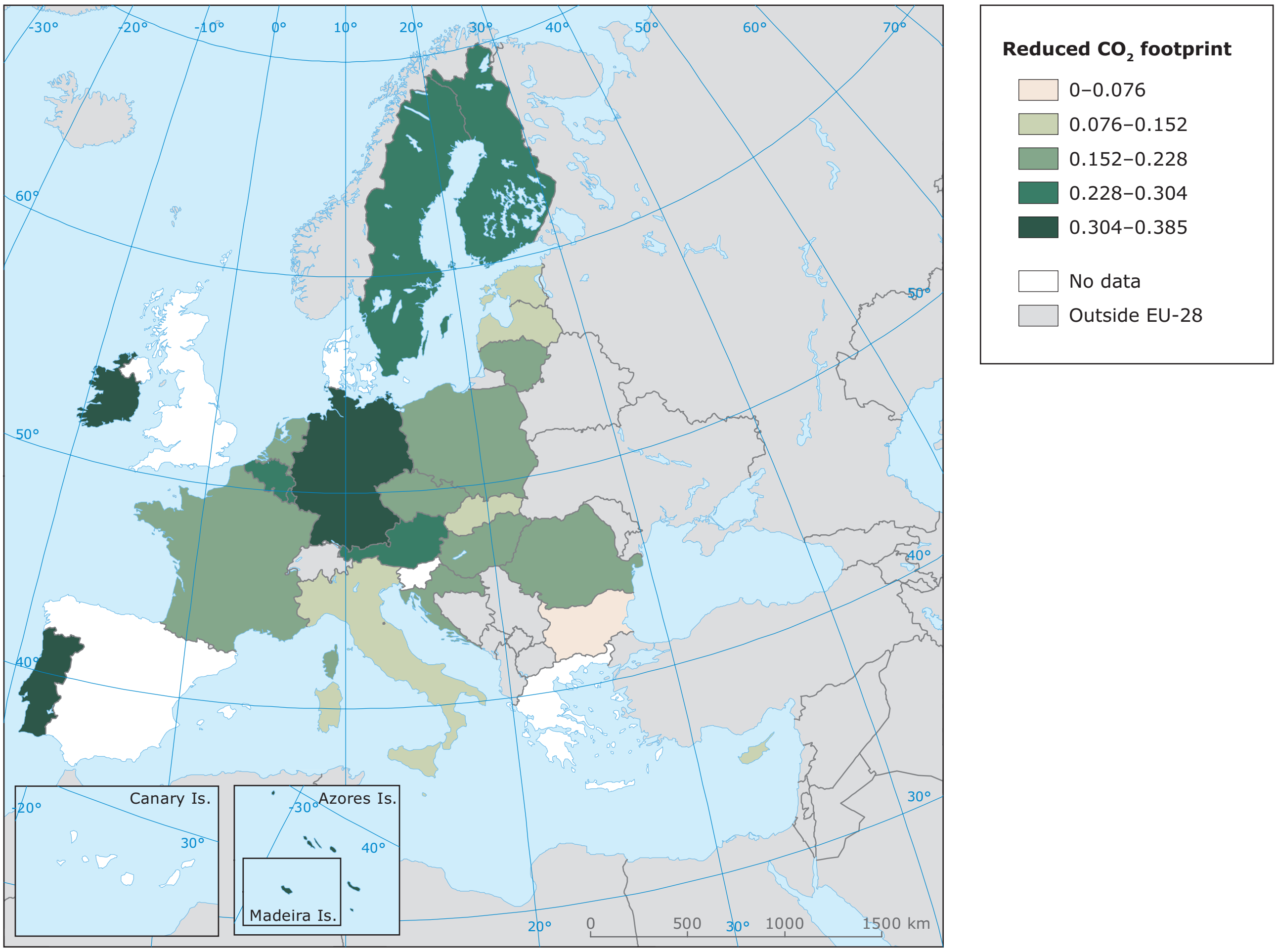
CO_2/VA performance (Figure 5.3), and between eco-innovation for CO_2 abatement (ECOCO) and CO_2/VA performance (Figure 5.4) in the EU for 2006–2008. Overall, the data show a significant correlation between high adoption of eco-innovation and low CO_2/VA, with Germany being a good example. However, there are exceptions to this, which are valid for an average result for the EU.

The correlation is stronger for ECOCO, which is consistent with the more specific nature of the innovations that are directly aimed at reducing CO_2 footprints.

In summary, the adoption of eco-innovation in the energy efficiency and CO_2 abatement realms is positively correlated with environmental efficiency per unit of economic value, for example CO_2/VA, in the EU when looking at most recently available data for eco-innovation adoption (2006–2008). Two key trends emerge from the data:

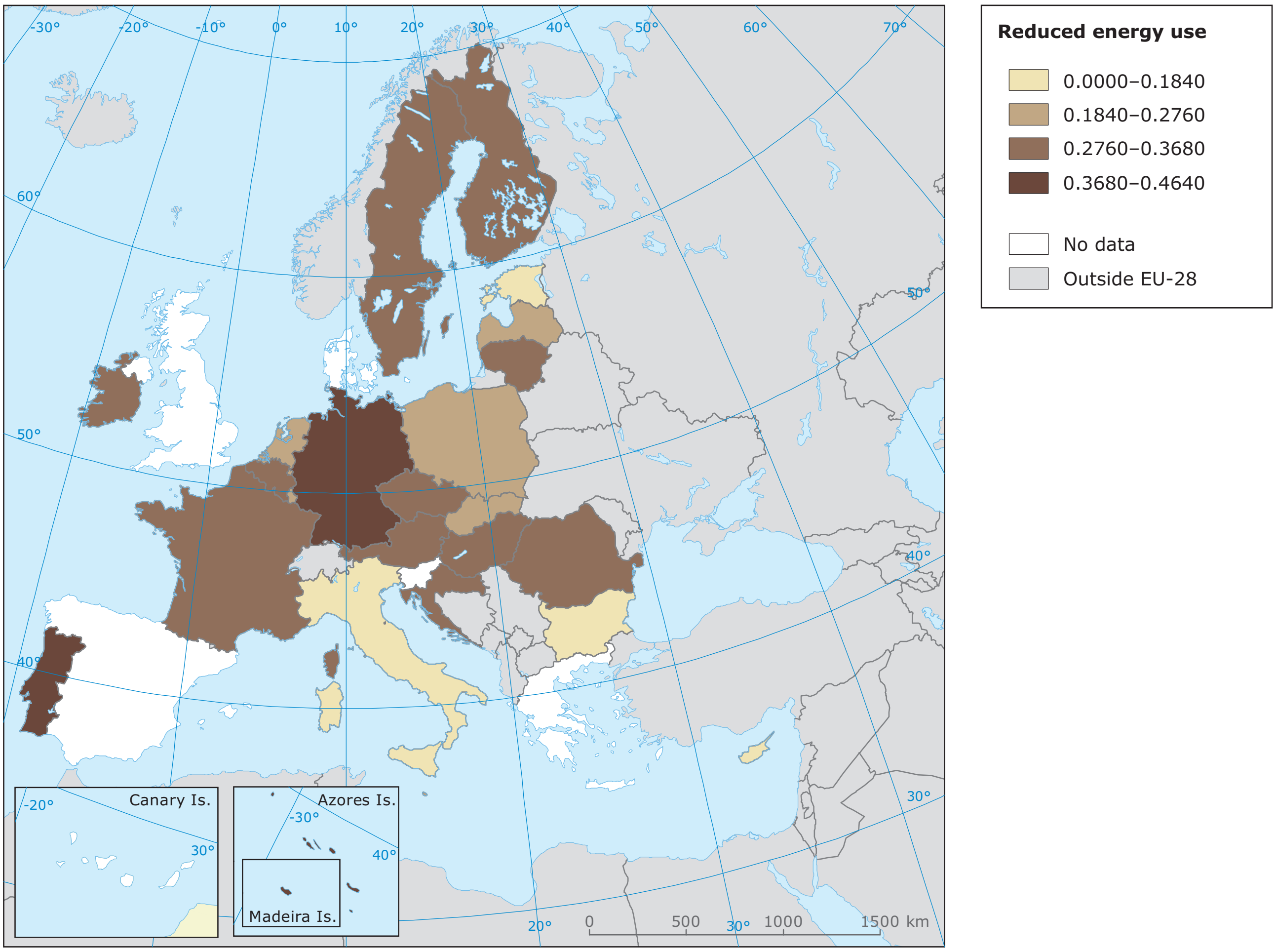
- Countries with lower CO_2/VA indicators typically have a higher adoption of eco-innovation. The relationship is slightly stronger for CO_2 abatement than energy efficiency innovation. Although there is a gap between innovation leaders and laggards, there are leaders among large countries, for example, Germany, and smaller/less industrialised countries, Ireland and Portugal. Some key EU Member States such as Italy show poor innovation adoption in 2006–2008, the years the CIS covers.
- Given the relatively low share of firms that adopt eco-innovation in many countries, there is room for more eco-innovation adoption and diffusion, especially in laggard countries. Higher adoption and diffusion of eco-innovation will further reduce CO_2/VA indicators across the EU. This is scope for eco-innovation oriented policy design in environmental and innovation domains.

Map 5.2 Adoption of CO_2 footprint-reducing innovations (share of firms in a country that have introduced eco-innovations to reduce the CO_2 footprint, average 2006–2008)



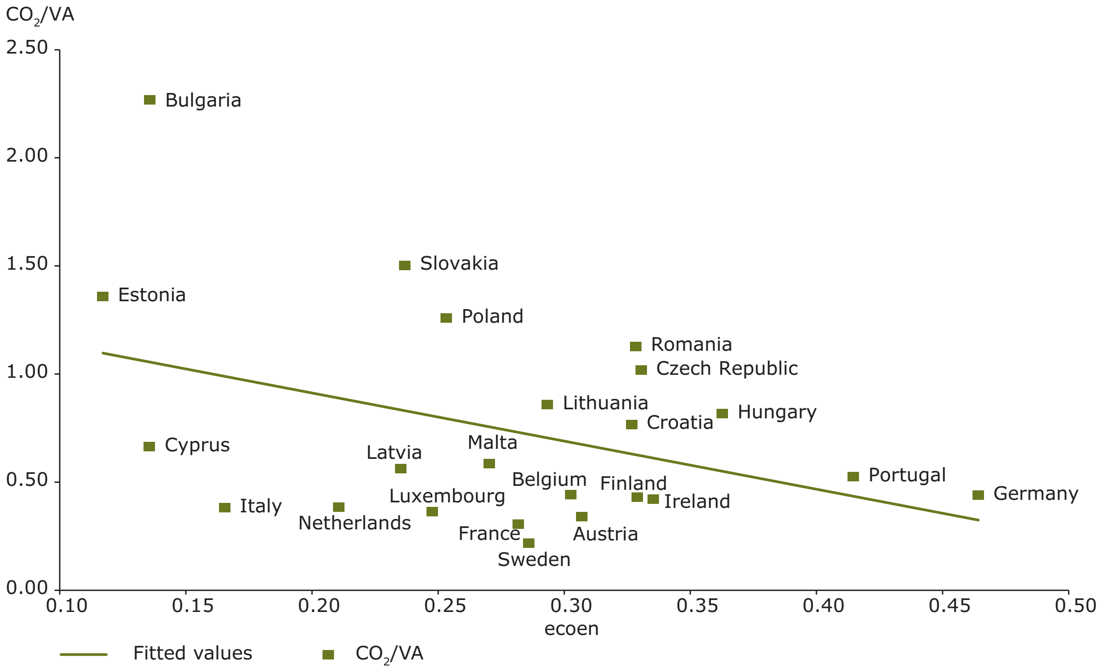
Source: Authors based on Eurostat data.

Map 5.3 **Adoption of innovation aimed at reducing energy use per unit of output (share of companies in a country that have introduced eco-innovations to enhance energy efficiency in production processes, average 2006–2008)**



Source: Authors based on Eurostat data.

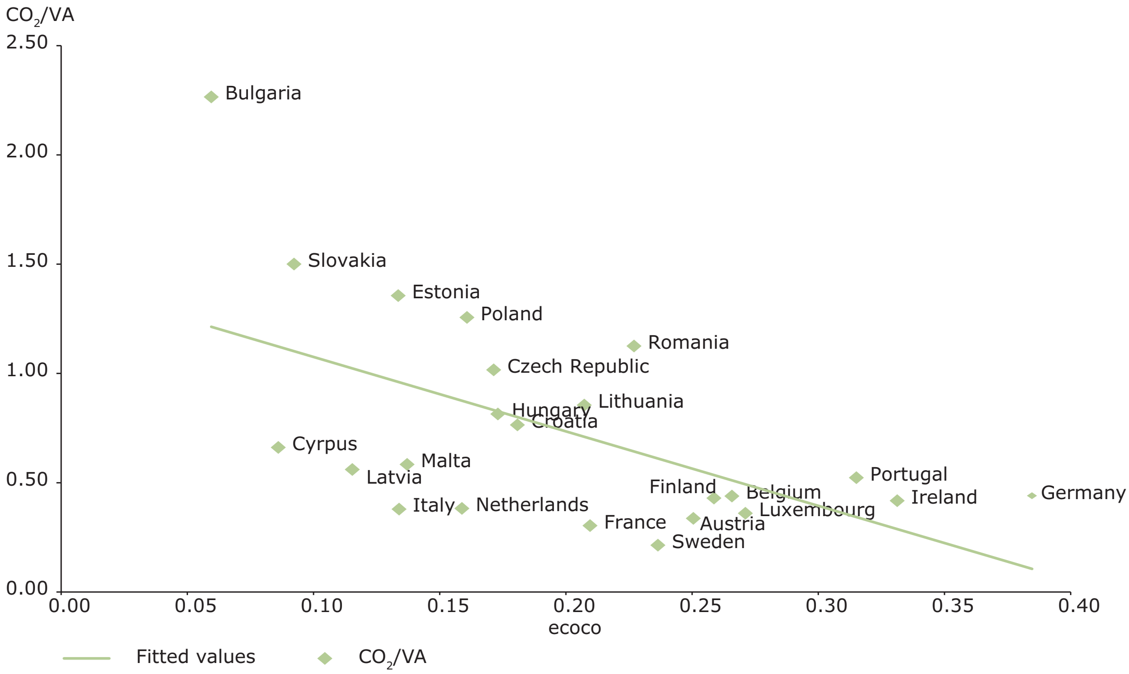
Figure 5.3 CO_2/VA (1 000 tonnes CO_2 per EUR 1 million, 2008) and eco-innovation adoption in energy efficiency (ECOEN, average 2006–2008)



Note: EU Member States covered by CIS survey; regression coefficient: – 2.096, statistically significant, 5 % tolerance.

Source: Authors based on Eurostat data.

Figure 5.4 CO_2/VA (1 000 tonnes CO_2 per EUR 1 million) and eco-innovation adoption for CO_2 abatement (ECOCO, average 2006–2008)



Note: EU Member States covered by CIS survey; regression coefficient: – 3.120, statistically significant, 5 % tolerance.

Source: Authors based on Eurostat data.

5.4 Barriers to eco-innovation

Companies can face significant barriers to adopting eco-innovation. These are critical in preventing the effectiveness of EU strategies, policy implementation, and company green strategies. And although eco-innovation barriers may be similar to conventional innovation barriers, they, and companies' reactions to them, may have specific features.

Many policies concerning the environment, natural resources and energy can explicitly, for example by technical standards, or implicitly, for example by economic instruments like taxation, drive companies to adopt innovative technological or organisational solutions in order to comply with these policies. But compliance does not necessarily provide the same economic benefits as conventional innovation strategies undertaken by companies as a result of market-only incentives. However, because of the increasing economic value of environmental improvements for many companies and the development of green markets, a transition from policy- to market-driven eco-innovation is now under way. Discussions of this transition refer to the Porter Hypothesis (Porter, 1991; Porter and van der Linde, 1995; Porter and Esty, 1998), which suggests that better environmental performance as well as eco-innovation strategies can be a source of competitive advantage for companies ([53]).

Information on barriers to eco-innovation faced by companies is limited. Data from the 2011 Flash Eurobarometer on attitudes of European entrepreneurs towards eco-innovation ([54]) can be used to get an understanding of how barriers to eco-innovation work, especially in SMEs. The interviews addressed 5 222 managers of SMEs in the EU-27 (NACE sectors A, C, E, F, I-56). The SMEs highlight that of the 14 types of barrier proposed in the interviews the most important are financing and funding; around 60 % say that their access to subsidies and fiscal incentives is insufficient. Another barrier is the uncertainty of market demand during the eco-innovation payback period, which makes the uptake of eco-innovation an uncertain business. Small companies are more sensitive to these barriers than medium-sized firms. These results mainly hold true for SMEs, which may see limited benefits from complex eco-innovation strategies, including corporate social responsibility (CSR), which is more typically the preserve of large companies in sensitive sectors, such as chemicals and energy.

However, the same SMEs facing barriers do investment in green R&D and adopt eco-innovations. To understand the relationship between perceived barriers and eco-innovation investments, Marin et al. (2014) identified six clusters of SMEs, each representing a typical combination of barriers and green investment behaviour ([55]).

Companies in the first cluster perceive the whole spectrum of barriers to eco-innovation as highly significant. Nevertheless, investment in green R&D is relatively high.

Companies in the second cluster are characterised by significant obstacles related to costs, market and knowledge. Unlike those in the first cluster, they have low investment in green R&D. Thus barriers are actual obstacles that prevent these firms from engaging in eco-innovation.

Companies in the third cluster report relatively high obstacles related to eco-innovation financing and costs, but relatively low barriers related to markets and knowledge. Their investment in green R&D is lower than average.

Companies in the fourth cluster perceive relatively low-cost and knowledge barriers to adopting eco-innovation, and typically spend less than the average on R&D. For them, market mechanisms do not provide enough incentive to encourage adoption of eco-innovation.

The companies in the fifth cluster are characterised by low levels of perceived barriers but also a very low level of green R&D.

([53]) More specifically, with imperfect information, complexity, and uncertainty, environmental issues and/or well-designed environmental policies can reveal hidden private benefits, even those associated with the production of environmental public goods. Quasi-rents associated with green innovation can enlarge the benefits.

([54]) The survey was conducted by The Gallup Organization and can be downloaded at www.ec.europa.eu/public_opinion/flash/fl_315_en.pdf.

([55]) The analysis is on a sub-set of 2 308 SMEs in EU-27 countries included in Eurobarometer (2011). The clustering technique (hierarchical cluster) allows to put each of the firms into one cluster or another according to its declared perception of 14 categories of barriers (grouped into cost, market and knowledge barriers), its green R&D investments, and its declared adoption of green innovations. The clustering procedure gives rise to six clusters that correspond to six different types of firms in terms of both perception of barriers and reactions to them.

The companies in the sixth cluster manage to achieve a high investment in green R&D while reporting medium-level obstacles to eco-innovation.

Table 5.1 organises these clusters, using the names assigned in Marin et al. (2014), in terms of barriers, green R&D engagement, and eco-innovation adoption. The two best-performing clusters in terms of adoption are Cluster 1: 'revealed barriers' (high barriers, high R&D, and high eco-innovation adoption) and Cluster 6: 'green champions' (medium barriers, very high R&D, and very high eco-innovation adoption). The two worst-performing clusters are Cluster 2: 'deterring barriers (high barriers, low R&D, and very low eco-innovation adoption) and Cluster 5: 'non innovators' (low barriers, very low R&D, and low eco-innovation adoption). In the middle is Cluster 3: 'cost deterred' and Cluster 4: 'market deterred', both of which show medium-level barriers, medium levels of R&D engagement, and medium levels of eco-innovation adoption.

These results highlight the diversity of companies in terms of perception, capabilities, and willingness to eco-innovate when faced with barriers. Even SMEs in similar industrial environments in the same country may perceive barriers and react to them in different ways, reducing the predictability of eco-innovation outcomes at the meso- and macro-level. Taking this diversity into account may reduce the risk of unsuccessful strategies.

EU strategies for eco-innovation should therefore look at barriers in a more specific way. Sectoral environmental policies often call for, or, *de facto*, impose company-level eco-innovation — from invention to adoption. But the evidence shows that one cannot expect a uniform response by companies because of their different perceptions of barriers and obstacles, even in the same sector, country, and size group. Innovative policy approaches more tailored to the different capabilities of companies should therefore be considered when environmental policy calls for eco-innovation.

Table 5.1 Clusters in terms of barriers, green R&D engagement, and eco-innovation adoption — product or process (indices from cluster analysis) [56]

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Total
	Revealed barriers	Deterring barriers	Cost deterred	Market deterred	Non innovators	Green champions	
	(N = 447)	(N = 434)	(N = 408)	(N = 463)	(N = 331)	(N = 225)	(N = 2 308)
Cost barriers	2.404	2.443	2.094	1.24	0.459	1.304	1.737
Knowledge barriers	2.023	2.042	1.147	1.205	0.364	0.96	1.366
Market barriers	2.2	2.18	1.233	1.619	0.558	1.311	1.587
Green R&D engagement	2.566	0.691	1.216	1.037	0.934	3.569	1.532
Adoption of eco-innovation product or process	0.619	0.26	0.399	0.387	0.231	0.731	0.422

Source: Marin et al., 2014.

([56]) The higher index the worse for cost, knowledge, and market barriers; the higher index the better for Green R&D engagement and Adoption of eco-innovation product or process.

5.5 Main conclusions

- 'Directed' technological change towards saving resources and reducing emissions matters more than macro-level structural change, for example a change of sector mix, in creating a resource-efficient economy. This is consistent with the non-critical role to be assigned to services for the green economy shift, as highlighted in Chapter 4.

- The benefits of innovation at the macro-scale can only be realised as a result of adoption and diffusion processes decided by firms and economic actors as a result of incentives coming from policies and/or markets and prices.

- The analysis of EU Community Innovation Survey (CIS) data for eco-innovation adoption by EU firms — for energy efficiency and carbon dioxide abatement — suggests that adoption is positively correlated to the emission efficiency of the countries where the companies are based. There are structural differences in this correlation across EU Member States, with leaders and laggards. There is room for higher eco-innovation adoption and diffusion in the EU, both in leading and lagging countries.

- Small and medium enterprises, which represent a large part of the EU industrial system, face a range of barriers — finance, costs, capabilities, etc. — to investing in eco-innovation and adopting available eco-innovation. Their small size can exacerbate the difficulties. However, firms facing the same level of barriers can have very different eco-innovation investment and adoption rates. These differences are policy-relevant in that policies addressing eco-innovation may have different outcomes depending on the response of the firms, and diffusion rates may not be fully predictable.

- Adoption and diffusion of green innovations can be a powerful level for a green economy transition strategy, possibly more significant in terms of outcomes than green invention, which nevertheless continuously feeds the reservoir of innovative options and solutions.

6 Green technology, trade and knowledge transfer

Technology and innovation are increasingly seen as knowledge, particularly as a form of useful knowledge (Mokyr, 2002), and major EU innovation and competitiveness strategies, from the Lisbon Strategy to Europe 2020, point the way to the creation of a knowledge-based economy. Green innovation can be seen as a selective form of new knowledge and the green economy can be seen as a green knowledge-based economy.

The statement of the 2012 Rio+20 conference on *The future we want* (UN, 2012) accorded a special role to the green economy in international cooperation for development. The EU has long stressed the importance of promoting the spread of green technologies and green knowledge to countries elsewhere.

The environmental implications of European trade patterns were examined in Chapter 4. In this chapter, the focus is on trade and other forms of exchange through which green (technological) knowledge, originating in the EU, is diffused internationally and through which green knowledge from other regions is received by the EU. This circulation of green knowledge can also reduce the global environmental footprint of Europe by improving international technological standards.

The three main channels of green knowledge transfer considered in this chapter are:

1. transfer via European trade of green technologies — embodied green knowledge;

2. international transfer of EU green intellectual property rights — disembodied green knowledge;

3. export of environmental regulation, through which European standards and regulations are imitated elsewhere.

Because they can drive a global green economy, the main focus of these channels should be on the open circulation of green knowledge, alongside the generation of commercial benefits for the EU.

6.1 European trade in environmental goods — embodied green knowledge

The EU plays a central role in the trade in manufactured goods and services. Trade among EU Member States represented about a quarter of world trade in manufactured goods in 2011 while intra-regional trade in Asia and North America accounted for about 17 % and 4 % respectively (EC, 2013). Almost half of all world trade — in goods and services, high and low value added (VA) — is between EU-27 and other high-income countries. China plays a prominent role in the group of BRIC countries (Brazil, Russia, India and China) because more than half of EU imports of furniture, leather and footwear and more than 40 % of clothing, computer, electronic and optical equipment, non-metallic mineral products, and metal products of EU imports come from China (EC, 2013).

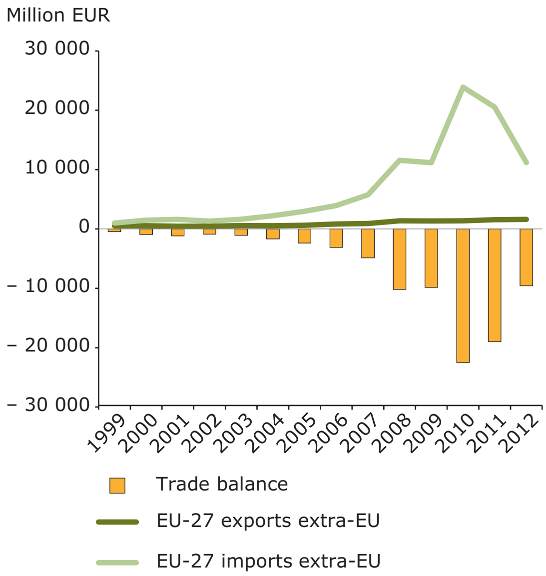
A number of bodies have proposed definitions of traded environmental goods, including green technologies, but these classifications have not been universally adopted (UNEP, 2013; Annex 4). Using OECD and Asia-Pacific Economic Cooperation (APEC) lists, UNEP compiled a list of traded environmental goods and calculated that the total export value of environmental goods more than doubled between 2001 and 2007 (UNEP, 2013) with developed and developing countries showing similar levels of growth. As EU and non-EU national priorities shift toward mitigating environmental damage, emerging/developing economies have become significant players in the production and trade of various clean technologies (UNEP, 2013).

The role of the EU in the trade of green technology goods is complex and evolving. An example is solar energy technologies ([57]). The international trade in EU-27 solar technologies is dominated by photovoltaic technologies. From 2006–2007, EU-27 international trade in these technologies, in particular photovoltaic cells, increased both in absolute value and as a share of EU-27 overall trade. Both intra- and extra-EU trade flows increased. For photovoltaic cells, and related technologies, intra-EU trade (exports) reached EUR 13.5 billion Euro in 2011 from very low levels just 10 years before (Figure 6.1).

In this same sector, imports from countries outside the EU-27 reached EUR 20.5 billion in 2010 with a trade deficit of around EUR 20 billion in 2010–2011, of which around EUR 15 billion was with China (Figure 6.2).

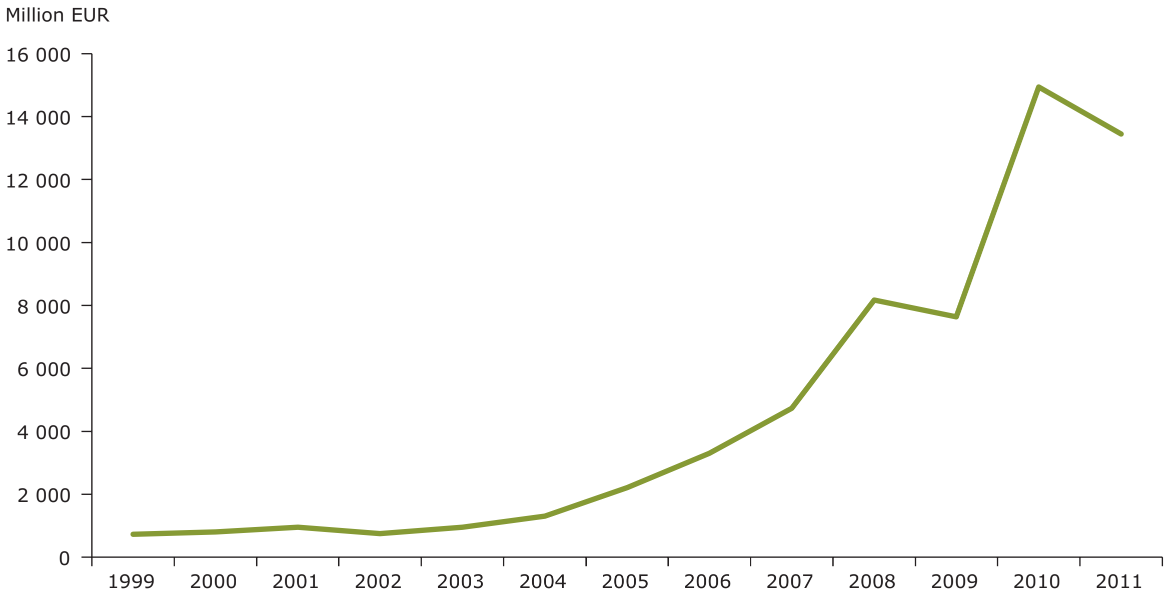
The drivers of these increasing trade flows are the development of renewable energy technology policies in the EU, which have created a strong demand for green technology goods through mandatory targets, such as the requirement for renewable energy to account for 20 % of final

Figure 6.2 Trend of trade in solar cells, code 8541.40, between the EU-27 and extra-EU countries, 1999–2011



Source: Authors based on COMEXT data.

Figure 6.1 Trend of intra-EU-27 trade (export) of solar cells, code 8541.40, 1999–2011



Source: Authors based on COMEXT data ([58]).

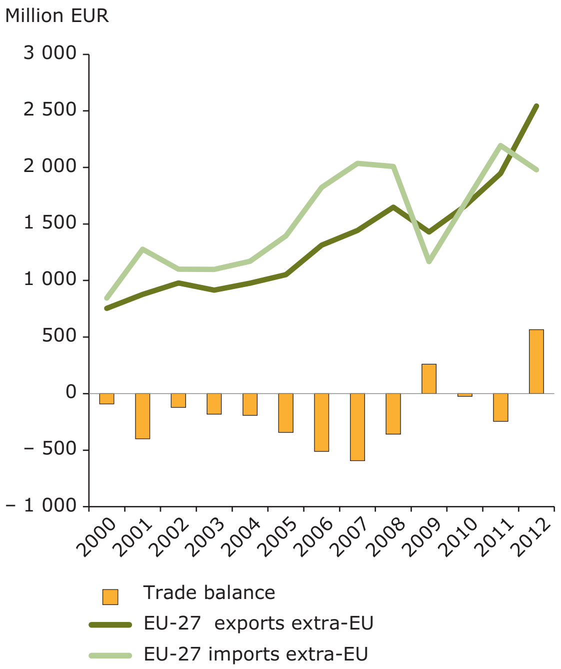
([57]) See ETC/SCP (2012) for a detailed analysis. The trade classification codes for solar technologies are: 8419.11 Instantaneous gas water heaters; (ex) 8419.19 Other instantaneous or storage water heaters, non-electric (Solar water heaters); (ex) 8541.40 Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light-emitting diodes (Solar cells). The data are elaborated from COMEXT for 1999–2011 for the single EU-27 countries and EU-27 aggregate, for both intra-EU and extra-EU trade. Major extra-EU trading partners, including China, are considered.

([58]) http://epp.eurostat.ec.europa.eu/newxtweb.

energy consumption by 2020. This driver seems first to have stimulated an increase in intra-EU trade, in which Germany took the lead as an exporter. In a subsequent phase, there was strong import penetration from China, with leading EU exporters, Germany and Spain ([59]), becoming importers from China ([60]). In spite of this, Germany maintains small export flows both to other EU Member States and to China, which suggests that there is technological diversity — quality, knowledge — within each product group.

The role of policy drivers can also be seen from the entry of Italy in the last few years as one of the main importers of solar technologies. The jump in installed photovoltaic capacity in Italy during 2009–2011 has been increasingly met by imports from China. According to UN COMTRADE data, in 2011, the value of Italian imports from China reached the 47 % of the total value of world imports of photovoltaic from China, from only 2.5 % in 1999.

Figure 6.3 Trend of trade of filtering or purifying machinery and apparatus for gases, code 8421.39, between EU-27 and non-EU-27 countries, 2000–2012

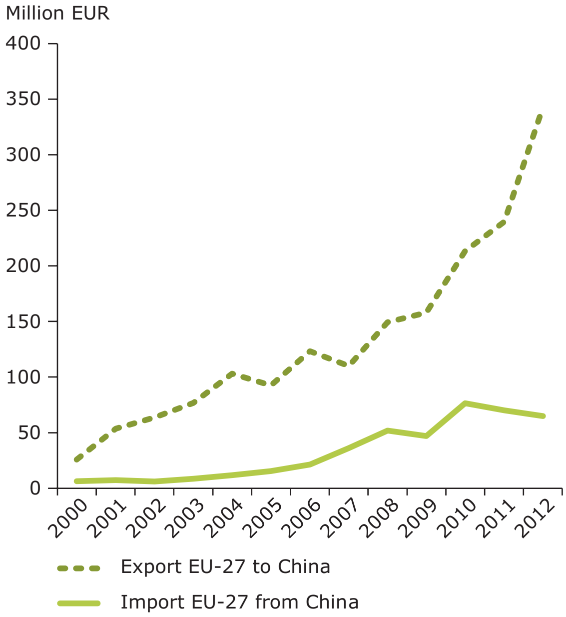


Source: Authors based on COMEXT data.

This surge in imports from outside the EU-27 has far-reaching effects beyond purely environmental ones. For example, the trade deficit for solar technologies has now achieved macro-economic significance and is already part of the debate on the implications of policy support for renewable energy sources (RES) in the EU. Recently, in December 2013, the EU approved a deal with China to limit EU imports of Chinese solar panels with an agreement that sets a minimum price and a volume limit until the end of 2015.

Different trends have emerged for other green technologies, for which the EU increased its role as an exporter to non-EU Member States. For example, for technologies related to filtering or purifying machinery for gases for pollution control (Figure 6.3), exports from EU Member States to the rest of the world show an increasing trend, exceeding imports of the same goods from the rest of the world since 2009. The EU is a net exporter of these technologies to China, with exports increasing steadily from 2000–2012 (Figure 6.4).

Figure 6.4 Trend of trade of filtering or purifying machinery and apparatus for gases, code 8421.39, between EU-27 and China, 2000–2012



Source: Authors based on COMTRADE data.

([59]) For further details of the role of China in renewable technology see Cao and Grabo, 2012.

([60]) EC (2011) stresses that it may seem as if China has become one of the most important trading partners of the EU in high technology goods but the apparently high comparative advantage of China may not be real since China exports proportionally more technology-intensive goods, but a large share of their content is imported from developed countries. The data on trade of intermediate goods shows that China is still more an assembler than a producer of high technology goods (EC, 2011).

6.2 Transfer of environmental technological knowledge — disembodied green knowledge

International patenting is a channel through which the transfer and diffusion of green technology around the world can be observed and quantified (Maskus, 2004). It therefore provides a useful insight into flows of environmental knowledge, an example of disembodied knowledge, around the world. Unless applicants claim for protection in foreign patent offices, through international patenting, patent protection is valid only within the boundaries of the country in which the inventor filed the application. But extending protection abroad is expensive, and generally takes between one and three years. Applicants generally, therefore, file first in their own country, and then extend protection only if they expect to have a high economic return from the patent, or if they think their patent might be particularly relevant in a given foreign country.

A side-effect of this international patenting process is that, along with extended protection, international patenting implies the transfer of knowledge about the technological content of new inventions. Thus, international patenting or patent families ([61]) can be used as a proxy for environmental technology transfer ([62]).

In this section, we consider a specific patent family that is filed at the European Patent Office (EPO ([63])). Patents filed at the EPO give protection in all EU-27 Member States only. The data used in this section are from the OECD and refer mainly to three categories:

1. green technologies as a whole ([64]);
2. waste technologies; and
3. renewable energy technologies ([65]).

Trends in international green patenting across European countries are presented in Table 6.1, through a ranking of the residence of the main inventors of green patents, renewables and waste-related technologies for 2001–2010. The data show that green innovation as represented by international patents is highly concentrated in a few countries. The four countries with the most patent applications account for about 75 % of total green inventions, although this dominance is slightly less pronounced for renewables and waste. However, even in these two categories the top four countries account for more than the 60 % of total patented innovation.

Table 6.2 presents a complementary analysis obtained by dividing the total number of patent applications filed at the EPO by the average national GDP per person for 2000–2010. Table 6.1 and Table 6.2 show a fairly similar ranking of countries, suggesting that high-income countries have a higher propensity to patent than average.

Figure 6.5 shows the numbers of EU patent applications in green technologies, renewables and waste technologies for 1978–2010: all three categories show an increasing trend. The number of waste-related patents in 2010 was four times that in 1978. The rate of increase in the other two technologies was much larger, about 10 times for green innovation and 14 for renewables.

For renewables and total green patents, the trends can be divided into two parts: fairly stable

([61]) OECD uses the term 'patent family' as '*a set of patents taken in various countries to protect a single invention (when a first application in a country — the priority — is then extended to other offices)*'.

([62]) As suggested in Dechezleprêtre et al. (2010), technological transfer operates through three different channels: trade in goods, international technology diffusion via foreign direct investment (FDI) and licensing. The authors conclude that patent data for which protection has been sought worldwide can be valuable because '*patent protection is relied upon for technology transfers along all three channels — trade, FDI, and licensing — as such transfers raise a risk of leakage and imitation in recipient countries*', and as a consequence patent data can be used as a proxy for international technology diffusion. However, there are limitations to using patent data as a proxy for innovation. A brief review on the pros and cons of using it as a proxy of environmental innovation can be found in Popp (2005).

([63]) If applicants chose to apply at the European Patent Office (EPO), rather than applying to individual patent offices, they can designate as many of the EPO member-states for protection as desired. The application is then examined by the EPO. If granted, the patent is transferred to the individual national patent offices designated for protection. Because EPO applications are more expensive, European inventors typically first file a patent application in their home country, and then apply to the EPO if they desire protection in multiple European countries. Since 1997, designation of any additional member states is free after the first seven. Since 2004, all EPO states are automatically designated.

([64]) This category includes: air and water pollution abatement, waste management, energy generation from renewables and non-fossil fuels, combustion technologies with mitigation potential, technologies specific for climate change mitigation, technologies with potential or indirect contribution to emission mitigation, emission abatement and fuel efficiency in transportation, energy efficiency in building and lighting.

([65]) These subgroups are created using the IPC system, and the counts of patent family are sorted by priority year — the year of first filing — and the applicant's country of residence.

Table 6.1 Residence of the main inventors of international green patents in the EU (% share, 2001–2010)

Member State	Green technologies (%)	Cumulative green technologies (%)	Renewables (%)	Cumulative renewables (%)	Waste (%)	Cumulative waste (%)
Germany	48.2		41.9		29.4	
France	13.8	62.0	9.6	51.4	11.7	41.1
United Kingdom	6.9	68.9	7.7	59.1	9.7	50.8
Italy	6.5	75.4	5.6	64.8	13.3	64.1
Netherlands	6.0	81.4	5.8	70.6	8.0	72.1
Sweden	3.8	85.2	2.8	73.4	3.0	75.0
Denmark	3.5	88.7	9.7	83.1	2.2	77.2
Austria	2.7	91.4	3.1	86.2	5.2	82.4
Spain	2.1	93.5	5.8	92.0	4.1	86.6
Finland	2.0	95.4	2.0	94.0	4.8	91.4
Belgium	1.7	97.2	2.4	96.4	2.8	94.3
Luxembourg	1.0	98.2	0.6	96.9	1.2	95.4
Ireland	0.6	98.7	1.1	98.0	1.2	96.6
Others	1.3	100.0	2.0	100.0	3.4	100.0

Source: Authors based on OECDStatExtract, http://stats.oecd.org.

Table 6.2 Ratio of international patents applications to GDP per person, average, 2001–2010

Member State	Green technologies/ GDP per person	Renewables/ GDP per person	Waste/ GDP per person
Germany	58.1	9.8	2.6
France	18.0	2.4	1.1
Italy	8.9	1.5	1.3
United Kingdom	8.1	1.8	0.8
Netherlands	6.5	1.2	0.6
Sweden	4.5	0.7	0.3
Denmark	4.1	2.2	0.2
Austria	3.1	0.7	0.4
Spain	3.0	1.6	0.4
Finland	2.5	0.5	0.4
Belgium	2.1	0.6	0.2
Ireland	0.6	0.2	0.1
Luxembourg	0.6	0.1	0.0

Note: GDP data are taken from the OECD and measured per person in constant prices, constant PPPs. The final index has been multiplied by 1 000.

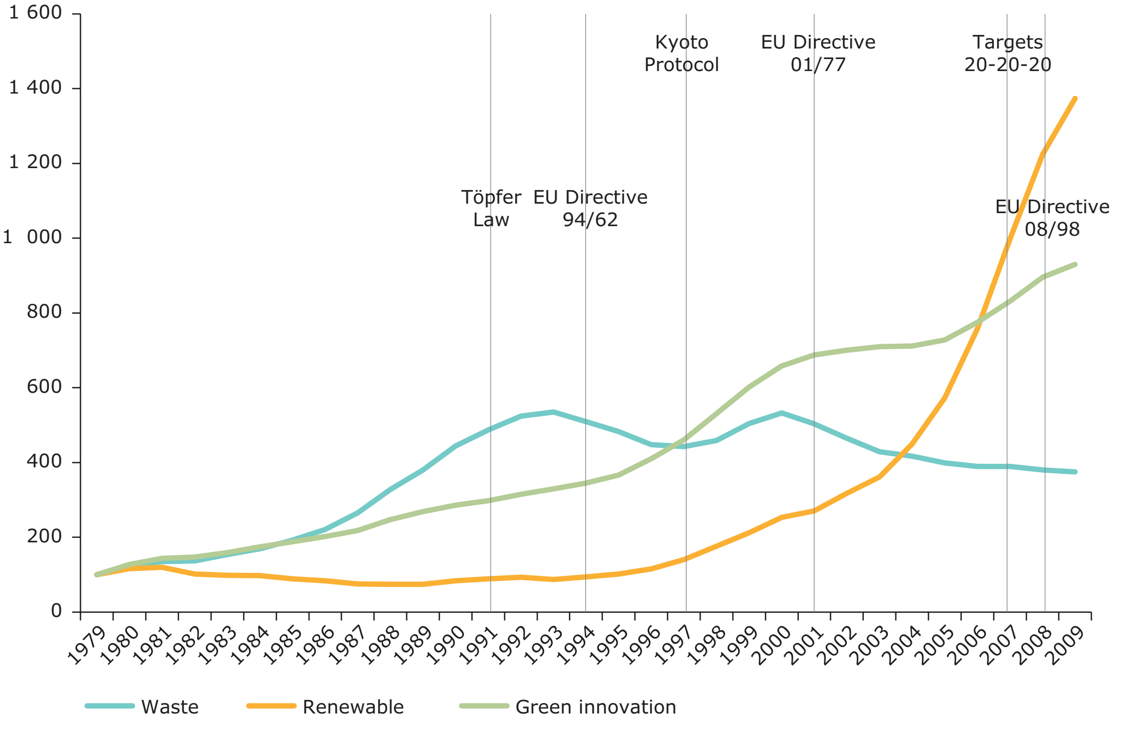
Source: Authors based on OECDStatExtract, available at http://stats.oecd.org.

innovation followed by rapid increase, explained by the propensity to seek patent protection abroad — to claim for protection against unauthorised use of the patent's intellectual property outside the home country and consequently promote forms of technological transfer. In contrast, waste patenting shows rapid expansion until 1993 and then stabilises at a level above that in 1978.

The growth activity surrounding renewable energy reflects policy initiatives in this sector. Several studies (Johnstone et al., 2010; Popp et al., 2011) stress the fundamental role of the Kyoto Protocol in promoting patenting, especially in renewable energy. Moreover, the years between 1998 and 2002 coincided with a second wave of energy policies, culminating in Directive 2001/77/EC on renewable energy in the electricity sector. Finally, the adoption of the 20-20-20 targets in the climate and energy package in the late 2000s may have influenced patenting activity by raising expectations about the future role of renewable energy. The effect of these policy initiatives can be clearly seen in renewables: the years 1997–1998 represented a real turning point in innovation activity, a change also clearly visible in the trend of total green patents seen in Figure 6.5.

However, innovation in waste management shows a completely different trend. On average waste patents seem to respond less consistently to policy stimuli than other green technologies. Patent applications for waste grew rapidly in the 1980s, peaked in the early 1990s, and then fell off, suggesting a general maturity of the sector [66]. The surge in patenting at the end of the 1980s and the beginning of the 1990s was entirely driven by Germany, which enacted several important pieces of legislation, the most important being the Töpfer Law [67] (Nicolli and Mazzanti, 2011). In contrast, later EU policy interventions, such as the EU

Figure 6.5 Trend in patenting activity (applications) with European coverage for three selected groups: green innovation, renewable energy sources and waste, (index 1978 = 100, three-year moving average)



Source: Authors based on OECDStatExtract, available at http://stats.oecd.org.

[66] This result is in line with a previous work by Nicolli and Mazzanti (2011), using data drawn from single patent offices, which as a consequence do not account for technology spill-overs, who found a similar result, namely that the waste sector has entered a phase of general technological maturity in the past 10 years.

[67] Before this act, the 1986 Waste avoidance and Waste management act (Abfallgesetz) was also important (Fishbein, 1994).

Directive 94/62, had a much weaker effect. Although the rate of patenting decreased slowly after 1994, it stabilised at a level four to six times higher than before the policy interventions. Any effects of the new Waste Framework Directive (2008/98) can only be expected to take place in the future.

Table 6.3 presents a breakdown of the three broad sectors and the specific technologies of which they are composed for 1981–1990, 1991–2000, and 2001–2010.

In the green innovation category, technologies specific to climate change mitigation are the most important, with 28 % of total green patents in the period 2001–2010, followed by emissions abatement, fuel efficiency in transportation, and water and air pollution abatement. The share of these technologies within the wider green innovation category remains fairly stable across different decades, with the important exception of emissions abatement and fuel efficiency in transportation, which have nearly doubled their share in the last decade. The surge in patent applications for emissions abatement and fuel efficiency in transportation was in contrast to patents in waste management and water pollution abatement, both of which saw shares fall by more than half between the first and third decades.

In the renewables category, the most relevant and rapidly increasing technologies are solar photovoltaic and wind energy, while solar thermal energy has decreased its role.

Recycling is the dominant technology among waste technology patent applications.

Table 6.3 Share of each technology among green patents, OECD countries, average value for each decade

Green innovation — main technologies	**1981–1990**	**1991–2000**	**2001–2010**
Technologies specific to climate change mitigation	25 %	29 %	28 %
Emission abatement and fuel efficiency in transportation	8 %	6 %	17 %
Air pollution abatement from stationary sources	12 %	15 %	16 %
Energy generation from renewable and non-fossil sources	14 %	13 %	11 %
Technologies with potential or indirect contribution to emission mitigation	8 %	8 %	9 %
Waste management	17 %	14 %	8 %
Water pollution abatement	13 %	12 %	6 %
Combustion technologies with mitigation potential	2 %	2 %	2 %
Energy efficiency in buildings and lighting	1 %	1 %	2 %
Waste — main technologies			
Material recycling	40 %	43 %	45 %
Waste management — not classified elsewhere	20 %	21 %	18 %
Solid waste collection	14 %	13 %	16 %
Incineration and energy recovery	19 %	15 %	15 %
Fertilisers from waste	7 %	8 %	6 %
Renewables — main technologies			
Solar photovoltaic (PV) energy	43 %	53 %	44 %
Wind energy	13 %	16 %	29 %
Solar thermal energy	28 %	18 %	15 %
Marine energy excluding tidal	4 %	3 %	4 %
Hydro energy — tidal, stream or dams	2 %	2 %	3 %
Hydro energy — conventional	7 %	6 %	3 %
Geothermal energy	3 %	2 %	2 %

Source: Authors based on OECDStatExtract, available at http://stats.oecd.org.

The EU is also a recipient of green technological knowledge from other countries. In Table 6.4, each column shows the number of patents filed at the EPO by residents of non-EU countries, as a percentage of the total number of patents filed at the EPO by European inventors ([68]).

The table shows that Japan and the United States are the two countries that filed the most patents in Europe. In some technological fields the share of patents from these two countries together is more than the 90 % of the total patents filed in that field. The fields with high levels of US and Japanese innovation include energy-efficiency technologies in buildings and lighting and technologies that reduce emissions. This result is not surprising given that Japan and the US are usually leaders in cross-country comparisons of green technological innovation (Johnstone, 2011; Popp et al., 2011).

Technologies related to renewables, transportation, and lighting and building all have high shares of extra-EU knowledge flow between 20 % and 120 % from Japan, 40 % and 80 % from the US, as well as from other countries. Other technologies are less dominated by extra-EU applicants, and include waste management, always less than 15 %, and to a lesser extent water pollution, a field in which only the US has a strong role. Finally, despite the increasing patenting trend that emerging economies like China have experienced in the past decade, the share of Chinese green patents at the EPO is still very limited. The only significant exception is in energy efficiency in buildings and lightning, where China has a 5.5 % share of patent applications.

6.3 Export of environmental regulations and standards

The EU's environmental standards for certain products and processes are increasingly being adopted elsewhere in the world, and have thus pushed the international adoption and diffusion of eco-innovation. These environmental standards promote eco-innovation in two main ways. First, higher environmental standards in the EU also affect production in countries that export to the EU, because the companies in these countries may have to adjust their export products to suit EU rules. Second, the EU's pioneering role in environmental protection can boost EU exports of products to countries outside the EU, as other countries often base their policies on the example of the market with the strictest environmental standards ([69]).

Table 6.4 Patents granted at the EPO filed by applicants outside the EU, % patents filed by non-EU residents to patents filed by EU residents, average for 2001–2010)

	AUS	C	J	CH	US	NZ	NO	CN
Environment-related patents (sum of all others)	1 %	2 %	27 %	2 %	21 %	0 %	1 %	1 %
Air pollution abatement (from stationary sources)	0 %	1 %	22 %	2 %	14 %	0 %	0 %	0 %
Combustion technologies with mitigation potential (using fossil fuels, biomass, waste, etc.)	1 %	1 %	12 %	7 %	31 %	0 %	1 %	1 %
Emission abatement and fuel efficiency in transportation	0 %	1 %	56 %	2 %	22 %	0 %	0 %	1 %
Energy efficiency in buildings and lighting	2 %	6 %	123 %	10 %	76 %	0 %	1 %	5 %
Energy generation from renewable and non-fossil sources	2 %	3 %	22 %	4 %	40 %	0 %	2 %	2 %
Technologies specific to climate change mitigation	0 %	0 %	1 %	0 %	2 %	0 %	0 %	0 %
Technologies with potential or indirect contribution to emission mitigation	1 %	4 %	71 %	4 %	47 %	0 %	0 %	3 %
Waste management	1 %	1 %	10 %	2 %	12 %	0 %	1 %	1 %
Water pollution abatement	3 %	4 %	17 %	5 %	35 %	0 %	1 %	2 %

Note: AUS: Australia, C: Canada, J: Japan, CH: Switzerland, US: United States, NZ: New Zealand, NO: Norway, CN: China.

Source: Authors based on OECDStatExtract, http://stats.oecd.org.

([68]) More than 100 % means that non-EU residents made more patent applications at EPO than European residents.
([69]) See Brack et al., 2000 for a discussion on environmental standards and WTO compatibility.

Multinational companies are an important agent of diffusion of environmental standards. This may happen through procurement contracts with local suppliers in foreign locations and also through the extension of internal environmental practices to affiliates in host countries. Perry and Singh (2001) found, in a survey of 89 transnational corporations across a range of industries in Singapore, that corporate environmental standards were the most frequently reported driver for environmental action by companies. Companies with operations all over the world may also encourage higher standards in non-EU countries so as to ensure that they do not lose market share in those countries. Birdsall and Wheeler (1993) provide an example of this: the Swiss company Nestlè found that once it began adhering to World Health Organization (WHO) marketing guidelines for infant formula, it started to lose market share in Indonesia. It therefore put heavy pressure on the Indonesian government to force all baby food manufacturers, domestic and foreign, to follow the WHO guidelines.

Jörgens (2003) analysed the worldwide trends of green plans and sustainable development strategies of a number of companies and showed how the mechanisms of diffusion and harmonisation regularly interacted with each other, leading to a process of mutual reinforcement. In their analysis of the spread of eco-labels, Tews et al. (2003) stressed that these are promoted by the dynamics of international trade. Assuming, at least in OECD countries, fairly homogeneous consumer preferences, eco-labelling schemes can help to ensure market share.

Emission standards are another way that European environmental regulations are exported to countries outside the EU. The standards for exhaust emissions of new vehicles that are in place in the EU include regulations on emissions of nitrogen oxides (NO_X), total hydrocarbon (THC), non-methane hydrocarbons (NMHC), carbon monoxide (CO) and particulates (PM).

Chinese emission standards for motor vehicles are based on European regulations. They were, however, adopted after a time delay ([70]) (Table 6.5). Euro 1 Emission standards for Light-Duty Vehicles, for example, were implemented in China in 2000, by which time Europe was implementing Euro 3 standards. Euro 4 standards were introduced in Europe in 2005 and were implemented in China in 2011 for gasoline and in 2013 for diesel vehicles. Some Chinese cities are moving more aggressively on regulations than the national government. Beijing, for example, implemented Euro 4 standards for light-duty vehicles in 2008, the year of the Beijing Olympics, and planned to introduce Euro 5-based standards from 2012.

Brazil is another country that has based its emission limits on EU regulations. It also provides an example of first-mover advantages for multinational companies with strong environmental regulations in their home market. From January 2012, emission standards for buses were increased to the Euro 5 standard ([71]).

The European emission standards for vehicles are an example of European standards being adopted by other countries. But there are also cases where a foreign standard has influenced European labelling. The energy star is one such example: the label was originally introduced in 1992 by the US Environmental Protection Agency (EPA), as a voluntary labelling programme. The aim was to guide customers into purchasing energy-efficient products and thus help protect the environment ([72]). This voluntary labelling programme started at the state level, as manufacturers of energy-inefficient products were able to block energy-efficiency standards in some but not in all states. After several years, the number of states that had introduced the energy star programme reached a tipping point, where companies started to lobby for the development of harmonised federal standards for the voluntary scheme, since this could save administrative costs.

The label has since been adopted by a range of countries — Australia, Canada, the EU, Japan, New Zealand, Taiwan, and Switzerland — and has become an international standard for energy-efficient consumer products.

The EU Energy Star programme follows an agreement between the government of the US and the EU on the coordination of voluntary energy labelling of office equipment. It is managed by the European Commission and was approved by the EU Council in 2003 ([73]). Brack et al. (2000) provide

([70]) See http://www.dieselnet.com/standards/cn.
([71]) See http://www.b4bschwaben.de/nachrichten/augsburg_artikel,-MAN-erhaelt-grossen-Auftrag-_arid,106090.html.
([72]) See http://www.energystar.gov/index.cfm?c=about.ab_history.
([73]) http://www.EU-energystar.org/en/index.html.

Table 6.5 Adoption of the EU's Euro emissions standards for road vehicles in Asian countries, 1995–2025

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
EU	E1	Euro 2					Euro 3				Euro 4			Euro 5					Euro 6												
HK ([a]), China	Euro 1		Euro 2				Euro 3					Euro 4			Euro 5																
South Korea												Euro 4			Euro 5																
China ([b])						Euro 1				Euro 2			Euro 3			Euro 4															
China ([c])					Euro 1			Euro 2			Euro 3			Euro 4				Euro 5													
Singapore ([b])	Euro 1						Euro 2																								
Singapore ([d])	Euro 1						Euro 2					Euro 4																			
India ([e])							Euro 1				Euro 2					Euro 3															
India ([f])					E1	Euro 2					Euro 3					Euro 4															
Thailand	Euro 1						Euro 2			Euro 3								Euro 4													
Malaysia			Euro 1												Euro 2				Euro 4												
Philippines									Euro 1				Euro 2								Euro 4										
Vietnam													Euro 2										Euro 4					Euro 5			
Indonesia											Euro 2																				
Bangladesh ([b])											Euro 2																				
Bangladesh ([d])											Euro 1																				
Pakistan															E2 ([b])		Euro 2 ([d])														
Sri Lanka									Euro 1																						
Nepal							Euro 1																								

Note: ([a]) Hong Kong.
([b]) Gasoline.
([c]) Beijing [Euro 1 (January 1999); Euro 2 (August 2002); Euro 3 (2005); Euro 4 (1 March 2008); Euro 5 (2012)], Shanghai [Euro 1 (2000); Euro 2 (March 2003); Euro 3 (2007); Euro 4 (2010)] and Guangzhou [Euro 1 (January 2000); Euro 2 (July 2004); Euro 3 (September–October 2006); Euro 4 (2010)].
([d]) Diesel.
([e]) Entire country.
([f]) Delhi, Mumbai, Kolkata, Chennai, Hyderabad, Bangalore, Lucknow, Kanpur, Agra, Surat, Ahmedabad, Pune and Sholapur.

Source: CAI, 2011.

an explanation for the late introduction of energy labelling in the EU, compared with the US. Unlike the US, which began the programme at the state level, the EU had tried to introduce harmonised standards for the whole Union from the outset, and it therefore took much longer.

The European Chemical Regulation, REACH, is a particularly interesting example of regulation export, as it has had such wide-ranging effects ([74]). Because all substances that are manufactured or marketed in the EU come under the Regulation, REACH also affects substances that are exported from and imported to the EU — these trade restrictions are not considered trade barriers under WTO rules. Thus REACH has implications for production and consumption of chemicals in third countries, even if they do not adopt the same

([74]) REACH is the EU-Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals and considered one of the strictest chemicals laws worldwide. It entered into force in June 2007. The Regulation places the burden of proof on companies. Manufacturers, importers and downstream users of chemicals must identify and manage the risks linked to the substances they manufacture and market in the EU. In addition, they have to communicate the risk management measures to the users, including clients in the supply chain. Firms are only allowed to produce and trade substances that are registered with the European Chemicals Agency (ECHA) in Helsinki.

regulations as the EU. Trading chemicals between EU Member States and countries outside the EU requires companies outside the EU to register and possibly substitute substances, to reappraise existing substances and to communicate the results of their appraisals to downstream users. In addition to the EU Member States, REACH has been adopted by Iceland, Liechtenstein and Norway, all part of the European Economic Area. Switzerland has not adopted REACH, but has adapted its own chemicals policy to the REACH Regulation to a great extent. Laws concerning chemicals are currently being amended in a number of countries outside the EU in order to align these laws more closely with REACH. Although none of these countries have fully adopted the European REACH Regulation, it has very often been one of the points that triggered and inspired further amendment in other countries ([75]).

In addition to the REACH legislation at the EU level, there have been some initiatives at the company or non-governmental organisation (NGO) level in setting up black lists of substances of very high concern (SVHC). Very often, these lists are based on criteria established under REACH.

Another EU Directive with direct implications for trade and other indirect effects on other countries is the Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic equipment (EU, 2003), also called the RoHS-Directive. The Directive directly affects exports to the EU, the countries of the European Free Trade Association (EFTA; Iceland, Liechtenstein, Norway, and Switzerland), and Turkey. It has also prompted several other countries to reform their own legislation on hazardous substances in EEE, and partly base this legislation on the European laws. Countries and states that have done this include South Korea, with its Act for Resource Recycling of Electrical and Electronic Equipment and Vehicles; California, with its Electronic Waste Recycling Act; Japan and China. Since standards for EEE are still quite different around the world, some international companies, including IBM and Hewlett-Packard, have adopted their own standards. These company-specific standards are a kind of strictest mix of national standards and allow the companies to distribute their products worldwide.

6.4 Main conclusions

- The total export value of environmental goods more than doubled in during the 2000s, with both developed and developing countries showing similar trends.

- The EU has a great openness for trade of green technologies. In some sectors the EU is a leader in global trade, while in others it has suffered import penetration after having leading production and trading roles. This is the case for renewable energy technologies, in particular photovoltaic cells, where domestic EU environmental policies were an important driver of both outgoing and incoming flows of green knowledge embodied in traded technological goods.

- Even international green patents — a form of disembodied green knowledge — see a dynamic and two-way role of EU economic actors. After the Kyoto Protocol, the number of international (European coverage) patent applications at EPO increased 2.5 times for all green technologies and 14 times for renewable energy technologies. A significant share of green patents at EPO is generated by non-EU residents from other industrialised and emerging countries, for example China.

- As well as being drivers of domestic green technological knowledge and its international diffusion, environmental policies have a range of effects on environmental standards of non-EU countries, including environmental regulation export. In some cases, for example air pollution from transport, EU environmental standards have been adopted around the world and have thus forced the related eco-innovation to be adopted and diffused. In other cases, countries that export to EU Member States with a high preference for green products have had to adjust their production standards accordingly, both to get access to the EU market and possibly enjoy a green price premium for their products.

- These developments suggest that open circulation of green knowledge can open new opportunities for commercial transactions and economic pay-off, and can benefit the international community as a whole in the development of a green economy.

([75]) For the difference between the so-called Japanese REACH and the EU REACH see http://enhesa.wordpress.com/2011/06/27/japanese-reach-now-fully-implemented.

7 The role of fiscal policies

Environmental taxes play a key role in promoting the shift to a green economy. By putting a price on environmental externalities, they can reduce pollution and increase resource efficiency in the most cost-effective way. They can help to promote behavioural change in consumers and in economic sectors. When environmental taxes are well-designed, they can achieve these objectives while also promoting economic growth. Finally, environmental taxes have an obvious fiscal benefit, providing governments with tax revenues. The revenues generated from environmental taxes could be used for different purposes:

- Reducing the budget deficit directly (fiscal consolidation). The sustainability of public finances against the background of the financial and economic crisis requires efforts by several EU Member States. Particular efforts will have to be made by some countries to meet the debt criterion, 60 % of GDP, and deficit criterion, 3 % of GDP, of the Maastricht Treaty.

- Tax shifting programmes — environmental or green fiscal reform. The aim here is to reduce the tax burden on labour — a 'good' — and to raise environmental taxes on environmental 'bads' such as pollution and the inefficient use of resources. This policy leads to a more efficient tax system as it shifts the burden from the most distortionary taxes to the least distortionary taxes.

- Financing support measures:

  - Environmental and especially energy and carbon taxes can impair the competitiveness of domestic industries. A means to offset these negative impacts is to use the revenues for compensating producers for the higher prices and costs. However, these compensations should be made conditional on producers undertaking energy efficiency improvements.
  - Compensating households for any unfair burdens imposed on the poor by environmental taxes ([76]).
  - Providing investment incentives aimed at stimulating innovation in resource productivity.

Not all of these options can be implemented simultaneously, and a mix of different options may be implemented depending on the actual economic and fiscal situation a country is facing. However, not all environmental taxes are appropriate for tax shifting programmes as they do not generate stable tax revenues over time as their principal objective is to incentivise green behaviour ([77]). Other environmental taxes are in contrast well-suited for these policy programmes as they generate stable tax revenues because they do not lead to major changes in the consumer behaviour as the demand for the taxed products is relatively inelastic. Taxes levied on energy products as well as on motor vehicles belong to this group.

It is also worth noting here that environmental taxes can be implemented in two principal ways: by broadening the tax base — taxing new activities (Box 7.1) as well as by increasing tax rates — both alternatives will lead to a higher environmental tax take.

7.1 Recent trends in environmental taxation in the EU

Although environmental taxation is increasingly raised in the economic debate in Europe, this has not yet resulted in the widespread application of environmental taxes, as evidenced by the sluggish growth of environmental tax revenues. During the period 1995–2012, EU-27 environmental tax

([76]) For a detailed discussion: EEA, 2011a.
([77]) One of the most successful environmental tax is the Irish plastic bag tax as the effects of this was dramatic as the use of plastic bags reduced by about 90 % after its introduction (Convery et al., 2007).

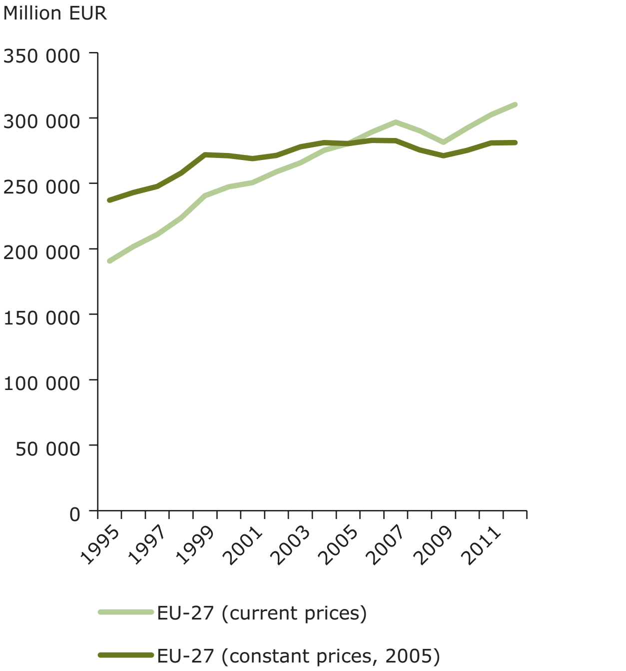
revenues increased by 63 %, an annual average increase of 2.9 %, in nominal terms (current prices) and by 19 % (an annual average increase of 1.0 %) in real terms (constant prices) (Figure 7.1). The respective GDP growth rates (annual average) at EU-27 level during this period were 3.4 % and 1.7 % respectively and the average annual growth of total tax take including social security contributions were the same. This implies that environmental taxes as a percentage of GDP fell from 2.8 % in 1999 to 2.3 % in 2008, and environmental taxes as a percentage of total tax revenues from 6.9 % to 5.9 %. Since then, a slight increase in the respective shares has been reported (Figure 7.2).

The composition of environmental tax revenues did not change during the period, with energy taxes contributing the largest share to the total (Figure 7.2). The economic and financial crisis accelerated the fall in the share of environmental taxes to GDP, as energy tax revenues fell on a year-on-year basis by 1.6 % in real terms in 2007 and by 2 % in 2008. The year-on-year decline in transport tax revenues was even greater during the crisis, 4.5 % in 2008 and 8 % in 2009.

As shown in the Figure 7.2, energy taxes, which include carbon pricing schemes, are generating the largest share of environmental tax revenues. And according to modelling exercises, revenues from carbon pricing schemes could be increased even further. One modelling exercise concludes: '*efficient carbon-pricing schemes could raise 0.75 % of GDP in advanced economies and 1.5 % of GDP in emerging economies within the next ten years, while targeted transfers could offset any impact on the poor*' (IMF, 2010). Other modelling results reveal an even higher revenue-raising potential of up to 2.3 % of GDP across countries if emissions could be cut by 20 % relative to 1990 by 2020 (Seres et al., 2010), achieving both fiscal gains and climate policy goals.

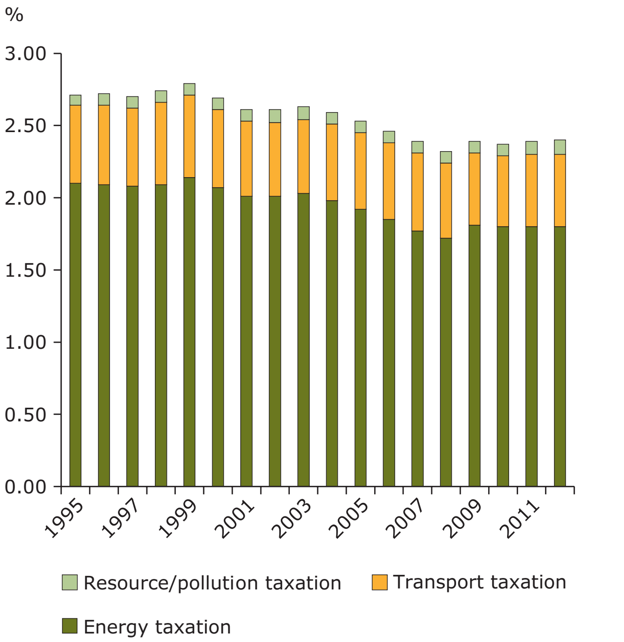
The German Advisory Council on Global Change (WBGU, 2011) discusses potential revenue figures from carbon pricing. It argues that the revenues depend critically on the carbon price, which *would have to be a minimum of USD 40–50 per tonne of CO_2 in 2020, and in 2050 a minimum of USD 110–130 per tonne of CO_2 to have a transformative impact in terms of achieving compliance with the 2 °C guard rail* (WBGU, 2011). The WBGU also states that these revenues would be a reliable source of revenues, an important point as one of the criticisms of economic instruments like environmental taxation and carbon pricing is that the revenues they generate may diminish over time.

Figure 7.1 Environmental tax revenue in EU-27, current and constant 2005 prices; deflated by GDP deflator



Source: Authors based on Eurostat, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_tax&lang=en (accessed 24 April 2014).

Figure 7.2 Environmental taxation as a percentage of GDP, energy, transport and pollution/resource in the EU-27



Source: Eurostat http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_tax&lang=en (accessed 24 April 2014).

An assessment of the potential for environmental taxation undertaken by the EEA ([78]) and the European Commission (EC, 2014a) demonstrated that EU Member States could increase revenues from environmental taxes by more widespread implementation of practices that are already established in some front-running European countries. Greece is a good example of this potential as environmental tax revenues increased by 17 % in real terms between 2008 and 2012, while environmental taxes as a share of GDP grew from 2.0 % to 2.9 %. One of the most wide-ranging EFR studies was done in the United Kingdom, modelling a sharp increase in environmental tax revenues — in the model scenario, environmental taxes as a share of total tax revenues surged from 6 % in 2006 to 15 % in 2020 (Green Fiscal Commission, 2009). The results show that the modelled EFR would ensure that the United Kingdom would meet its 34 % carbon reduction target in 2020, based on 1990 levels. The effects on GDP would be negative, but small, and the reduction in income taxes and employers' social security contributions would lead to an increase in employment.

7.2 Environmental taxation in the policy framework of the EU

Europe 2020, the EU's growth strategy, puts great emphasis on growth, competitiveness, and jobs. However, it also established a number of priorities in the environmental and social domains, such as increasing education and employment, and reducing CO_2 emissions. Environmental taxation can contribute to these priorities, but it is certainly

Box 7.1 Resource taxation

The focus in the analysis of environmental taxation is generally on energy and carbon taxes. However, interest in taxes levied on other resources, such as minerals and metals, is increasing, which can partly be attributed to the resource efficiency strategy of the EU.

A recent project assessed different designs of resource taxes by studying their pros and cons (ETC/SCP, 2012; 2014). The possibility of introducing a tax aimed at resource saving was explored for three mineral resources/materials — steel, copper, and phosphorous. For each, three different levels of the value chain were considered for taxation: a tax on mineral extraction; a tax on the metal as an input in industrial process; a tax on final products containing the metal/material. The possible consequences were assessed in terms of extraction in Europe, international trade with mineral/metal producing countries, material substitution, material savings, recycling and environmental implications — emissions.

A first general conclusion was that taxation at different levels of the value chain could be feasible but may have different consequences and implications. Taxation on resource extraction in Europe might stimulate extraction leakage with no effects on global resource efficiency, and border tax adjustments would be required. Taxation on metals/materials as industrial inputs — first use — can stimulate complex substitution effects, thus affecting technological innovation as well as the market and technical relationships between different metals/materials. Taxation at the level of production input is already applied in some EU Member States in the case of phosphorus with different aims, such as reducing pollution, and different observed effects. Taxation of final products can raise difficult issues of measurement of the content of metals/materials, unless definitions of metal/material intensive products can be reliably adopted. In all cases, international trade issues are raised and require specific attention in policy design, in particular regarding the WTO rules.

A second conclusion is that, for metals, a very high tax rate may be necessary to stimulate resource efficiency — a net saving. Furthermore, specific flexible taxation schemes able to cope with the intrinsic instability of metal prices would have to be designed so that a possible neutralisation of the tax due to market price oscillations could be avoided.

A third conclusion is that each metal/material can have very specific features for the application of a taxation scheme aimed at resource efficiency. Import dependence, market structure, technological innovation potential (including substitution), and recycling potential at reasonable cost are all material-specific and may or may not provide conditions for designing an effective taxation scheme.

([78]) See http://www.eea.europa.eu/highlights/fiscal-reform-can-create-jobs including links to country reports discussing the potential for environmental fiscal reforms in Ireland, Italy, Spain and Portugal.

a challenge to design a tax structure that achieves economic growth, helps to reduce national debt levels, creates jobs, and promotes the environmental and social aspects of a green economy.

The European Commission has recognised the importance of this challenge. As part of the Europe 2020 strategy, the European Commission established the European Semester process, an annual cycle of economic and budgetary policy coordination building on the Stability and Growth Pact (SGP) ([79]), as part of which the EC publishes the Annual Growth Survey (AGS). The 2014 AGS, published in November 2013, reported progress in the fiscal consolidation by EU Member States (EC, 2013a). Among the priorities identified by the EC is a call for redesigning their tax systems by broadening tax bases so that they are more growth-friendly thereby referring to changes in the taxation structures by *shifting the tax burden away from labour on to taxes bases linked to consumption, property, and combating pollution* (EC, 2013a). Further, efforts should be made to reduce environmentally harmful subsidies. The priorities laid down in the AGS are aimed to boost growth and job creation.

The significance of market based instruments in correcting market failures is also underlined in the Flagship Initiative for a Resource-Efficient Europe (EC, 2011a) and in the Roadmap to a Resource Efficient Europe (EC, 2011b). The roadmap draws attention of how Europe's economy can be transformed into a sustainable one by 2050 and states as a milestone: *By 2020 a major shift from taxation of labour towards environmental taxation, including through regular adjustments in real rates, will lead to a substantial increase in the share of environmental taxes in public revenues* (EC, 2011b).

The environmental benefits of environmental taxation in terms of reduction of environmental pollution have been sufficiently assessed (EEA, 2005; OECD, 2006 and 2013; Speck et al., 2006). However, apart from these environmental benefits the revenue potential of environmental taxation is significant. This revenue potential is all the more important considering the current economic and fiscal conditions faced by EU Member States.

The overall role and significance of taxes in the fiscal consolidation process has been reviewed recently, concluding that reductions in government spending should not dominate the fiscal consolidation process at the expense of tax increases. International Monetary Fund (IMF) scholars summarise the results of the review as follows: *Unlike previous research on fiscal consolidation, our findings show that raising tax revenue is key to successful debt reduction in countries with large fiscal adjustment needs* (Baldacci et al., 2010). Furthermore, they conclude that … *carbon taxation may help the budget while at the same time addressing efficiency concerns* (Baldacci et al., 2010). Stiglitz (2010) backs these findings, arguing that economic efficiency can be improved by imposing taxes on activities that generate negative externalities. In its study of environmental taxation, the OECD concluded that environmental taxes are an important part of fiscal consolidation programmes from an efficiency and revenue-raising perspective (OECD, 2012).

Environmental taxes have an additional advantage for fiscal consolidation: their mostly positive effect on growth. Recent studies have concluded that environmental taxes — besides consumption taxes and recurrent taxes on immovable property, in particular the taxation of real estates and land — are the taxes which are considered less detrimental to growth (EC, 2012; 2013b).

The results of a simulation exercise studying different paths to fiscal consolidation ([80]) confirmed the advantages of consumption and environmental taxes as compared to taxes on labour and corporate profits. The three alternative scenarios in the exercise all showed a fall in GDP, but taxes on consumption emerged as the best option, as they led to the smallest short-term negative impacts on GDP, and after 3–4 years GDP and employment growth both became positive (Wöhlbier et al., 2014). Another modelling study draws the same conclusion that environmental taxation is the least detrimental in terms of economic growth, arguing that *energy taxes would cause less economic harm per unit of revenue than direct (i.e. income) or indirect taxes, while also producing other benefits* (Vivid Economics, 2012).

Another aspect of fiscal policies has to be discussed in the context of the transition towards a green economy, namely the phasing out of environmentally harmful subsidies, which may generate additional revenues for governments and

([79]) The Stability and Growth Pact is a rule-based framework for the coordination of national policies in the European Union — see for further information: http://ec.europa.eu/economy_finance/economic_governance/sgp/index_en.htm.

([80]) The study posited a permanent reduction of the deficit-to-GDP ratio of 1 % by applying the macro-economic QUEST model, which is used by the Directorate-General for Economic and Financial Affairs (DG ECFIN) of the European Commission for macroeconomic policy analysis and research.

lead to behavioural changes by their recipients (EC, 2011b). Environmental taxation and removing environmentally harmful subsidies can unlock the economy from the unsustainable path as these policies will ensure that the real costs of resource use and environmental pollution are paid by consumers and producers.

7.3 Environmental taxation and jobs — environmental fiscal reform; tax shifting programmes

As mentioned earlier in this chapter, environmental taxes can be used to either increase the overall tax take, or to tax-shift by reducing taxes on other activities. The European Commission defines tax-shifting as *shifting taxation from the most growth-detrimental taxes, such as labour tax and corporate income tax, to revenue sources less harmful to growth. The objective is generally* long-term *gain, in terms of growth and jobs* (EC, 2013b). Tax-shifting programmes have existed for more than two decades in EU Member States, and evaluations of these environmental fiscal reforms confirm that tax-shifting can meet environmental objectives — such as reduction of environmental pollution — and also provide economic gains in terms of job creation (Box 7.2; Andersen and Ekins, 2009).

This policy approach may adhere to the principle of tax neutrality meaning that the revenue generated by environmental taxes should be entirely used to reduce taxes elsewhere, so that central government tax revenues are unchanged. Although tax-shifting programmes of this nature are promoted heavily by the EC, it is possible for EU Member States to use environmental taxes to increase tax take, thus reducing their overall budget deficit. Environmental fiscal instruments, such as energy taxes, carbon taxes or emission trading schemes can raise revenues considerably, avoiding the need for states to implement other policy measures, such as income or capital tax increases, to reduce their budget deficits (De Mooij et al., 2012).

7.4 Environmental taxation and competitiveness

Competitiveness is a highly topical issue in any discussion of the green economy, and in particular with regard to the Europe 2020 initiative and the EU's industrial policy. One of the major concerns for competitiveness is the increasing price of electricity and natural gas faced by European industry compared to their foreign competitors (EC, 2014b; 2014c). The surge in US shale gas and the accompanied fall in prices of natural gas and electricity for US industry is a critical factor in this debate (EEA, 2013; EC, 2014c), raising fears that European industry may be losing competitiveness. However, shale gas extraction raises public concerns of the associated environmental risks, in particular the risk of contamination of ground and surface waters [81].

The debate over high energy prices has been further fuelled by national policy developments concerning the financing of renewable energies. However, carbon pricing schemes either implemented in form of energy/carbon taxes or as part of the EU emission trading scheme (EU ETS) are of minor relevance in this current debate as stated by the EC *the carbon price is not found to have any statistical significant impact on electricity retail prices* (EC, 2014c) and the increases in energy/carbon tax rates were not striking although EU Member States have very high

Box 7.2 Environmental fiscal reform — tax-shifting programmes

Environmental fiscal reform (EFR) is 'a reform of the national tax system where there is a shift of the burden of taxes from conventional taxes such as labour to environmentally damaging activities, such as resource use or pollution' (EEA, 2005). During the last two decades several EU Member States — Denmark, Finland, Germany, the Netherlands, Sweden, and the United Kingdom — implemented EFRs and the overall performance of these were evaluated in the EC-funded research project Competitiveness Effects of Environmental Tax Reforms (COMETR) — the findings of which are published in Andersen and Ekins (2009). The results of the assessment exercise show that the environmental objectives of EFRs are being met, measured by a reduction in greenhouse gas emissions and in total fuel consumption, and that the effects of EFRs on GDP are small and, if anything, positive.

([81]) See for a detailed discussion of the environmental risks of shale gas extraction: EC, 2014d.

taxes on natural gas and electricity compared to many other countries, particularly the US.

Although the differential in energy costs is an important component of competitiveness, many other components are just as important. Some of these are political and social, such as the quality of governance in a country, and some are technological, such as the energy-intensity of a country's industry. International competitiveness is influenced by factors such as the existence and the nature of trade barriers and exchange rate variations, for example between the US dollar and the Euro (Ekins and Speck, 2012).

In the case of Europe, the increases in energy prices have been offset by an improvement in the energy intensity of EU manufacturing industry. This may be the consequence of changes in the EU's industrial structure with increased specialisation toward higher-value-added products with lower energy intensity and a move away from more energy-intensive production (Chapter 4).

As a result, although average EU industrial retail prices of natural gas and electricity are among the highest in the world (EC, 2014e), real unit energy costs (RUEC) of EU manufacturing industry are among the world's lowest, together with Japan, and are in a similar range as real unit energy costs for US manufacturing industry ([82]) (EC, 2014c). It is worth stressing, however, that RUECs for manufacturing industry are facing an upward trend and that RUECs in China are converging with RUECs in the EU, Japan, and US (EC, 2014c).

The relationship between environmental tax revenues and GDP in recent years can be seen in Table 7.1. It shows interesting differences between the EU Member States that were hardest hit by the financial and economic crisis. For example, Greece and Italy pursued a policy of increasing

Table 7.1 Change in environmental tax revenues and GDP in selected EU Member States (% change in constant 2005 prices)

	2008–2012		2000–2012	
	Total change over 4-year period	**Annual average change during 4-year period**	**Total change over 12-year period**	**Annual average change during 12-year period**
Change in environmental tax revenues				
Estonia	19 %	5 %	165 %	8 %
Greece	17 %	4 %	30 %	2 %
Italy	13 %	3 %	– 3 %	– 0.2 %
Spain	– 11 %	– 3 %	– 14 %	– 1 %
Ireland	– 2 %	– 0.4 %	15 %	1 %
Change in GDP				
Estonia	0.3 %	0.1 %	61 %	4 %
Greece	– 20 %	– 5 %	6 %	1 %
Italy	– 6 %	– 1 %	2 %	0 %
Spain	– 6 %	– 1 %	20 %	2 %
Ireland	– 5 %	– 1 %	30 %	2 %

Source: Authors based on Eurostat ([83]).

([82]) Real unit energy cost (RUEC) measures the energy cost in current prices per unit of value added; RUEC follows the concept of calculating unit labour cost (ULC). ULC is determined by wages and labour productivity and RUEC by energy costs (the value of energy inputs) and energy intensity/productivity.

([83]) Environmental tax revenues [env_ac_tax] (http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_tax&lang=en) and GDP and main components — volumes [nama_gdp_k] (http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_gdp_k&lang=en).

environmental tax rates between 2008 and 2012, mainly by increasing the taxes on transport fuels. This is reflected in an increase in environmental tax revenues with the highest annual average growth rates of EU Member States. This is in stark contrast to the situation in Spain and Ireland which both experienced a reduction in environmental tax revenues in this four-year period, as did the majority of EU Member States. The most interesting development occurred in Estonia where environmental tax revenues more than doubled in 2000–2012 and environmental tax revenues as a share of GDP increased from 1.7 % to 2.8 %.

A comprehensive study of environmental taxes and their implications on competitiveness requires more detailed analysis. However, the findings of a recent analysis shows that for 92 % of German manufacturing industry energy bills on average account for less than 1.6 % of revenue, and international competitiveness is therefore not affected by energy costs (Neuhof et al., 2014; see also EC, 2014b). However it must also be disclosed that the economic performance of certain sub-sectors of the manufacturing industry, such as chemicals, metals and non-metallic minerals, are highly sensitive to energy price shocks or increases in energy and carbon taxes. The competitiveness of these energy-intensive industries may be harmed by an increase in energy costs (EC, 2014c).

Table 7.2 provides country-specific information related to competitiveness, eco-innovation and environmental taxation. It shows a snapshot of the situation of EU Member States but without making any clear-cut statement about causes and effects. The EU Member States are ranked in Table 7.2 according to their competitiveness. The table shows that there is no unique relationship between competitiveness, eco-innovation and environmental taxation. Nevertheless, countries that are highly competitive in the international business community are regularly listed as also being highly innovative. This is particularly true for the Northern European countries. Although a specific analysis is not possible — it is difficult to account for the causal relationship between competitiveness, eco-innovation and environmental taxation — it is obvious that high environmental taxes, as expressed as the ratio of environmental tax revenues to GDP, do not necessarily harm competitiveness or impair eco-innovation. It further demonstrates that competitiveness depends on a whole range of different economic, legal, political factors and environmental taxation — mainly in form of energy/carbon taxation — is only one of them ([84]).

An interesting development concerning the future application of environmental taxation, in particular regarding carbon pricing, happens at the company level as companies are increasingly using an internal carbon price (CDP, 2013) or shadow carbon price (Sustainable Prosperity, 2013) as part of their business strategies. The internal carbon price is a notional price set by a company on their carbon emissions. Companies often set an internal carbon price on their activities in order to anticipate future regulatory action, and ensure that their activities will still be economically viable if regulation drives carbon prices higher. Internal carbon prices are often used for the evaluation of large investments and *as a way to drive performance (operational efficiency and profit maximisation) and to create opportunities, including technological innovation and market access* (Sustainable Prosperity, 2013). Internal carbon prices have been adopted by companies from many different economic sectors but mainly energy companies or utilities. The internal carbon price in corporate business strategies ranges from USD 6–60 per tonne of CO_2 equivalent ([85]) (CDP, 2013). Although the application of internal carbon prices by companies as part of their planning and business strategies does not affect competitiveness directly, it indicates that companies expect the introduction of economic instruments — via carbon taxes or emission trading schemes.

7.5 Environmental taxation and innovation

The benefits of environmental taxation can be increased by reinvesting some of the revenues in eco-innovation, which may promote increased employment (EEA, 2011b) and increased efficiency of technology. One of the challenges is how to make the link between the higher short-term costs of investment in new technologies and the medium-to-long-term cost savings resulting from an increase in efficiency. In order to make this link, policy integration is essential so that industrial policy concerns can be dealt with when designing environmental and climate policy. It is important

([84]) It must be stated that households are the main contributors to environmental tax revenues (Eurostat, 2012).
([85]) The prices reported in the report published by Sustainable Prosperity are in the similar range, i.e. between CAD 15–68 per tonne of CO_2.

Table 7.2 Competitiveness, eco-innovation and environmental taxation

	Global Competitiveness Index — 2013–2014	Eco-innovation scoreboard — 2012	Environmental tax revenue as a share of GDP — 2012
	Global ranking (out of 148 countries)	EU wide ranking	EU wide ranking (and environmental tax revenues in % of GDP)
Finland	3	1	5 (3.07)
Germany	4	4	21 (2.18)
Sweden	6	3	15 (2.49)
Netherlands	8	10	3 (3.56)
United Kingdom	10	12	12 (2.62)
Denmark	15	2	1 (3.87)
Austria	16	9	17 (2.44)
Belgium	17	6	23 (2.16)
Luxembourg	22	11	18 (2.42)
France	23	13	25 (1.83)
Ireland	28	8	15 (2.49)
Estonia	32	19	10 (2.78)
Spain	35	5	28 (1.57)
Malta	41	22	7 (2.98)
Poland	42	26	14 (2.52)
Czech Republic	46	15	20 (2.35)
Lithuania	48	27	27 (1.66)
Italy	49	14	6 (3.02)
Portugal	51	16	21 (2.18)
Latvia	52	23	18 (2.42)
Bulgaria	57	17	9 (2.82)
Cyprus	58	20	11 (2.67)
Slovenia	62	7	2 (3.82)
Hungary	63	21	13 (2.55)
Croatia	75	n.a.	4 (3.18)
Romania	76	18	24 (1.94)
Slovakia	78	25	26 (1.75)
Greece	91	24	8 (2.85)
Switzerland	1	n.a.	n.a.
Norway	11	n.a.	99 % of EU-28 average (2.38)
Iceland	31	n.a.	87 % of EU-28 average (2.08)
Turkey	44	n.a.	n.a.

Sources: Source of information with regard to competitiveness: The Global Competitiveness Report 2013–2014 assesses the competitiveness landscape of 148 economies and competitiveness is defined based on the set of institutions, policies, and factors that determine the level of productivity of a country distinguishing between 12 pillars (World Economic Forum (WEF), Global Competitiveness Report 2013–2014, Geneva) www.weforum.org/gcr.

Source of information with regard to eco-innovation: The Eco-Innovation Scoreboard is the first tool to comprehensively assess and compare eco-innovation performance across the EU-27 Member States. The Eco-Innovation Scoreboard is an index based on indicators in five areas: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, environmental outcomes and socio-economic outcomes. The EC's Directorate-General for the Environment is the primary stakeholder and funder of this project http://www.eco-innovation.eu.

Source of information with regard to environmental taxation: Eurostat http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_tax&lang=en.

to appreciate that environmental taxes *stimulate the development and diffusion of new technologies and practices* (OECD, 2010) and many studies have shown that they *are powerful tools to promote green investment and innovation* (UNEP, 2010) which themselves are essential facets of a green economy transition.

Empirical studies assessing the impact of environmental and energy taxes on eco-innovation are finding that they have a positive impact on diffusion of eco-innovation and patenting activities (EEA, 2011b). For example, De Vries and Medhi (2008) found out that an increase in fuel prices by USD 0.1 per litre would induce a 14 % increase in patenting activity. The OECD comes to the same conclusion as *[T]axes, especially those levied directly on the pollutant, provide incentive for the creation of innovation because there are incentives for its adoption in order to minimise tax payments* (OECD, 2010). Taxes are more effective than non-tax-based instruments and support the transfer of innovation across countries. In addition, studies are showing that the tax induced increase in costs does not lead to reduced innovation outputs although this increase can reduced the profitability of firms (OECD, 2010).

7.6 Main conclusions

- The political discussion of the use of environmental taxes to support the shift to a green economy continues, with the European Commission fostering the more widespread use of economic instruments in various publications from different Directorates General (DG) of the European Commission, such as DG Taxation and Customs Union, DG Economic and Financial Affairs, DG Environment.
- In spite of their potential in achieving fiscal, social and environmental benefits simultaneously, a wider application of environmental taxes did not happen in EU Member States and environmental tax revenues as a percentage of GDP fell from 2.7 % to 2.4 % between 1995 and 2012.
- Realising the benefits of environmental taxation greatly depends on the design of the particular taxation policies. The environmental fiscal policy framework must integrate demands from other policy areas, in particular economic policies in order to achieve the dual objectives of economic and environmental policies by taking into account social inclusiveness ([86]).
- Otherwise shortcomings of environmental taxes may prevail: a loss of competitiveness of domestic industry compared to foreign competitors (Ekins and Speck, 1999 and 2012) and regressive impacts that disadvantage the poor (EEA, 2011a).

([86]) It may be required to integrate climate/environment proofing with competitiveness proofing of any policy initiatives.

8 The role of finance

When the financial crisis began in 2008, the policy responses included a green component, directing stimulus packages in ways intended to promote the green economy (Chapter 2). However, this phase of green stimulus was soon overtaken by a push for fiscal discipline amid pressure from financial markets on sovereign debt. This development has made the need for green economy investment all the more pressing. There is a significant financial need associated with achieving EU energy and climate policy targets, improving energy efficiency, cutting greenhouse gas emissions, upgrading energy infrastructures, and promoting new technologies, including carbon capture and storage and electric mobility.

The main problem with financing long-term, risky projects such as green investments is the scarcity of 'patient' capital ([87]) (EC, 2013a). Many investors operate with a short-term perspective so the initial phase of financing the green economy transition may well have to rely largely on government support. However, recent estimates by UNEP suggest that private capital sources are expected to supply 80 % of the amount required for the transition to a low-carbon economy (UNEP, 2013). The financial crisis resulted in reduced private sector lending, making it more difficult to mobilise this private funding. One possible solution is to combine public and private lending through public-private partnerships or other types of hybrid funding.

It is therefore important to look at newly emerging trends in the world of green finance, and consider the different types of public and private vehicles that can direct resources to green economy investment, and to look at financial innovations which may provide new solutions and the right incentives to mobilise private capital. For example, securitisation ([88]) enables banks to refinance loans by pooling assets and converting them into securities that are attractive to institutional investors. Such securities, if of sufficient size, offer liquid investment opportunities in asset classes in which institutional investors do not invest directly, such as SMEs and mortgages. After the crisis, the market for securitisation in Europe almost collapsed, but it is now recovering. Securitisation is beneficial both for banks and for investors, freeing liquid resources which can be mobilised for green economy investment.

Another financial innovation with high potential is crowd-funding. This is an emerging alternative form of financing which connects those who can give, lend or invest money directly with those who need financing. Promoters of an initiative can collect funds directly, launching open calls to the wider public through the internet. A web-based intermediary, a crowd-funding platform, usually helps with publishing campaigns and collecting funds. The practice has become increasingly widespread since the financial crisis, as bank lending reduced and access to finance became more difficult. Industry estimates show that almost half a million projects were financed through crowd-funding across Europe during 2012, raising EUR 735 million, 65 % more than in 2011, and the forecast for 2013 is EUR 1 billion (EC, 2014). Crowd-funding has the potential to finance different types of projects, including green ones that have difficulties in accessing other forms of funding. An example is the German start-up, E-volo, which raised EUR 1.2 million in a reward-based crowd-funding campaign for the development of an environment-friendly and emission-free helicopter.

8.1 Financial needs for transition to a green economy

The investments needed to achieve a green economy will have to include the key areas of energy, climate, and environmental EU policies. Estimating the

([87]) Patient capital is an alternative term used for long term capital and gained momentum with the increased interest in environmentally and social responsible enterprises.
([88]) Securitisation is the financial practice of pooling various types of debt and selling the corresponding 'consolidated debt' in the form of bonds, various forms of securities and obligations to various investors.

investment needed is difficult given the different variables that must be considered.

Table 8.1 presents a global summary of the different financial needs estimates for transition to a green economy. For example, they range from USD 300 billion to USD 400 billion per year for 2010–2020 for reducing greenhouse gas emissions, with additional total investments of USD 9.3 trillion between 2010 and 2050 for de-carbonisation of the power sector, and USD 15 trillion to USD 20 trillion for replacing existing fossil fuel and nuclear power infrastructure.

A report for the Financial Times (Arnold, 2010) states that *total clean-tech investment needs to reach USD 500 billion a year to hold global warming to less than 2 °C, beyond which scientists say climate change becomes irreversible and catastrophic … last year [2009], 77 clean-tech funds raised a total of USD 26.9 billion, down sharply from the 104 funds that raised USD 48.5 billion in 2008*.

An analysis by Ecofys et al. (2011), based on Bloomberg New Energy Finance estimates, indicates that the capital inflow for asset investments in renewable energy in the EU was around EUR 35 billion in 2008. This figure can be compared to the EUR 70 billion in annual capital investment needed to achieve the EU's target of 20 % renewable energy by 2020. The estimated gap is EUR 35 billion per year for 10 years.

In the EU, energy infrastructure is critical to achieving both the EU 20-20-20 targets and security of supply. The European Commission estimated in 2011 that upgrading trans-European energy transmission infrastructure for gas and electricity would require a total investment of more than EUR 200 billion a year between 2010 and 2020. The Commission identified financing and regulation as major obstacles to proceeding with this investment.

According to the EC, investing in a low-carbon future encompassing smart grids, passive housing, carbon capture and storage, advanced industrial processes and electrification of transport, including energy storage technologies, will require major and sustained investment. Over the coming 40 years, the EC estimates that this would require an increase in public and private investment averaging around EUR 270 billion a year. This represents an additional investment of around 1.5 % of EU GDP per year ([89]) on top of overall current investment representing 19 % of GDP in 2009. According to the Energy Roadmap 2050, electricity grid

Table 8.1 Ranges of investment needs for green growth, mostly energy-related

Financing need	Capital required (USD)	Source/note
Developed to developing country flows for climate change adaptation and mitigation	100 billion per year by 2020	UNFCCC (2010) Cancun decisions
Water infrastructure	800 billion per year by 2015	OECD infrastructure to 2030 (2007)
IEA's Blue Map scenario of halving worldwide energy-related CO_2 emissions by 2050	300–400 billion between 2010–2020; up to 750 billion by 2030 rising to over 1.6 trillion per year from 2030 to 2050	IEA Energy technology Perspectives (2010)
Clean energy investment needs to restrict global warming < 2 °C	500 billion per year (by 2020)	World Economic Forum and Bloomberg New Energy Finance (2010)
Investment requirement for energy transformation (BAU + incremental needs)	65 trillion by 2050 or 1.6 trillion per year	UN World Economic and Social Survey 2011 and Global Energy Assessment (forthcoming)
Implementing 'sustainable growth'	0.5–1.5 trillion per year in 2020 rising to 3–10 trillion per year in 2050	WBCSD (2010)

Source: Della Croce et al., 2011.

([89]) This figure can be compared with UNEP Green Economy Report estimates. UNEP (2010) argues that investing 2 % of global GDP in 10 key sectors can kick-start a transition towards a low-carbon, resource-efficient economy. Of the 2 % investment, 0.52 % of GDP is allocated to the energy-supply sector in UNEP's modelling exercise, a much lower figure than the estimate by the EC.

investments alone might cost between EUR 1.5 and EUR 2.2 trillion between 2011 and 2050 (EC, 2011a).

The latest data published at the annual meeting of the World Economic Forum in Davos in January 2014 state that '*globally, investment in infrastructure of an estimated USD 6 trillion annually to 2030 is needed to deliver a low-carbon economy. Of this, nearly USD 1 trillion is over and above the business-as-usual trajectory*' ([90]).

According to the Climate Policy Initiative (2013), achieving clean energy by 2020 needs USD 5 trillion of additional investment. However in 2012, only USD 359 billion were spent on climate change investment, even lower than the USD 364 billion invested in 2011. Of the USD 359 billion spent, USD 224 billion came from the private sector and USD 135 billion from the public sector through incentives such as low-cost loans, risk-coverage mechanisms, direct project investments and technical support.

The scale of green economy investment needed to achieve EU policy targets to 2020 and visions to 2050 is far beyond the levels of capital currently available for such investment. It is therefore essential to identify alternative ways to finance the green economy transition.

The following sections illustrate some possible vehicles of alternative and additional funding. They are unlikely to fill the entire gap, but mobilising them will help to cover a significant part of it. The instruments, financial vehicles and initiatives are not necessarily focused on domestic European needs alone, some are on a global scale. However, EU bodies, European governments and private economic operators in Europe are or could be involved in these financial opportunities for the green economy, for example through climate funding to less developed countries, thus contributing to the international transfer of green knowledge discussed in Chapter 6.

8.2 Public initiatives

This section discusses examples of public initiatives to finance the shift to a green economy that do not only focus on the European region. They may, however, involve European companies, and their spill-over effects both in terms of technology and green economy transition are relevant to European economies (Chapter 6). The first example examines the role of the EU with its main institutions such as the Commission and the European Investment Bank (EIB) in financing green economy in the Mediterranean region. Critical here is the kind of institutional arrangement between two European institutions, the European Commission and the EIB, a multilateral financial institution, the European Bank for Reconstruction and Development (EBRD) and national governments which may also involve the private sector. The second examines the role of multinational development finance institutions and climate funds. These are particularly relevant for cooperation to develop the potential of green business for European companies. Both examples start as public initiatives, but may end up involving the private sector.

Even if the role of the public sector is set to decrease and leave room to private actors, public funds remain crucial providers of the right incentives and economic rationales for private companies to be successful in the first round of investments (Mazzucato, 2013). For example, the public US agency, the Defense Advanced Research Projects Agency (Darpa), provided a USD 500 million guaranteed government loan to the latest big Silicon Valley export, Tesla Motors. The role of public funding remains particularly important in the light of the reluctance of private investors to provide long-term capital to fund the riskiest projects.

8.2.1 Energy technology financing in the Mediterranean

European institutions, in particular the European Commission and the EIB, are committed to supporting renewables, in accordance with the EU targets. Both institutions have several financial facilities specifically devoted to promoting the green economy and renewables.

Particularly significant in this respect is the Euro-Mediterranean cooperation in the field of renewable energy, which involves the EBRD, the Neighbourhood Investment Facility (NIF) ([91]), and several EIB facilities such as the Facility for

([90]) See the UNEP article at http://www.unep.org/newscentre/Default.aspx?DocumentID=2758&ArticleID=10698&l=en (accessed 10 March 2014).
([91]) For further information on NIF see: http://ec.europa.eu/europeaid/where/neighbourhood/regional-cooperation/irc/investment_en.htm (accessed 10 February 2014).

Euro-Mediterranean Investment and Partnership (FEMIP) ([92]) and the InfraMed Fund ([93]).

There is great potential for cooperation on renewable energy between the Mediterranean region and the EU. The EBRD concluded six investment transactions in 2012 in the southern and eastern Mediterranean region with a total investment of EUR 181 million (EBRD, 2013).

The Neighbourhood Investment Facility (NIF) is a financial facility created in 2008 to support energy and transport projects in partner countries covered by the European Neighbourhood Policy (ENP; EC, 2013b). For 2007–2013, the EC committed to contributing a minimum of EUR 745 million to the NIF. In 2012, EUR 172 million was made available by the EU budget, bringing its contribution to the NIF since 2007 to EUR 567 million. A total of 66 projects have received final approval since the launch of the NIF in 2008, and 41 of which were low-carbon and climate-resilience projects, which received NIF contributions of EUR 332 million (EC, 2012a).

The FEMIP is the main financial instrument created by the EU for the southern Mediterranean, which, since 2002, has invested more than EUR 14 billion in the region. Around EUR 5.4 billion, 38 % of the total, of FEMIP investment between October 2002 and December 2012 targeted the energy sector (EIB, 2013a) and renewable energy in particular, including solar, wind and hydropower (Table 8.2). Other FEMIP investments in the energy sector include upgrading national energy infrastructure and strengthening regional energy interconnections. The FEMIP has contributed to the construction of power plants in Egypt, Syria, and Tunisia, gas pipelines in Egypt, Jordan and Tunisia, liquid natural gas (LNG) plants in Egypt, hydropower plants in Morocco and wind farms in Morocco and Egypt.

InfraMed is a long-term infrastructure investment fund launched in May 2010 by five major institutional investors: Cassa Depositi e Prestiti (Italy), Caisse des Dépôts et de Consignations (France), Caisse de Dépots et de Gestion (Morocco), EFG Hermes (Egypt), and the European Investment Bank. The first investment by InfraMed in the field targeted the Tafila greenfield wind farm project in Jordan.

8.2.2 International Climate Finance

Financial resources mobilised to fund climate-change mitigation and adaptation projects in developing countries can support the worldwide shift to a green economy. These are still split into different funds as a result of commitments

Table 8.2 FEMIP investments: breakdown by sector and country, EUR 1 million, October 2002–December 2012

	Energy	Environ-ment	Credit lines	Human capital	Industry	Trans-port	Private equity	Urban develop-ment	Total
Algeria	500				72		18	46	636
Egypt	2 288	70	100		511	490	58	45	3 562
Gaza/West Bank	45						15		60
Israel	111	592	89						792
Jordan	90	166		40	81	63	9		449
Lebanon		175	423			135	7		740
Morocco	990	166		300	604	1 389	57	85	3 591
Regional projects							193		193
Syria	475	150	107	130	105	90	2		1 059
Tunisia	875	81	656	110	420	923	4	56	3 132
Total	**5 381**	**1 400**	**1 375**	**580**	**1 793**	**3 090**	**362**	**232**	**14 213**

Source: European Investment Bank, 2013.

([92]) See for further information on FEMIP: http://www.eib.org/projects/regions/med (accessed 12 February 2014).
([93]) See for further information on InfraMed Fund http://www.inframed.com (accessed 10 February 2014).

undertaken by the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC COPs) between 2009 and 2013. Further changes to these funds may occur in the near future with the establishment in 2013 of the Green Climate Fund (GCF), agreed in 2011 at UNFCCC COP 17 in Durban.

According to 2013 data from the Climate Funds Update (CFU), an estimated total of USD 35 billion of public funds have been pledged by donors to the different funds. Of this total, USD 26 billion has been deposited, USD 19 billion has been set aside for approved projects, and only USD 2.3 billion has actually been disbursed. Four donor countries, Japan, Germany, the United Kingdom and the US, together represent 81 % of total pledges, mainly through the bilateral funds they have created while Brazil, India, Indonesia, Mexico and Vietnam together account for 47 % of total spending by these funds (Buchner et al., 2011; Cavani et al., 2012).

Most of the funds and commitments arose during the last few years and most of the projects supported by the funds were approved in 2011 and 2012. The flow of expenditure to be expected in the near future is therefore very large and EU Member States have pledges in place for about one third of the total amount.

The CFU inventoried 1 545 projects supported by existing climate funds. Although projects have a great variety of specific aims and topics, two main groups can be identified: climate-change mitigation and climate-change adaptation. In terms of approved spending, the largest share, USD 13.3 billion or more than 70 % of approved spending, is for projects focused on mitigation ([94]). Only around 14 % of the approved sum is scheduled to be spent on adaptation, which usually involves more complex projects.

International promotion of the green economy through investments in developing countries can clearly have indirect benefits for the green economy in the EU by promoting green domestic technological capabilities and know-how, with resource-efficiency effects in the host countries. Overall, global and international instruments such as the system of funds linked with global climate policy can be an opportunity for the EU to contribute to and benefit from the global shift to a green economy.

8.3 The role of private investors

This section focuses on the role of private investors, first on the role of patient long-term capital — pension funds and other long-term oriented institutional investors — and second on socially responsible investments (SRI) — a growing sector in private finance that selects financial assets according to the social and environmental characteristics of the investment.

8.3.1 Pension funds and other long-term institutional investors ([95])

With USD 30 trillion in assets at the global level, pension funds, along with other institutional investors such as insurance companies, which have USD 25 trillion in assets, could play an important role in financing green economy initiatives. Regulations introduced following the financial crisis, such as the Basel III standards on bank capital ([96]), have set stricter liquidity standards, which discourage banks from undertaking long-term investments such as in infrastructure. With these new restrictions on banks, the burden of financing infrastructure and other long-term, risky projects rests increasingly on institutional investors such as pension funds and insurance companies.

These are now emerging as providers of long-term capital. The long duration of their liabilities along with their longer time horizons enable institutional investors to behave in a patient, counter-cyclical manner, restraining short-termism and reducing the need for maturity transformation. At the same time, the current low-yield environment makes the search for higher returns ever more pressing. Allocating substantial shares of their portfolios to long-term instruments provides opportunities in this direction.

Most pension funds are very interested in lower-risk investments that provide a steady, inflation-adjusted income stream in the long term. Yet, despite the

([94]) If we add the Reducing Emissions from Deforestation and Forest Degradation (REDD) projects in developing countries to these, around 78 % of the total is reached.
([95]) This section relies mainly on Della Croce et al., 2011.
([96]) Basel III is a comprehensive set of reform measures aiming to improve the banking sector's ability to:
- absorb shocks arising from financial and economic stress, whatever the source;
- improve risk management and governance;
- strengthen banks' transparency and disclosures (see http://www.bis.org/bcbs/basel3.htm).

fact that green investments may meet these criteria, pension funds do relatively little green investment (Della Croce et al., 2011). There are different reasons for this including a lack of appropriate investment vehicles, issues of scale and regulatory disincentives. Another particularly important reason is the lack of knowledge, track record and expertise among pension funds about these investments and their associated risks.

To tap into this source of capital, governments have a role to play by creating a policy framework to ensure that attractive opportunities and instruments are available to pension funds and institutional investors. The role of pension fund regulatory and supervisory authorities is also important, since regulations may encourage or discourage investment in this sector. For example new insurance regulations, Solvency II, which are also applicable to pension funds, may discourage them from investing in long-term projects such as green infrastructure.

According to Della Croce et al. (2011), pension funds and other institutional investors are already investing in climate change-related assets. They are also exploring how to pool resources to achieve the scale that investment in some of these projects requires. Table 8.3 collects information on major investor initiatives.

The Institutional Investors Group on Climate Change (IIGCC) is a forum for collaboration on climate change for European investors. The group has 72 members, representing around EUR 6 trillion of assets, and its key objective is catalysing greater investment in a low-carbon economy. The P8 Group ([97]) consists of 12 of the world's leading pension funds, collectively managing USD 3 trillion. Its members are from the United States (4 funds), Europe (4 funds), Asia (3 funds) and an Australian collective. The Long-term Investors Club is formed by the *Caisse des Dé*pots, the French public investment group; the Italian *Cassa Depositi e Prestiti*; the German *KfW Bankengruppe* and the EIB. The group works with other financial institutions from Europe, Asia and the Gulf, with total assets of USD 3 trillion.

In addition to the initiatives shown in Table 8.3, most of the pension funds around the world are interested in environmental issues and have invested part of their portfolios in renewable or other climate-related initiatives (Della Croce et al., 2011). It is important to acknowledge the attitude of institutional investors to tapping long-term investment opportunities able to cope with important challenges such as climate change, while at the same time delivering a fair yield.

Table 8.3 shows a total of USD 14.86 trillion of assets under management. Even a small fraction — 0.5–1 % ([98]) — of this invested in climate change-related assets, would equal USD 74 billion to USD 148 billion of investments in the sector. As well as considering the impact in terms of total capital invested, the change in corporate governance that institutional investors can foster in the companies they invest in and among their fellow investors is also important. This kind of impact may be difficult to measure, but it may become one of the most important consequences of the involvement of institutional investors in climate-change initiatives.

8.3.2 *Socially Responsible Investments*

Socially Responsible Investments (SRIs) are selected by fund managers according to criteria related to the social and environmental attributes of the investment and the activities that investment supports. There is no agreed definition of what constitutes an SRI ([99]). In a few years, SRIs have come to play a significant role in the European financial market and are growing quickly. The total SRI assets under management in Europe increased from EUR 2.7 trillion in 2007 to EUR 5 trillion by the end of 2009. This is spectacular growth, about 87 % in two years. Growth of this type of investment strategy has been stronger than broader asset management market growth. Between 2009 and 2011, capital invested in SRIs increased by another 34 % (Eurosif, 2012).

The overall picture of SRI investments in European countries for 2011 is summarised in Table 8.4 (Eurosif, 2012). The aggregated data are consolidated by Eurosif (2012) to avoid double counting of overlapping strategies. In 2011, the total estimated level of SRIs was EUR 6.7 trillion, with France and the United Kingdom accounting for 46 % of total European SRI strategies. The other significant EU Member States — Germany, Italy and the Netherlands — represent respectively 9 %,

([97]) See for further information at www.responsible-investor.com/home/article/p81 (accessed 10 January 2014).
([98]) This would appear a reasonable estimate if we look at the approach adopted by California Public Employees' Retirement System (CalPERS) and California State Teachers' Retirement System (CalSTRS).
([99]) Definitions and strategies of investments behind the data on SRI reported here are those presented in detail in Eurosif (2012).

Table 8.3 Major institutional investors in climate change-related assets

Group	Type of investor	Size of assets	Objectives
Institutional Investors Group on Climate Change (IIGCC)	70+ European institutional investors, including major pension funds	EUR 6 trillion	Catalyse greater investment in low-carbon economy
Investor Network on Climate Risk (managed by Ceres)	90+ US institutions	USD 10 billion	Identify opportunities and risks in climate change, tackle the policy and governance issues that impede investor progress towards more sustainable capital markets
Investor Group on Climate Change	Australian and New Zealand investors	AUD 600 billion	Raise awareness, encourage best practice in terms of analysis and provide information relating to climate change
P8	World's leading pension funds	USD 3 trillion	Create viable investment vehicles to combat climate change and promote sustainable development
Long-term Investors Club	Mainly public sector financing institutions	USD 3 trillion	Identify long-term investment funds and vehicles

Source: Della Croce et al., 2011.

7 % and 10 % of the total; the Nordic countries — Denmark, Finland, Norway and Sweden — together 20 %, and other countries the rest.

The SRI market is driven by institutional investors — institutional assets represented 94 % of the market in 2011 compared with 92 % in 2009 (Eurosif, 2012). The allocation of SRIs in terms of instruments is 33 % to equity capital and 51 % to bonds. Allocation to alternative assets, hedge funds and venture capital, has decreased in recent years.

The increasing importance of SRI investment strategies shows the continuing sophistication of financial players who are adopting multiple responsible investment strategies. Although the definition of SRI is uncertain and the concept is probably being interpreted in broad terms, SRI clearly has the potential to provide answers to the growing concerns of society and policymakers about reconciling finance with long-term sustainable growth, including the mitigation of climate change effects.

Table 8.4 Socially responsible investments in Europe, 2011, EUR 1 million

Country	Total SRI investment strategies
Austria	8 251
Belgium	96 905
Denmark	244 227
Finland	107 600
France	1 884 000
Germany	621 020
Italy	447 592
Netherlands	666 248
Norway	574 100
Poland	1 174
Spain	57 091
Sweden	378 300
Switzerland	441 637
United Kingdom	1 235 201
Europe	6 763 347

Source: Adapted from Eurosif, 2012.

8.4 Mixed public-private initiatives

Another important tool is hybrid initiatives, which finance the transition to a green economy by combining public and private involvement: green bonds are one example. Although these may be issued either by private and public issuers, public international organisations so far represent the lion's share of green bond issue activity. However, many private investors issued green bonds in 2013.

The public and private sectors are also closely intertwined in public-private partnerships. An example is the EU Project Bond Initiative, which includes a guarantee provided by a public institution, the EIB, to encourage private funds to invest in projects. Another example is sovereign wealth funds, which are hybrid by their nature. These are government-owned investment funds that can invest in private companies or bonds in order to maximise returns, blending public ownership with privately-oriented investment behaviour.

8.4.1 Green bonds

Green bonds are aimed at financing investments with an environmental benefit or a focus on reducing vulnerability to environmental change. This definition includes climate bonds, which focus on investments relating to mitigating or adapting to climate change. Green bonds differ from conventional bonds as they are generally subject to a monitoring system to track whether they have indeed produced the expected results in environmental terms. Using green bonds rather than conventional bonds enables the issuer to attract institutional investors interested in SRIs (Section 8.3.2). These bonds usually offer a fixed rate of return and have a maturity of three to ten years. They enjoy the same level of credit-rating valuation as the issuer, which in the case of multilateral institutions is typically high — AAA (Figure 8.1). This keeps the cost of credit low for projects being supported by the green bonds.

The timing of cash flows for green projects is generally compatible with payments from bonds. Green projects usually require substantial upfront investment and subsequently produce regular returns, which is why bonds are particularly suitable for financing renewable energy or energy-efficiency initiatives.

The first issues of green bonds were by the European Investment Bank in 2007 and the World Bank in 2008. Since then, most have been issued by supra-national organisations. However, corporate issuers are increasing as they are generally more responsive to changes in investor preferences and able to deploy capital more quickly and efficiently. For example, in November 2013 EDF, the French power group, launched the first euro-denominated corporate green bond worth USD 1.9 billion. At the end of 2013, Toyota, the carmaker, issued a USD 1.75 billion green bond for supporting green projects within the company. Also in 2013, Unilever, the world's second largest food producer by sales, issued a GBP 250 million green bond for financing initiatives aimed at reducing the environmental footprint of the company, opening a new chapter for this kind of instrument (Scheherazade and Bolger, 2014).

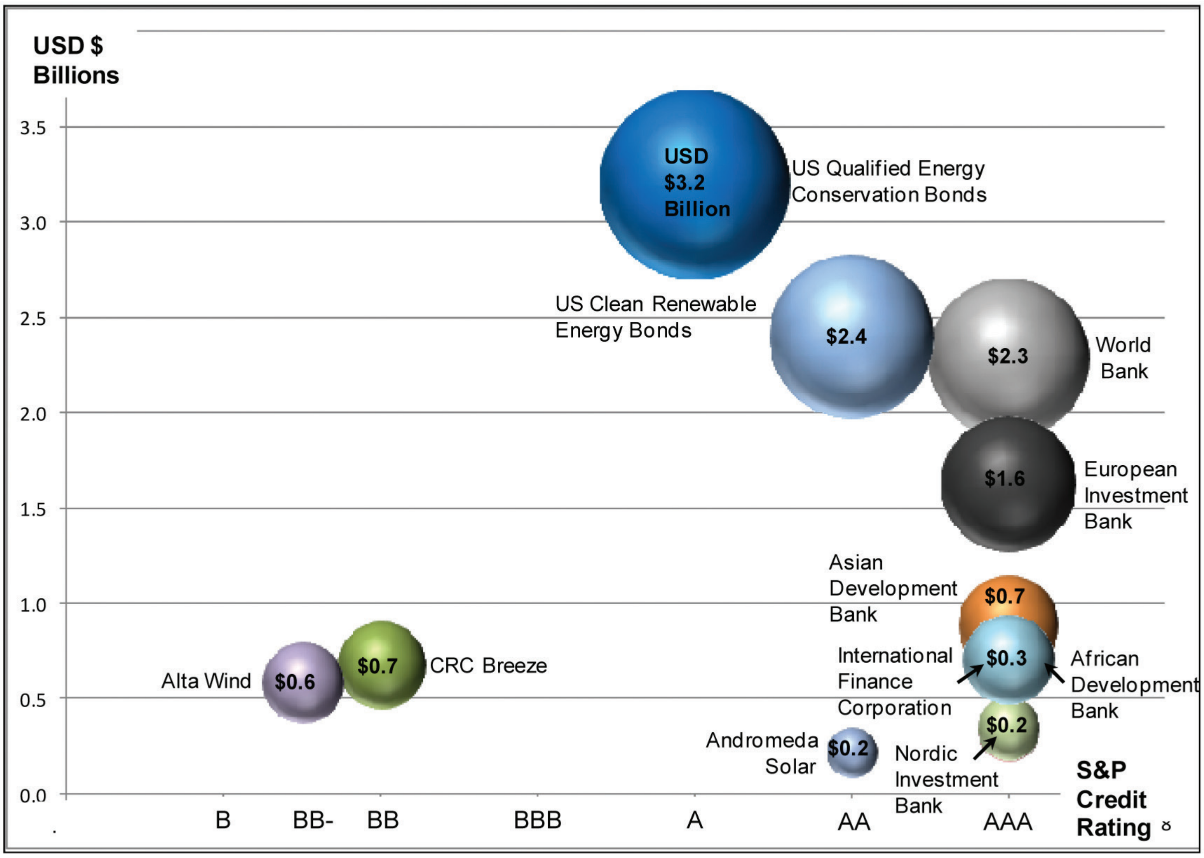
Overall, including both corporate and international organisations, green bond issues are estimated to have increased more than fivefold in 2013 compared to 2012, with Dealogic recording 29 deals worth a total of USD 11.2 billion in 2013 compared to USD 2.2 billion in 2012. By March 2014, 11 bonds had been issued, worth a total of USD 3.78 billion, so the surge is continuing. Jim Yong Kim, president of the World Bank, speaking at the World Economic Forum in Davos in 2014, called for a doubling of the global market for green bonds to USD 20 billion by the end of the year (World Bank, 2014). He believes that the market should aim at USD 50 billion of issuance by 2015. If this happens, green bonds could account for 10–15 % of global bond issuance within five to seven years.

On the demand side, green bonds are set to become a mainstay of investors' fixed income portfolios, illustrated by the decision by the Zurich Insurance Group in November 2013 to invest up to USD 1 billion in green bonds, Morgan Stanley buying USD 4.75 billion of green bonds in 2013, and asset managers launching green fixed income funds for institutional investors. All this is expected to lead to acceleration in interest in green paper among other asset managers.

In spite of their potential and the optimistic figures reported so far, green bonds still only represent a tiny fraction of the total market, and are also well below the financing needs and opportunities of the green economy.

Several factors limit the development of green bond issues. They vary according to whether the issuer is a public or a private body. For corporate issuers, one of the main limitations is the difficulty of obtaining an investment-grade credit rating,

Figure 8.1 The green bond market in 2011



Source: Della Croce et al., 2011.

a necessity for investors seeking low-risk assets ([100]) and without which it is more difficult for private companies to raise money. This could explain why the main issuers of green bonds are entities with high credit ratings, such as the World Bank and the EIB, both of which are rated AAA. From the investor's point of view, investing in green bonds presents specific risks, such as a reputational risk if the financed does not meet the stated green targets. At the same time, from the issuer perspective, green bonds involve additional costs for implementation of the monitoring system needed to certify that the funds raised have actually been used for green projects. This is a further burden for corporate issuers. There is also a problem that arises when the issuer's conventional bonds attract responsible investors even without the green bond label. In that case, the issuer may, through green bonds, promote initiatives that would have occurred in any case.

Another critical issue relates to the liquidity of the green bond market. The Institute of Economic Affairs (IEA, 2012) estimates that in order to be sufficiently liquid, the green bond market requires annual issuance of USD 200–300 billion, made up of bonds rated BBB or higher, which is far from the issuance activity so far.

In order to compensate for these difficulties, governments could introduce regulatory or tax incentives targeted at green bonds. Governments could also provide public guarantees, which could increase the rating of green bonds to investment grade. Another option might be to build green enabling institutions, for example green banks. One such example is the 2011 commitment of the United Kingdom Government to establish a Green Investment Bank, endowing it with GBP 3 billion over the period to 2015. The bank will receive full

([100]) Regulatory constraints, especially after the financial crisis, have moved in the direction of promoting low-risk investments, for example Basel III for the banking sector.

market borrowing powers in 2015, which will probably translate into the issuance of green bonds.

The sub-national level — regions, cities and local areas — is also a promising area for green bond issuance. Encouraging local governments to finance green infrastructure by enabling them to use local green bonds could help them diversify their sources of funding. Nordic countries are pioneering this model, with Sweden's *Kommuninvest* being one example. A number of French municipalities have also started to launch sustainability bonds.

On the private side, a set of voluntary guidelines for green bonds was published at the beginning of 2014, by a consortium of leading banks, to address some of the issues concerning the instrument. These are intended to ensure the integrity of the rapidly-developing green bond market.

8.4.2 The EU Project Bond Initiative

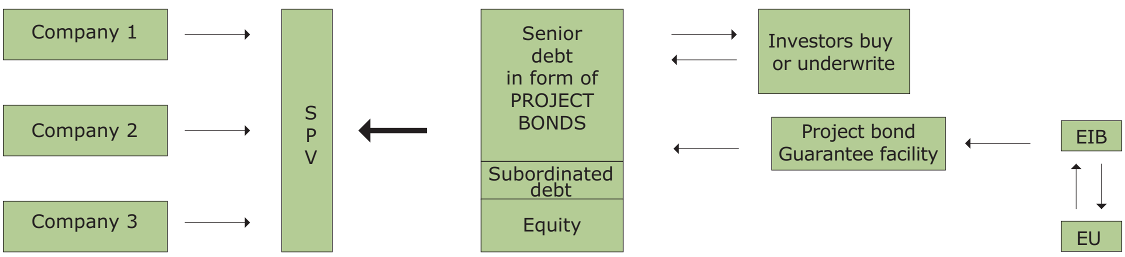
Making the most of private sector investment in green infrastructure is one of the central aims of green infrastructure policy. A particularly interesting example of how this is being done is the EU's Project Bond Initiative (PBI), an increasingly important element in the financing of many major infrastructures.

The European Parliament and the ECOFIN Council formally adopted the PBI in 2012 and the European Commission and the European Investment Bank beginning to operate the initiative in November 2012.

The PBI aims to respond to the financing gap for European infrastructure in the fields of transport, energy, and information and communication technology within the framework of the Connecting Europe Facility (EC, 2012a and 2012b). It is designed to enable eligible infrastructure project promoters, usually public-private partnerships (PPP), to attract additional private finance from institutional investors, such as insurance companies and pension funds.

The idea of the PBI is to allow the project company that promotes the infrastructure to raise finance for its construction and operation by issuing debt through project bonds, instead of using the traditional channel of bank lending. In this way, capital market investors would buy the bonds directly, provided an investment grade credit rating is achieved. To achieve such a rating, the debt to finance the project is divided into different tranches of varying creditworthiness, senior and subordinated (Figure 8.2). Although the resources come from the EU budget, the EIB guarantees the most senior debt of the project so as to encourage private investors to buy it (EC, 2013c). The subordinated debt, or Project Bond Credit Enhancement (PBCE), can take the form of a loan from the EIB, given to the promoter at the outset. It may also take the form of a contingent credit line, which can be drawn upon if the revenues generated by the project are not sufficient to ensure service of the senior debt. The PBCE underlies the senior debt and therefore improves its credit quality, offering safer bonds to institutional investors. Once an infrastructure project is deemed eligible for a PBI, the EIB appraises the project, carries out due diligence and financial analysis, structures the loan into different tranches, and then monitors the project itself. The support, in the form of guarantee of the senior debt, is available during the lifetime of the project, including the construction phase. The credit enhancement mechanism will benefit from the EIB's proven due diligence, valuation and pricing methodologies. A stated objective of the PBI is to ensure that the senior debt rating is firmly in investment-grade territory, preferably in the A category (EIB, 2013a).

Figure 8.2 The Project Bond Initiative



Note: SPV: special purpose vehicle.

Source: EC, 2013d.

The initiative has started with a pilot phase, which will run until 2016. The scope of this is to test the PBI. During this phase, EUR 230 million of unused EU budgetary resources from existing programmes will be deployed, of which up to EUR 200 million will be allocated to Trans European Network (TEN) transport projects, up to EUR 10 million to TEN-energy projects, and up to EUR 20 million to information and communications technology projects.

One of the three projects already supported through the use of project bonds is related to green finance. This is the financing in the United Kingdom of the Greater Gabbard offshore transmission link which attracted GBP 305 million from a broad range of investors. The link will connect the 140 turbine wind farm off the Suffolk coast with the mainland electricity grid. The European Investment Bank has provided a GBP 45.8 million guarantee, representing 15 % of the bonds issued, allowing for a one notch upgrade in the project's credit rating provided by Moody's (EIB, 2013b).

Among the six projects currently in the pipeline to be supported through the PBI initiative, two are in the field of green energy — grid connections to several offshore wind farms in the United Kingdom for EUR 150 million — and grid connections to several offshore wind farms in Germany for EUR 170 million.

The investors targeted by the PBI are institutional investors with long-term liability structures and regulated rating requirements for their assets. These institutional investors hold an estimated total of EUR 13.8 trillion in assets, a figure higher than the EU's annual GDP.

8.4.3 Sovereign wealth funds

Sovereign wealth funds (SWFs) are state-owned investment vehicles that manage portfolios of assets, partly denominated in foreign currency. In 2013 there were 70 SWFs in the world with total assets under management of USD 6.2 trillion ([101]) (Table 8.5). This is more than the assets of private equity funds, USD 2.6 trillion, and hedge funds, USD 1.8 trillion, but less than those of other important institutional investors such as pension funds and insurance companies. Fifty-nine per cent of SWFs derive their wealth from oil and other natural resource-related surpluses, such as the Norwegian Pension Fund and the Middle Eastern funds (Miceli, 2013). These are often referred to as commodity funds. From a financial point of view, it would make sense for these commodity funds to diversify away from natural resources and in particular from the most common resource, oil. For example, for oil- and gas-related SWFs, it would make sense to invest in renewable energy, and indeed Middle Eastern SWFs do that. Non-commodity funds derive their financial resources from balance-of-payment surpluses, privatisation revenues and other fiscal proceeds — China's SWF fall into this category. As China's economic development depends on the availability of cheap energy sources, and the country is increasingly aware of international requirements for cleaner energy, its SWF is therefore a good candidate for investing part of the country's wealth in the green energy sector.

Sovereign wealth funds have specific characteristics that make them particularly suitable for investors in green energy projects. In particular, SWFs typically have medium-to-long term horizons and are therefore not subject to the risk of sudden withdrawals. This means that their liquidity constraint is low, which in turn means that they can invest in less-liquid assets such as infrastructure and energy projects.

The energy sector accounted for 9 % of equity investments of SWFs for the whole period 1990–2010, a total of USD 54 billion, but the investments in this sector tripled from 5 % of the total in 2000 to 15 % in 2010. This is clearly an increasing trend, suggesting that SWFs are developing a comprehensive strategy for the energy sector. Some recent investments by the China Investment Corporation fund and the Middle Eastern funds confirm this potential (ETC/SCP, 2013). Within the broad energy sector, the renewable energy field is increasingly a target for investment. This makes sense if SWFs are considered patient investors, aiming to promote the well-being of their citizens, which includes supporting long-term and sustainable energy initiatives. Moreover, some of the richest SWFs belong to oil-rich countries, which must eventually manage a transition to low-carbon economies.

The Norwegian SWF, which is the most transparent and at the same time the most concerned with issues of environmental sustainability, is expected to increase its share of investments in the green

([101]) Ciarlone and Miceli, 2013, and Sovereign Wealth Fund Institute update.

Table 8.5 The 20 largest SWFs by asset value, end-2013

Country	SWF	Total assets (USD billion)	Year	Source	Policy purpose
Norway	Norwegian Government Pension Fund — Global (NGPF-G)	818	1990	Comm	SF + PRF
UAE — Abu Dhabi	Abu Dhabi Investment Authority (ADIA)	773 *	1976	Comm	SF
Saudi Arabia	SAMA Foreign Holdings	676 *	n.a.	Comm	RIC
China	China Investment Corporation (CIC)	575	2007	NC	RIC
China	SAFE Investment Company	568	1997	NC	RIC
Kuwait	Kuwait Investment Authority (KIA)	410 *	1953	Comm	StF + SF
China-HK	HK Monetary Authority — Investment Portfolio (HKMA)	327	1998	NC	RIC
Singapore	Government Investment Corportaion (GIC)	285 *	1981	NC	RIC
Singapore	Temasek Holdings	173	1974	NC	SF
Qatar	Qatar Investment Authority (QIA)	170 *	2005	Comm	SF
China	National Social Security Fund (NSSF)	161 *	2000	NC	PRF
Australia	Australian Government Future Fund (AGFF)	89	2006	NC	PRF
Russia	National Wealth Fund (NWF)	88	2008	Comm	PRF
Russia	Reserve Fund (RF)	87	2008	Comm	StF + SF
Algeria	Revenue Regulation Fund	77 *	2000	Comm	StF + SF
South Korea	Korea Investment Corporation (KIC)	72	2005	NC	RIC
UAE — Dubai	Investment Corporation of Dubai (ICD)	70 *	2006	Comm	SF
Kazakhstan	Kazakhstan National Fund	69	2000	Comm	StF + SF
UAE — Abu Dhabi	International Petroleum Investment Company (IPIC)	65	1984	Comm	SF
UAE — Abu Dhabi	Mubadala Development Company	56	2002	Comm	SF

Source: Ciarlone and Miceli, 2013 and Miceli, 2013 and updates from Sovereign Wealth Funds Institute.

n.a.: not available; RIC: Reserve Investment Corporation; SF: Saving Fund; StF: Stabilization Fund; DF: Development Fund; PF: Pension Reserve Fund; Comm: Commodity Fund; NC: Non-commodity Fund.
* Estimates.

economy to 1 % in 2014 in order to achieve a more ambitious target in the future of 5 %. In broader terms, it invested 3.6 % of its portfolio in environmentally-friendly companies in 2013.

Considering this virtuous case, it is estimated that a share of between 1 % and 5 % of SWF portfolios, between USD 63 billion and USD 315 billion, could be devoted to green investments in the near future.

8.5 Main conclusions

- Adequate financial resources are essential to the realisation of a resource-efficient green economy. Estimated financial needs for investment in green technologies, infrastructure and innovation at the European and global scale are huge. For example, the estimated investment need for the diffusion of advanced low carbon technologies in the EU is EUR 270 billion a year for the next 40 years.
- There are opportunities for creating and directing financial resources to the green economy through many different channels. Some of these are publicly-driven, including specific initiatives undertaken by the EU and its financial institutions; others are in the private domain, for example pension funds and socially responsible investments. A third category is made of hybrid players — sovereign wealth funds — and hybrid instruments — green bonds and the Project Bond Initiative.

- Among the positive trends emerging, some novel approaches to green and socially sustainable finance, as in the case of socially responsible investments, could become mainstream, and already are in some European countries e.g. France and the United Kingdom. This selectiveness of funding, based on sustainability criteria, could be a powerful mechanism to redirect resources towards the green economy in a competitive financial market.

- Among international scale opportunities, financial resources mobilised to fund climate-related projects in developing countries can be a fast-growing support for a global green economy. After the commitment by Annex I countries of the UNFCCC to provide USD 100 billion per year by 2020 for projects in non-Annex I countries, climate finance has evolved rapidly into a complex web of different funds, up to the establishment in 2013 of the Green Climate Fund (GCF).

- The expected flow of climate-related spending in the near future is huge and EU Member States have pledges in place corresponding to around one third of the total global amount. These channels can be important for the international transfer of green knowledge (Chapter 6).

- To realise these opportunities and avoid competition with conventional allocations and strategies being adopted by the financial system in times of crisis, a high level of commitment, persistence and risk-reducing strategies are needed. Furthermore, even if activating most of the above channels proves to be successful, there may still be a financing gap making a green economy transition out of reach, in which case additional instruments will be needed.

- Financing the shift to a green economy is a macro-economic scale process which may require public policy initiatives to act as catalysers as well as the incorporation of the financial dimension in environmental policies.

- As leading financial institutions increasingly appreciate the imperative of climate change, resource scarcity and other environmental challenges, current financial regulations may not be well suited to accelerate this shift.

References

Introduction

EEA, 2013, *Towards a green economy in Europe EU environmental policy targets and objectives 2010–2050*, EEA Report No 8/2013, European Environment Agency, Copenhagen.

UN, 2012, *The Future we want*, Resolution adopted by the General Assembly on 27 July 2012, A/RES/66/288, United Nations, New York.

Chapter 1

AtKisson, 2013, *Green Economy 2013 A Strategic Briefing on the State of Play in the Global Transition*, Boston.

Barbier, E.B., 2010, How is the global green new deal going? *Nature* 464, p. 832–833, London.

Bowen, A., 2012, Green growth: what does it mean? *Environmental Scientist*, December 2012, p.6–11, http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2014/02/green-growth-environmental-scientist-dec12.pdf (accessed 15 May 2014).

Bowen, A., Fankhauser, S., Stern, N. and Zenghelis, D., 2009, *An outline of the case for a 'green' stimulus*, The Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy, Policy Brief, LSE's Grantham Research Institute on Climate Change and the Environment, London.

Cambridge Econometrics and Ecorys, 2011, *Assessing the Implementation and Impact of Green Elements of Member State's National Recovery Plans*, Final report for European Commission, Directorate-General Environment, Brussels.

DB Climate Change Advisors, 2009, *Global Climate Change Policy Tracker: An Investor's Assessment*, New York.

EC, 2008, *A European Economic Recovery Plan,* Communication from the Commission to the European Council, COM(2008) 800 final, Brussels.

EC, 2009, *Economic Crisis in Europe: Causes, Consequences and Responses,* European Economy No.7/2009, Directorate-General for Economic and Financial Affairs, Brussels.

EC, 2011, *European Competitiveness Report 2011,* Directorate-General Enterprise and Industry, Brussels.

Edenhofer, O. and Stern, N., 2009, *Towards a Global Green Recovery — Recommendations for Immediate G20 Action*. Potsdam Institute for Climate Impact Research, LSE's Grantham Research Institute on Climate Change and the Environment, London.

EEA, 2010, *The European environment — state and outlook 2010: synthesis*, European Environment Agency, Copenhagen.

EEA, 2012, *Environmental indicator report 2012 — Ecosystem resilience and resource efficiency in a green economy in Europe*, European Environment Agency, Copenhagen.

EEA, 2013, *Environmental indicator report 2013 — Natural resources and human well-being in a green economy*, European Environment Agency, Copenhagen.

Ekins, P. and Speck, S., 2011, *Environmental Tax Reform: A Policy for Green Growth*, Oxford University Press, Oxford.

Eurostat, 2013, *Sustainable development in the European Union 2013 monitoring report of the EU sustainable development strategy*, 2013 edition, Luxembourg.

Fedrigo-Fazio, D. and ten Brink, P., 2012, *Green Economy — What do we mean by Green Economy,* Briefing, http://www.unep.org/pdf/Main_briefing_2012.pdf (accessed 20 April 2013).

Geels, F.W., 2013, *The impact of the financial-economic crisis on sustainability transitions: Financial investment, governance and public discourse*, Working Paper no 39, WIFO — Austrian Institute of Economic Research, Vienna, www.foreurope.eu (accessed 5 December 2013).

HSBC, 2010, *Overview of global green stimulus spending*, HSBC Global Research.

Jacobs, M., 1991, *The Green Economy Environment, Sustainable development and the Politics of the Future*, Pluto Press, London.

Mazza, L. and ten Brink, P., 2012, *Green Economy — Green Economy in the European Union*, Supporting Briefing. http://www.ieep.eu/assets/963/KNOSSOS_Green_Economy_Supporting_Briefing.pdf (accessed 15 April 2014).

OECD, 2010, *Tax Policy Reform and Economic Growth,* OECD Tax Policy Studies, No. 20, Organisation for Economic Co-operation and Development, Paris.

OECD, 2011, *Towards a Green Growth,* Organisation for Economic Co-operation and Development, Paris.

Pearce, D., Markandya, A. and Barbier, E.D., 1989, *Blueprint of a green economy*, Earthscan Publications, London.

Stiglitz, J.E., Sen, A. and Fitoussi, J.-P., 2009, *Report of the Commission on the Measurement of Economic Performance and Social Progress*, Paris. http://www.stiglitz-sen-fitoussi.fr/documents/rapport_anglais.pdf (accessed 20 November 2013).

SRU, 2012, *Environmental Report 2012 Responsibility in a finite world*, Sachverständigenrat für Umweltfragen — German Advisory Council on the Environment), Berlin.

UNECE, 2013, *Framework and suggested indicators to measure sustainable development*, Paper prepared by the Joint UNECE/Eurostat/OECD Task Force on Measuring Sustainable Development, http://www.unece.org/fileadmin/DAM/stats/documents/ece/ces/2013/SD_framework_and_indicators_final.pdf (accessed 15 April 2014).

UNDESA, 2012, *A Guidebook on Green Economy Issue 1: Green Economy, Green Growth, and low carbon development — history, definitions and a guide to recent publications*, United Nations Department of Economics and Social Affairs, New York.

UNEP, 2011, *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*, United Nations Environment Programme, Nairobi.

UNSD, 2012, *Revision of the System of Environmental-Economic Accounting (SEEA) SEEA Central Framework*, United Nations Statistical Commission, New York.

Vergragt, P.J., 2013, A possible way out of the combined economic-sustainability crisis, *Environmental Innovations and Societal Transition*, Vol. 6, pp. 123–125, Elsivier, Amsterdam.

World Bank, 2012, *Inclusive Green Growth The Pathway to Sustainable Development*, Washington, DC.

WCED, 1987, *Our Common Future*, (the Brundtland report), World Commission on Environment and Development, Oxford University Press, Oxford.

WEF, 2014, *Global Risks 2014,* Ninth Edition, World Economic Forum, Geneva.

Chapter 2

EC, 2010a, *Europe 2020 A strategy for smart, sustainable and inclusive growth*, Communication from the Commission, COM(2010) 2020 final, Brussels.

EC, 2010b, *An Integrated Industrial Policy for the Globalisation Era Putting Competitiveness and Sustainability at Centre Stage*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2010) 614, Brussels.

EC, 2011a, *A resource-efficient Europe — Flagship initiative under the Europe 2020 Strategy,* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2011) 21, Brussels.

EC, 2011b, *Roadmap to a Resource Efficient Europe,* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2011) 571, Brussels.

EC, 2011c, *Roadmap for moving to a competitive low carbon economy in 2050,* Communication from the Commission to the European Parliament, the Council, the European Economic and Social

Committee and the Committee of the Regions, COM(2011) 112, Brussels.

EC, 2011d, *Energy Roadmap 2050*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2011) 885, Brussels.

EC, 2013, *The 7th Environment Action Programme to 2020. Living Well, Within the Limits of our Planet,* European Decision No 1386/2013/EU of the European Parliament and the Council, Brussels.

EC, 2014, *For a European Industrial Renaissance*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2014) 14/2, Brussels.

Chapter 3

EC, 2011, *Roadmap for moving to a competitive low carbon economy in 2050,* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2011) 112, Brussels.

EC, 2014a, *A policy framework for climate and energy in the period from 2020 to 2030*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2014) 15, Brussels.

EC, 2014b, *Transport and GHG Emissions Trends to 2050 reference scenario 2013*, published by the Directorate-General for Energy, Brussels.

EEA, 2010, *The European environment — state and outlook 2010: synthesis*, European Environment Agency, Copenhagen.

EEA, 2012, *Environmental indicator report 2012 — Ecosystem resilience and resource efficiency in a green economy in Europe*, European Environment Agency, Copenhagen.

EEA, 2013a, *Towards a green economy in Europe EU environmental policy targets and objectives 2010–2050*, EEA Report No 8/2013, European Environment Agency, Copenhagen.

EEA, 2013b, *Trends and projections in Europe 2013 — Tracking progress towards Europe's climate and energy targets until 2020*, EEA Report No 10/2013, European Environment Agency, Copenhagen.

EEA, 2013c, *Air quality in Europe — 2013 report*, EEA Report No 9/2013, European Environment Agency, Copenhagen.

EEA, 2013d, *Managing municipal solid waste — a review of achievements in 32 European countries*, EEA Report No 2/2013, European Environment Agency, Copenhagen.

EEA, 2014, *Multiannual Work Programme 2014–2018 Expanding the knowledge base for policy implementation and long-term transitions*, European Environment Agency, Copenhagen.

ETC/SCP, 2011, *Towards a Green Economy in the EU. Gaps and macro processes*, Final report, December, Copenhagen.

ETC/SCP, 2013, *Targets and scenarios for the Green Economy, Instruments for policy analysis and assessments — Gap analysis*, Final report, November 2013, European Topic Centre on Sustainable Consumption and Production, Copenhagen.

Chapter 4

Ahmad, N. and Wyckoff, A., 2003, *Carbon Dioxide Emissions Embodied in International Trade of Goods*, OECD Science, Technology and Industry Working Papers 2003/15, Organisation for Economic Co-operation and Development, Paris.

Arto, I., Roca, J., and Serrano, M., 2014, Measuring emissions avoided by international trade: Accounting for price differences, *Ecological Economics*, 97:93–100, Elsevier, Amsterdam.

Baumol, W.J., 1967, Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis, *The American Economic Review*, 57(3), 415–426, American Economic Association, Washington, DC.

EC, 2012, *A Stronger European Industry for Growth and Economic Recovery Industrial Policy Communication Update*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, SWD(2012) 582 final, Brussels.

EC, 2013, *European Competitiveness Report 2013. Towards Knowledge Driven Reindustralisation*, Commission Staff Working Document SWD(2013) 347 final, Brussels.

EC, 2014, *For a European Industrial Renaissance*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2014) 14/2, Brussels.

EEA, 2013a, *European Union CO_2 emissions: different accounting perspectives*, EEA Technical report No 20/2013, European Environment Agency, Copenhagen.

EEA, 2013b, *Environmental pressures from European consumption and production. A study in integrated environmental and economic analysis*, EEA Technical report No 2/2013, European Environment Agency, Copenhagen.

ETC/SCP, 2012, *Structural change and CO_2 emissions in Europe: Focus on services*, European Topic Centre on Sustainable Consumption and Production, Copenhagen.

ETC/SCP, 2013, *Targets and scenarios for the Green Economy. Extension of structural decomposition analysis and 'what if' scenarios*, Final draft, European Topic Centre on Sustainable Consumption and Production, November 2013, Copenhagen.

Eurostat, 2011, *CO_2 emissions induced by EU's final use of products are estimated to be 9 tonnes per capita*, Statistics in Focus 22/2011, Luxembourg, http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-11-022/EN/KS-SF-11-022-EN.PDF (accessed 14 May 2014).

Eurostat, 2012, *Energy, transport and environmental indicators*, Pocketbooks 2012 edition, Luxembourg.

Giljum, S., Lutter, S., Bruckner, M. and Aparcana, S., 2013, State-Of-Play of National Consumption-Based Indicators, final report to European Commission Directorate-General Environment, Brussels.

Jungbluth, N., Stucki, M. and Leuenberger, M., 2011, *Environmental Impact of Swiss Consumption and Production. A combination of input-output analysis with life-cycle assessment*, Federal Office for the Environment, Environmental studies no. 1111, Bern.

Hillman, J., 2013, *Changing Climate for Climate Taxes Who's Afraid of the WTO?*, published by German Marshall Fund of the United States, Washington, DC.

Kratena, K., and Meyer, I., 2010, *CO_2 emissions embodied in Austrian international trade*, FIW Research Reports 2009–2010 no. 02, Forschungschwerpunkt Internationale Wirtschaft, Vienna.

Li, Y. and Hewitt, C.N., 2008, The effects of trade between China and the UK on national and global carbon dioxides emissions, *Energy Policy*, 36, 1 907–1 914, Elsivier, Amsterdam.

Nakano, S., Okamura, A., Sukurai, N., Suzuki, M., Tojo, Y. and Yamano, N., 2009, *The Measurement of CO_2 Embodiments in International Trade: Evidence from the Harmonised Input-Output and Bilateral Trade Database*, Statistical Analysis of Science, Technology and Industry Working Paper 2009/3, Organisation for Economic Co-operation and Development, Paris.

Peters, G. and Hertwick, E., 2008, CO_2 Embodied in International Trade with Implications for Global Climate Policy, *Environmental Science and Technology*, 42(5), 1 401–1 407, ACS Publications, Washington, DC.

Schettkat, R. and Yocarini, L., 2006, The Shift to Services Employment: a Review of the Literature, *Structural Change and Economic Dynamics*, 17, 127–147, Elsevier, Amsterdam.

Taylor, C., Jowett, A. and Hardie, M., 2014, *An Examination of Falling Real Wages, 2010–2013*, Office for National Statistics (ONS), Newport, the United Kingdom, http://www.ons.gov.uk/ons/dcp171766_351467.pdf (accessed 30 April 2014).

Wiedmann, M., 2009, A first empirical comparison of energy Footprints embodied in trade — MRIO versus PLUM, *Ecological Economics*, 68(7), 1 975–1 990, Elsevier, Amsterdam.

Wiedmann, T.O., Schandl, H., Lenzen, M., Moran, D., Suh, S., West, J. and Kanemoto, K., 2013, The material footprint of nations, Proceedings of the National Academy of Sciences, www.pnas.org/cgi/doi/10.1073/pnas.1220362110.

Yunfeng, Y., Laike, Y. and Priewe, J. 2011, *The Impact of China-EU Trade on Climate Change*, Working Paper No 2/2011, Berlin Working Papers on Money, Finance, Trade and Development, University of Applied Science, Berlin.

Chapter 5

Section 5.1

Antonioli, D., Mancinelli, S. and Mazzanti, M., 2013, Is Environmental Innovation Embedded within High-Performance Organisational Changes? The role of human resource management and complementarity in green business strategies, *Research Policy*. 42 (4), 975–988, Elsevier, Amsterdam.

Brock, W. and Taylor, M., 2010, The Green Solow model, *Journal of Economic Growth*, 15(2), 127–153, Springer, Berlin.

Brunnermeier, S.B. and Cohen, M.A., 2003, Determinants of EI in US manufacturing industries. *Journal of Environmental Economics and Management*, 45 (2), 278–293, Elsevier, Amsterdam.

Carrion-Flores, C. and Innes, R., 2010, EI and environmental performance, *Journal of Environmental Economics and Management*, 59 (1), 27–42, Elsevier, Amsterdam.

CML, PSI, CSM, 2008, ECO-DRIVE: A framework for measuring eco-innovation: typology of indicators based on causal chains, Final Report, FP6-2005-SSP-5-A, Leiden, London and Lüneburg.

Costantini, V. and Mazzanti, M., 2013, *The Dynamics of Economic and Environmental Systems. Innovation, Policy and Competitiveness*, Springer, Berlin.

Dechezlepretre, A., Glachant, M., Haščič, I., Johnstone, N. and Ménière, Y., 2011, Invention and Transfer of Climate Change-Mitigation Technologies: A Global Analysis, *Review of Environmental Economics and Policy*, 5 (1), 109–130, Oxford University Press, Oxford.

EC, 2004**,** *Stimulating technologies for sustainable development: an Environmental Technologies Acton Plan for the European Union,* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2004) 38, Brussels.

EC, 2010a, *Europe 2020 Flagship Initiative Innovation Union,* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2010) 546, Brussels.

EC, 2010b, *EUROPE 2020 A strategy for smart, sustainable and inclusive growth*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2010) 2020, Brussels.

EC, 2011, *Innovation for a sustainable Future — The Eco-innovation Action Plan (Eco-AP),* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2011) 899, Brussels.

EC, 2013a, *State of Innovation Union 2012,* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2013) 149, Brussels.

EC, 2013b, *Innovation Union Scoreboard*, European Commission, Brussels.

Edenhofer, O., Carraro, C. and Hourcade, J-C., 2012, On the economics of decarbonization in an imperfect world, *Climatic Change*, 114 (1), 1–8, Springer, Berlin.

EEA, 2013, *Towards a green economy in Europe — EU environmental policy targets and objectives 2010–2050*, EEA Report No 8/2013, European Environment Agency, Copenhagen.

Europe Innova, 2008, *Sectoral Innovation Watch in Europe. Eco-Innovation*. Final Report, May 2008, European Commission, Brussels.

Fankhauser, S., Shelleier, F. and Stern, N., 2011, Climate change, Innovation and Jobs, *Climate Policy*, 8 (4), 421–429, Taylor and Francis, Abingdon.

Ghisetti, C. and Quatraro, F., 2013, Beyond inducement in climate change: Does environmental performance spur environmental technologies? A regional analysis of cross-sectoral differences, *Ecological Economics*, 96, 99–113, Elsevier, Amsterdam.

Gilli, M., Mazzanti, M. and Nicolli, F., 2013, Sustainability and Competitiveness in Evolutionary Perspectives. Environmental Innovations, Structural Change and Economic Dynamics in the EU, *Journal of socio-economics*. vol. 45(C), 204–215, Elsevier, Amsterdam.

Horbach, J., 2008, Determinants of Eco-innovations, New Evidence From German Panel Data Sources, *Research Policy*, 37, 1, 163–173, Elsevier, Amsterdam.

Jaffe, A.B., Newell R.G. and Stavins, R.N., 2003, Technological change end the environment, In *Handbook of Environmental Economics*, in: K. G. Mäler and J. Vincent (eds.), vol. 1, pp. 461–516, North-Holland, Amsterdam.

Jaffe, A. B., Peterson, S. R., Portney, P. R. and Stavins, R. N., 1995, Environmental regulation and the competitiveness of U.S. Manufacturing: What does the evidence tell us? *Journal of Economic Literature*, 33 (1), 132–163, American Economic Association, Washington, DC.

Jaffe, A.B. and Palmer, K., 1997, Environmental regulation and innovation: a panel data study. *Review Economic and Statistics*, 79 (4), 610–619, MIT Press, Cambridge, MA.

Johnstone, N., 2007, *Environmental Policy and Corporate Behaviour*, Edward Elgar, Cheltenham.

Kemp, R., 1997, *Environmental Policy and Technical Change*. Edward Elgar, Cheltenham.

Kemp, R. and Pontoglio, S., 2011, The innovation effects of environmental policy instruments —A typical case of the blind men and the elephant? *Ecological Economics*, 72, 28–36, Elsevier, Amsterdam.

Marin, G. and Mazzanti, M., 2013, The evolution of environmental and labour productivity dynamics, *Journal of Evolutionary Economics*, 23(2), 357–399, Springer, Berlin.

Mazzanti, M. and Montini, A., 2010, *Environmental Efficiency, Innovation and Economic Performances,* Routledge, London.

Mohnen, P. and Roller, L.H., 2005, Complementarities in Innovation Policy. *European Economic Review*, 49, 1 431–1 450, Elsevier, Amsterdam.

Montresor, S., Ghisetti, C. and Marzucchi, A., 2013, *The 'green-impact' of the open innovation mode. Bridging knowledge sourcing and absorptive capacity for environmental innovations*. JRC-IPTS Working Papers JRC83831, Institute for Prospective and Technological Studies, Joint Research Centre, Seville.

OECD, 2008, *Environmental Policy, Technological Innovation and Patents*, Organisation for Economic Co-operation and Development, Paris.

OECD, 2010a, *Climate Policy and Technological Innovation and Transfer: An Overview of Trends and Recent Empirical Results*, Organisation for Economic Co-operation and Development, Paris.

OECD, 2010b, *Environmental Policy Design Characteristics and Technological Innovation: Evidence from Patent Date*, Organisation for Economic Co-operation and Development, Paris.

OECD, 2011, *Invention and Transfer of Environmental Technologies*, Organisation for Economic Co-operation and Development, Paris.

OECD, 2012, *Energy and Climate Policy: Bending the Technological Trajectory* (2012). Policy brief — Energy and Climate Policy: Bending the technological trajectory of key findings. Organisation for Economic Co-operation and Development, Paris.

OECD, 2013, International Cooperation for Climate Change Innovation: A Problem Shared is a Problem Halved, Organisation for Economic Co-operation and Development, Paris.

Popp, D., 2010, Exploring Links Between Innovation and Diffusion: Adoption of NOX Control Technologies at U.S. Coal-fired Power Plants, *Environmental and Resource Economics*, 45 (3), 319–352, Springer, Berlin.

Rennings, K., 2000, Redefining innovation — eco-innovation research and the contribution from ecological economics. *Ecological Economics*, 32, 319–332, Elsevier, Amsterdam.

Roberts, J., 2006, *The Modern Firm. Organizational Design for Performance and Growth*. Oxford University Press, Oxford.

Stern, N., 2007, *The Economics of Climate Change — The Stern Review.* Cambridge University Press, Cambridge.

UCL, 2014, *Greening the Recovery,* Report of the UCL Green policy commission, University College London, London.

UNU-MERIT, ZEW, RISO, ICL, LEIA, 2008, *MEI — Measuring Eco- Innovation*, Draft Final Report, March, Organisation for Economic Co-operation and Development, Paris.

van den Bergh, J.C.J.M., 2007, Evolutionary thinking in environmental economics, *Journal of Evolutionary Economics,* 17 (5), 521–549, Springer, Berlin.

Section 5.3

Costantini, V. and Mazzanti, M., 2012, On the green and innovative side of trade competitiveness? *Research Policy*, 41, 1, 132–153, Elsevier, Amsterdam.

Dechezlepretre, A., Glachant, M., Johnstone, N., Hascics, I. and Meniere, Y., 2011, Invention and Transfer of Climate Change–Mitigation Technologies: A Global Analysis, *Review of Environmental Economics and Policy*, 5, 1, 109–130, Oxford University Press, Oxford.

ETC/SCP, 2009, *Environmental Pressures from European Consumption and Production — A study in integrated environmental and economic analysis*, ETC/SCP working paper 1, European Topic Centre on Sustainable Consumption and Production, Copenhagen.

Ghisetti, C. and Quatraro, F., 2013, Beyond inducement in climate change: Does environmental performance spur environmental technologies? A regional analysis of cross-sectoral differences, *Ecological Economics*, 96, 99–113, Elsevier, Amsterdam.

Gilli, M., Mancinelli, S. and Mazzanti, M., 2014, Innovation complementarity and environmental productivity effects: reality or delusion? Evidence from the EU, *Ecological Economics*, Elsevier, Amsterdam, (previous version nota di lavoro FEEM 88 October 2013, http://www.feem.it/getpage.aspx?id=73&sez=Publications&tab=1&padre=20&searchby=d).

Gilli, M., Mazzanti, M. and Nicolli, F., 2013, Sustainability, Environmental Innovations and competitiveness in evolutionary perspectives. Evidence from the EU, *Journal of Socio Economics*, 45(C), 204–215, Elsevier, Amsterdam.

Horbach, J., 2008, Determinants of Eco-innovations, New Evidence From German Panel Data Sources, *Research Policy*, 37, 1, 163–173, Elsevier, Amsterdam.

Johnstone, N., 2007, (ed.) *Environmental Policy and Corporate Behavior*, Edward Elgar, Cheltenham.

Kemp, R. and Pontoglio, S., 2011, The innovation effects of environmental policy instruments—A typical case of the blind men and the elephant? *Ecological Economics* 72, 28–36, Elsevier, Amsterdam.

Lissoni, F. and Metcalfe, S., 1994, Diffusion of Innovation Ancient and Modern: a review of the main themes', in Rothwell, R. andDodgson, M., (eds.), *New Developments in the Economics of Innovation*, Pinter 1994.

Mazzanti, M. and Montini, A., 2010, *Environmental Efficiency, Innovation and Economic Performances*, Routledge, London.

Mohnen, P. and Roller, L.H., 2005, Complementarities in Innovation Policy, *European Economic Review*, 49, 1 431–1 450, Elsevier, Amsterdam.

Montresor, S., Ghisetti, C. and Marzucchi, A., 2013, *The 'green-impact' of the open innovation mode. Bridging knowledge sourcing and absorptive capacity for environmental innovations*. JRC-IPTS Working Papers JRC83831, Institute for Prospective and Technological Studies, Joint Research Centre, Seville.

OECD, 2011, *Invention and transfer of Environmental Technologies*, OECD Studies on Environmental innovation, Organisation for Economic Co-operation and Development, Paris.

Roberts, J., 2006, *The Modern Firm. Organizational Design for Performance and Growth*, Oxford University Press, Oxford.

UCL, 2014, *Greening the recovery*, Report of the UCL Green policy commission, University College London, London.

Section 5.4

Marin, G., Marzucchui, A. and Zoboli, R., 2014, SMEs and Barriers to Eco-Innovation in *EU: A Diverse Palette of Greens*, INGENIO (CSIC-UPV) Working Paper Series 2014-04, Valencia.

Porter, M. and Van der Linde, C., 1995, Toward a new conception of the environment — competitiveness relationship, *Journal of Economic Perspective*, 9 (4), 97–118, American Economic Association, Washington, DC.

Porter, M., 1991, America's Green Strategy, *Scientific American*, 264 (4), 168, New York.

Porter, M. and Esty, D., 1998, Industrial ecology and competitiveness: Strategic implications for the firm, *Journal of Industrial Ecology*, 2, 35–43, John Wiley, Hoboken, NJ.

Chapter 6

Mokyr, J., 2002, *The Gifts of Athena: Historical Origins of the Knowledge Economy*, Princeton: Princeton University Press, Princeton, NJ.

UN, 2012, *The Future we want*, Resolution adopted by the General Assembly on 27 July 2012, A/RES/66/288, United Nations, New York.

Section 6.1

Cao, J. and Groba, F., 2012, Chinese Renewable Energy Technology Exports: The Role of Policy, Innovation and Markets, Discussion Paper 1263, German Institute for Economic Research (DIW), Berlin.

EC, 2011, *EU industrial structure 2011 Trends and Performance*, Directorate-General for Enterprise and Industry, Brussels.

EC, 2013, *Competing in Global Value Chains EU Industrial Structure Report 2013*, Directorate-General for Enterprise and Industry, Brussels.

ETC/SCP, 2012, Trade and the green economy. Technology and knowledge transfer, November 2012, European Topic Centre on Sustainable Consumption and Production, Copenhagen.

Johnstone, N., Haščič, I. and Popp, D., 2010, Renewable Energy Policies and Technological Innovation: Evidence Based on Patent Counts. *Environmental and Resource Economics*, 45, 133–155, Springer, Berlin.

Nicolli, F. and Mazzanti, M., 2011, Diverting waste: the role of innovation, in OECD: *Invention and transfer of environmental technologies*, Organisation for Economic Co-operation and Development, Paris.

UNEP, 2013, *Green Economy and Trade*. *Trends, Challenges and Opportunities*, Geneva.

Section 6.2

Maskus, K., 2004, *Encouraging International Technology Transfer*, UNCTAD/ICTSD Project on Intellectual Property Rights and Sustainable Development, Issue Paper no. 7, International Center for Sustainable Development, Geneva.

Johnstone, N., Haščič, I. and Popp, D., 2010, Renewable Energy Policies and Technological Innovation: Evidence Based on Patent Counts. *Environmental and Resource Economics* 45, 133–155, Springer, Berlin.

Dechezleprêtre, A., Glachant, M., Haščič, I., Johnstone, N. and Ménière, Y., 2010, Invention and transfer of climate change-mitigation technologies: A global analysis. *Review of Environmental Economics and Policy*, 2011, 5, 1, 109–130, Oxford University Press, Oxford. Post-Print hal-00488214, HAL, EconPapers.

Popp, D., 2005, *Using the Triadic Patent Family Database to Study Environmental Innovation*, prepared for the Organisation for Economic Co-operation and Development Environmental Directorate, report # ENV/EPOC/WPNEP/R&D(2005)2, Paris.

Popp, D., Haščič, I. and Medhi, N., 2011, Technology and the diffusion of renewable energy. *Energy Economics*, 33, 648–662, Elsevier, Amsterdam.

Nicolli, F. and Mazzanti, M., 2011, Diverting waste: The role of innovation. In OECD (2011): *Invention and transfer of Environmental Technologies*, OECD Studies on Environmental innovation, Organisation for Economic Co-operation and Development, Paris.

Fishbein, B.K., 1994, *Germany, Garbage and the Green Dot: Challenging a Throwaway Society*. EPA/600/R-94/179, United States Environmental Protection Agency, Washington, DC.

Section 6.3

Birdsall, N. and Wheeler, D., 1993, Trade Policy and Industrial Pollution in Latin America: Where are the Pollution Havens? *Journal of Environment and Development*, 2,1. Cambridge University Press, Cambridge.

Brack, D., Grubb, M. and Windram, C., 2000, *International Trade and Climate Change Policies*, Earthscan Publications Ltd, London.

EU, 2003, Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, Brussels.

Jörgens, H., 2003, *Governance by Diffusion — Implementing Global Norms Through Cross-National Imitation and Learning*, FFU-report 07-2003, Freie Universität Berlin, Department of Political and Social Sciences, Environmental Policy Research Centre, Berlin.

Perry, M. and Singh, S., 2001, Corporate greening of foreign transnationals in Singapore, *Singapore Journal of Tropical Geography*, 22 (1), Singapore.

Tews, K., Busch, P.-O. and Jörgens, H., 2003, The diffusion of new environmental policy instruments, *European Journal of Political Research*, 42, 569–600, John Wiley, Hoboken, NJ.

Tietje, C. and Wolf, S., 2005, *REACH Registration of Imported Substances — Compatibility with WTO Rules*, Beiträge zum Transnationalen Wirtschaftsrecht, Heft 42, Martin-Luther-Universität Halle-Wittenberg.

Chapter 7

Andersen, M.S. and Ekins, P. (eds.), 2009, *Carbon-Energy Taxation: Lessons from Europe*, Oxford University Press, Oxford.

Baldacci, E., Gupta, S. and Mulas-Granados, C., 2010, Getting Debt under Control, *Finance and Development*, 47 (4) 18–21, International Monetary Fund, Washington, DC.

CDP, 2013, *Use of internal carbon price by companies as incentive and strategic planning tool A review of findings from CDP 2013 disclosure*, A white paper from Carbon Disclosure Project (CDP) North America, New York.

Convery, F., McDonnell, S. and Ferreira, S., 2007, The most popular tax in Europe? Lessons from the Irish plastic bags levy, *Environmental and Resource Economics*, 38:1–11, Springer, Berlin.

De Mooij , R., Parry, I.W.H. and Keen, M., (eds.), 2012, *Fiscal Policy to Mitigate Climate Change A Guide for Policymakers*. International Monetary Fund, Washington, DC.

De Vries, F. and Medhi, N., 2008, Environmental regulation and international innovation in automotive emissions control technologies, in: *Environmental Policy, Technological Innovation and Patents*, Organisation for Economic Co-operation and Development, Paris.

EC, 2011a, *A resource-efficient Europe — Flagship initiative under the Europe 2020 Strategy,* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2011) 21, Brussels.

EC, 2011b, *Roadmap to a Resource Efficient Europe,* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2011) 571, Brussels.

EC. 2012, *Annual Growth Survey 2012 — Annex: Growth-Friendly Tax Policies in Member States and Better Tax Coordination in the EU*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Vol.5/5 Annex IV, COM(2011) 815 final, Brussels.

EC, 2013a, *Annual Growth Survey 2014*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2013) 800 final, Brussels.

EC, 2013b, *Tax reforms in EU Member States 2013 Tax policy challenges for economic growth and fiscal sustainability*, European Economy 5/2013, Brussels.

EC, 2014a, *Study on Environmental Fiscal Reform Potential in 12 EU Member States*, European Commission Directorate-General Environment, Brussels.

EC, 2014b, *Energy prices and costs in Europe*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2014) 21, Brussels.

EC, 2014c, *Energy Economic Developments in Europe*, European Economy 1/2014, Directorate-General for Economic and Financial Affairs, Brussels.

EC, 2014d, *On the Exploration and production of hydrocarbons (such as shale gas) using high volume hydraulic fracturing in the* EU, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2014) 23 final/2, Brussels.

EC, 2014e, *Energy prices and cost report*, Commission Staff Working Document, accompanying the paper *Energy prices and costs in Europe*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, SWD(2014) 20 final/2, Brussels.

EEA, 2005, *Market-based instruments for environmental policy in Europe*, Technical report No 8/2005, European Environment Agency, Copenhagen.

EEA, 2011a, *Environmental tax reform in Europe: implications for income distribution*, Technical report No 16/2011, European Environment Agency, Copenhagen.

EEA, 2011b, *Environmental tax reform in Europe: opportunities for eco-innovation*, Technical report

No 17/2011, European Environment Agency, Copenhagen.

EEA, 2013, *Global megatrend update: 7 Intensified global competition for resources*, European Environment Agency, Copenhagen.

Ekins, P. and Speck, S., 1999, Competitiveness and Exemptions from Environmental Taxes in Europe, *Environmental and Resource Economics*, Vol. 13, pp. 369–396, Springer, Berlin.

Ekins, P. and Speck, S. (eds.), 2011, *Environmental Tax Reform: A Policy for Green Growth*, Oxford University Press, Oxford.

Ekins, P. and Speck, S., 2012, Impacts on Competitiveness: What Do We Know From Modeling?, In: J. Milne and M.S. Andersen (eds.): *Handbook of Research on Environmental Taxation*, pp. 377–396, Edward Elgar, Cheltenham.

ETC/SCP, 2012, Resource taxation and resource efficiency along the value chain of mineral resources, ETC/SCP Working Paper 3/2012, Copenhagen, http://scp.eionet.europa.eu/wp/wp2012_3 (accessed 5 May 2014).

ETC/SCP, 2014, Resource taxation. Discussion for selected materials, Copenhagen, forthcoming.

Eurostat, 2012, *Environmental taxes account for 6.2 % of all revenues from taxes and social contributions in the EU-27*, Statistics in focus 53/2012, Luxembourg.

Green Fiscal Commission, 2009, *The Case for a Green Fiscal Reform — Final Report of the UK Green Fiscal Commission,* London.

IMF, 2010, *Fiscal Exit: From Strategy to Implementation*. International Monetary Fund Fiscal Monitor, Washington, DC.

Neuhoff, K., Acworth, W., Dechezleprêtre, A., Dröge, S., Sartor, O., Sato, M., Schleicher, S., and Schopp, A., 2014, *Staying with the leaders — Europe's path to a successful low-carbon economy*, Climate Strategies. Berlin and London.

OECD, 2006, *The Political Economy of Environmentally Related Taxes*, Organisation for Economic Co-operation and Development, Paris.

OECD, 2010, *Taxation, Innovation and the Environment*, Organisation for Economic Co-operation and Development, Paris.

OECD, 2012, *Fiscal Consolidation: How Much, How Fast and by What Means?* OECD Economic Policy Papers No. 1, April 2012, Organisation for Economic Co-operation and Development, Paris.

OECD, 2013, *Effective Carbon Prices*, Organisation for Economic Co-operation and Development, Paris.

Seres, A. de, Murtin, F. and Nicolleti, G., 2010, *A Framework for Assessing Green Growth Policies*, OECD Economics Department Working Papers, No. 774, Organisation for Economic Co-operation and Development, Paris.

Speck, S., Andersen, M.S., Nielsen, H., Ryelund, A. and Smith, C., 2006, *The Use of Economic Instruments in Nordic and Baltic Countries 2001–2005,* TemaNord 2006:525, Nordic Council of Ministers, Copenhagen.

Stiglitz, J.E., 2010, *Principles and Guidelines for Deficit Reduction*. Working Paper No.6, December 2010, The Roosevelt Institute, New York, NY.

Sustainable Prosperity, 2013, *Shadow Carbon Pricing in the Canadian Energy Sector*, Policy Brief, March 2013, University of Ottawa, Ottawa.

UNEP, 2010, *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*, United Nations Environment Programme, Nairobi.

Vivid Economics, 2012, C*arbon Taxation and fiscal consolidation: the potential of carbon pricing to reduce Europe's fiscal deficits*, Vivid Economics, London.

WBGU, 2011, *World in Transition A Social Contract for Sustainability*, German Advisory Council on Global Change, Berlin.

Wöhlbier, F., Astarita, C. and Mourre, G., 2014, *Consolidation on the revenue side and growth-friendly tax structures: an indicator based approach*, European Commission Directorate-General for Economic and Financial Affairs, Economic Papers 513, February, Brussels.

WEF, 2014, *Global Competitiveness Report 2013–2014*, World Economic Forum, Geneva.

Chapter 8

Arnold, M., 2010, Private equity: Specialist funds are keen to invest in clean technology, *Financial Times*, 3 June 2010, London.

Buchner, B., Falconer, A., Hervé-Mignucci, M., Trabacchi, C. and Brinkman, M., 2011, *The Landscape of Climate Finance*. Climate Policy Initiative, Venice.

Caravani, A., Nakhooda, S., Watson, C. and Schalatek, L., 2012, *The Global Climate Finance Architecture. Climate Funds Update*, November 2012, http://www.climatefundsupdate.org/resources/finance-fundamentals (accessed 9 June 2014).

Ciarlone, A. and Miceli, V., 2013, *Le strategie di portafoglio dei fondi di ricchezza sovrani e la crisi globale*, Questioni di Economia e Finanza (Occasional Papers), N°156, Banca d'Italia, Rome.

Climate Policy Initiative, 2013, *Global Landscape of Climate Finance 2013*, available online: http://climatepolicyinitiative.org/publication/global-landscape-of-climate-finance-2013 (accessed 9 June 2014).

Della Croce, R., Kaminker, C. and Stewart, F., 2011, *The Role of Pension Funds in Financing Green Growth Initiatives*, OECD Working Papers on Finance, Insurance and Private Pensions, No. 10, Organisation for Economic Co-operation and Development, Paris. http://dx.doi.org/10.1787/5kg58j1lwdjd-en (accessed 9 June 2014).

EC, 2011a, *Energy Roadmap 2050,* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2011) 885/2, Brussels.

EC, 2012a, *Connecting Europe. The energy infrastructure for tomorrow*, available at: http://ec.europa.eu/energy/mff/facility/doc/2012/connecting-europe.pdf (accessed 9 June 2014).

EC, 2012b, *Connecting Europe Facility. Investing in Europe Growth*, available at: http://ec.europa.eu/bepa/pdf/cef_brochure.pdf (accessed 9 June 2014).

EC, 2013a, *Long-Term Financing of the European Economy*, Green Paper 150, COM(2103) 150 final, 25 March 2013, available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0150:FIN:EN:PDF (accessed 9 June 2014).

EC, 2013b, *Promoting investment through the Neighbourhood Investment Facility (NIF)*, available online: http://ec.europa.eu/europeaid/where/neighbourhood/regional-cooperation/irc/investment_en.htm (accessed 9 June 2014).

EC, 2013c, Interim Report on the Pilot Phase of the Europe 2020 Project Bond Initiative, Report from the Commission, COM(2013) 929 final, Brussels.

EC, 2013d, *The pilot phase of the Europe 2020 Project Bond Initiative*, available online: http://ec.europa.eu/economy_finance/financial_operations/investment/europe_2020/index_en.htm (accessed 9 June 2014).

EC, 2014, *Communication on crowdfunding in the European Union*, Frequently Asked Questions, MEMO/14/240, 27 March 2014, available online: http://europa.eu/rapid/press-release_MEMO-14-240_en.htm (accessed 9 June 2014).

Ecofys, Fraunhofer ISI, TU Vienna EEG, Ernst & Young, 2011, *Financing Renewable Energy in the European Energy Market*, Ecofys, available online: http://ec.europa.eu/energy/renewables/studies/doc/renewables/2011_financing_renewable.pdf (accessed 9 June 2014).

ETC/SCP, 2013, The role of finance for the green economy, Final report, November 2013, European Topic Centre on Sustainable Consumption and Production, Copenhagen.

EBRD, 2013, EBRD Annual Report 2012, European Bank for Reconstruction and Development, London, available online: http://www.ebrd.com/downloads/research/annual/ar12e.pdf (accessed 9 June 2014).

EIB, 2013a, *FEMIP Annual Report 2012*, European Investment Bank, Luxembourg, available online: http://www.eib.org/infocentre/publications/all/femip-2012-annual-report.htm (accessed 9 June 2014).

EIB, 2013b, *Second project bond issue for Greater Gabbard OFTO demonstrates strong investor interest*, available online: European Investment Bank, Luxembourg, available online: http://www.eib.org/projects/press/2013/2013-204-institutional-investor-support-for-greater-gabbard-offshore-transmission-link-encouraged-by-first-use-of-project-bond-credit-enhancement-scheme-in-uk.htm (accessed 9 June 2014).

Eurosif, 2012, *European SRI Study 2012*, available online: http://www.eurosif.org/research/eurosif-sri-study/sri-study-2012 (accessed 18 June 2014).

IEA, 2012, *Tracking Clean Energy Progress*, IEA input to the Clean Energy Ministerial, International Energy Agency, Paris, available online: http://www.iea.org/publications/TCEP_web.pdf (accessed 9 June 2014).

Mazzucato, M., 2013, Serious innovation requires serious state support, *Financial Times*, 4 December 2013, London.

Miceli, V., 2013, Do Sovereign Wealth Funds Herd in Equity Markets? *Quantitative Finance*, 13(9), Taylor and Francis, Abingdon.

Scheherazade, D. and Bolger, A., 2014, Unilever issues £250m green bond, *Financial Times*, 19 March 2014, London.

UNEP, 2013, Green economy and trade. Trends, Challenges and Opportunities, Geneva.

World Bank, 2014, *Growing the Green Bond Market to Finance a Cleaner, Resilient World*, 4 March 2014, World Bank, Washington, DC, available online: http://www.worldbank.org/en/news/feature/2014/03/04/growing-green-bonds-market-climate-resilience (accessed 9 June 2014).

Annex 2

Miller, R.E. and Blair, P.D., 2009, *Input-Output Analysis: Foundations and Extensions*, Second Edition, Cambridge University Press, Cambridge.

Serrano, M. and Dietzenbacher, E., 2010, Responsibility and trade emission balances: An evaluation of approaches, *Ecological Economics*, 69(11), 2 224–2 232, Elsevier, Amsterdam.

Annex 4

APEC, 2001, *Survey of Environmental Markets in APEC*, Asia-Pacific Economic Cooperation (APEC) Committee on Trade and Investment, June 2001, Singapore.

Economic Analytical Unit. (no date), *Australia's Trade in Environmental goods and services*, Working Paper, Canberra.

ECORYS, 2009, *Study on the competitiveness of the EU eco-industry*, A Final Report to European Commission Directorate-General Enterprise and Industry, Brussels.

ECOTEC, 2002, *Analysis of the EU Eco-Industries, their Employment and Export Potential*, A Final Report to European Commission Directorate-General Environment, Brussels.

Ernst & Young, 2006, *Eco-industry, its size, employment, perspectives and barriers to growth in an enlarged EU*, A Final Report to European Commission Directorate-General Environment, Brussels.

ETC/SCP, 2012, Trade and the green economy. Technology and knowledge transfer, November 2012, European Topic Centre on Sustainable Consumption and Production, Copenhagen.

Eurostat, 2009, *Handbook on Environmental goods and services sector*, Luxembourg.

OECD/Eurostat., 1999, *The Environmental goods and Services Industry, Manual for data collection and analysis*, Organisation for Economic Co-operation and Development, Paris.

Steenblik, R., 2005, *Environmental Goods: a comparison of the APEC and the OECD lists*, OECD Trade and Environment Working Paper No. 2005-4, Organisation for Economic Co-operation and Development, Paris.

UNCTAD, 2001, WTO Accessions and Development Policies, UNCTAD/DITC/TNCD/11, United Nations, New York and Geneva.

UNEP, 2013, *Green economy and trade. Trends, Challenges and Opportunities*, Geneva.

WTO, 2001, Ministerial Declaration, WT/MIN(01)/DEC/1, 14 November, Doha, World Trade Organization, Geneva.

WTO, 2005, Synthesis of submissions Environmental Goods, TN/TE/W/63, World Trade Organization, Geneva.

Annex 1 Structural break analysis and projections techniques

Projections of indicators in Chapter 3 are based on time series techniques. Before estimating these, data have been processed to identify structural change in the series, i.e. a year/period in which the statistical behaviour of the series changes steadily compared to the previous period, thus highlighting underlying stable changes in the phenomenon represented by the time series. Structural breaks are identified in a recursive way.

The statistical tool used for structural breaks detection is the Chow test. A structural break is defined as a change in the estimated parameter linking the dependant variable to the independent variable(s). The independent variable here is a linear time trend and the structural break represents a stable change in the time pattern of the variable, which can resume the change of different underlying drivers.

A structural break does not necessarily correspond to a change in the trend, from increasing to decreasing and vice versa, but it signals a stable (statistically significant) change in the slope of the trend and in the intercept. An easy way to perform the Chow test is to add a dummy variable to the linear regression model for the period after which the break is expected to take place, and to add the interaction terms of this dummy variable with the independent variables. The coefficient for the dummy variable shows the estimated change in the intercept while the coefficients for the interaction terms show the differential effect for the sub-period of the original covariate. The null hypothesis of the Chow test is that the parameters of the dummy variable for the break and of the interaction terms are jointly equal to zero. The test is usually performed by mean of a simple F test. This procedure is performed recursively: once a break is identified, the part of the series before the break is removed and the test is repeated on the remaining years of the series.

The part of the series after the most recent structural break (statistically significant at least at a 5 % level) has been processed by applying an autoregressive of order one — AR(1) — model on the series to have projections of the series up to 2030 ([102]). Original data have been smoothed through a two-year moving average in order to reduce unstable year-by-year changes.

The AR(1) model is a regression model in which the dependent variable at time t (y_t) is a linear function of the same variable at $t\text{-}1$ (y_{t-1}):

$$y_t = \alpha + \rho\, y_{t-1} + \varepsilon_t$$

These techniques are extensively used for (economic) forecasting and they allow for the production of forecasts, even those simply based on past observed data, provided that certain conditions are fulfilled. In our case, the following features of the projection must be considered:

1. We make purely statistical projections into the future of the structurally stable part of current trends. We do not make any assumption on the future effects of either policies currently in place or new policies expected to be implemented at a later date. Our projections then implicitly assume a continuation of observed trends into the future (up to 2020), and that policies currently being implemented will not change future trends in any different way than they have done until the last year of observation.

2. By being a purely statistical projections of current trends, our model does not include assumptions on the effects of possible key market changes in the future (such as energy price changes) nor on the possible effects of technological changes and their diffusion into the economic system.

([102]) We have tested other specifications, for example AR(2), and projections in terms of intensities then translated into levels of the variables by using assumption on GDP growth, but they are either not statistically good, or they need additional assumptions difficult to justify on realistic grounds, and a loss of simplicity. Non-stationary series have been transformed by taking the first difference, making them stationary.

In short, by projecting these trends into the future through simple time series econometrics, a 'minimum assumptions' approach has been adopted and then it is implicitly assumed that all policy, market, and technology effects will continue to develop as they did until the late-2000s. In this respect, the analysis departs from what is done in macro model-based projections available from other studies, which usually assess *ex ante* the implications of, for example, the introduction of new policy measures. However, although methodologically different from macro-econometric or calibrated models, our projections could be somewhat close to baseline/reference scenarios of some model-based studies, which assume, for example, that policies already enacted or adopted will continue unchanged into the future ([103]).

([103]) See for example the report 'EU Energy, Transport and GHG Emissions Trends to 2050 reference scenario 2013' published by the DG Energy in 2014, http://ec.europa.eu/energy/observatory/trends_2030/index_en.htm.

Annex 2 Structural decomposition analysis and consumption perspective estimates

Structural decomposition analysis (SDA) aims at decomposing aggregate changes in time (between t = 0 and t = 1) of a variable of interest (for example, CO_2 emissions) into various components by considering the input-output relationships between sectors (structure of the economy). In this report (Chapter 5), we decompose changes in aggregate emissions by production sectors into four components: change in (i) emission intensity: (ii) technical change; (iii) structure of final demand, and (iv) level of final demand. The notation employed for the structural decomposition is explained in Table A2.1.

The accounting identity used to decompose total CO_2 emissions is given by equation 1 (similarly to Miller and Blair, 2009, p. 606):

$$\Delta w=w_1-w_0=e'_1L_1f_1-e'_0L_0f_0 = 0.5*\Delta e'(L_0f_0+L_1f_1)+0.5*(e'_0\Delta Lf_1+e'_1\Delta Lf_0)+0.5*(e'_0L_0+e'_1L_1)\Delta f\_c(f\_l_0+f\_l_1)+$$

$$+0.5*(e'_0L_0f\_c_0+e'_1L_1f\_c_1)\Delta f\_l \quad (1)$$

where:

- Emission intensity component = $0.5*\Delta e'(L_0f_0+L_1f_1)$
- Technical change component = $0.5*(e'_0\Delta Lf_1+\hat{y}_1\Delta Lf_0)$

Table A2.1 Notation for structural decomposition analysis

w	Scalar of total emissions
e	Vector of emission coefficients (CO_2/output)
Z	Inter-industry transaction matrix
x	Output vector
A=Z<x>-1	Matrix of technical coefficients
L=(I-A)-1	Leontief inverse
f	Final demand vector
f_l=f' i	Aggregate level of final demand (scalar)
f_c=f*(1/f_l)	Composition of final demand vector

- Structure of final demand component = $0.5*(e'_0L_0+e'_1L_1)\Delta f\_c(f\_l_0+f\_l_1)$
- Level of final demand component = $0.5*(e'_0L_0f\_c_0+e_1L_1f\_c_1)\Delta f\_l$

Two different versions of SDA are shown in Chapter 5 that refer to the two approaches — the 'production perspective' or footprint, and the 'consumption perspective' or footprint — usually adopted for the analysis of emissions in an EEIO framework These same two approaches have been extensively referred to in Chapter 4.

In the first approach (the production perspective, or production footprint), only direct domestic emissions are considered while final demand consists of total final demand (domestic demand and export) of domestically produced goods. In the second version (the consumption perspective or consumption footprint), foreign emissions are also considered by including in the matrix of inter-industry transactions both domestically produced and imported intermediate inputs, while final demand includes overall demand by resident agents, thus including domestic and imported final consumption but excluding exports.

In developing the consumption footprint analysis, we have adopted the so called domestic technology assumption (DTA). The DTA is based on two basic assumptions: (a) imported goods are produced with the same technology (Leontief matrix) of domestically produced goods; (b) the emission intensity of imported goods (environmental technology) is the same of that of domestically produced goods. According to these simplifications, emissions embodied in imported goods can be interpreted as domestically-avoided emissions.

The notation used is similar to that of Serrano and Dietzenbacher (2010) and it is the following:

i => summation vector

I => identity matrix

w => total emissions

$<e>$ => vector of emission coefficients (CO2/output)

Z => matrix of domestic intermediate inputs

M => matrix of imported intermediate inputs

$<f_d>$ => diagonal matrix of domestic final demand (including final demand for imported goods and excluding exported goods)

$<x_{d+m}> = Z+M+_d$ => diagonal matrix of domestic and imported output

$A_{d+m} = (Z+M) <x_{d+m}>^{-1}$=> matrix of technical coefficients under the DTA

$L_{d+m} = (I-A_{d+m})^{-1}$ => Leontief inverse under the DTA

Total consumption footprint emissions are represented by:

$w_{cp} = e' L_{d+m} <f_d>$

Annex 3 'What if' scenarios

The simulation tool for *ex ante* what if scenarios exploits an EEIO framework and it is based on Eurostat IO tables for the EU-27 as a whole, with air emissions accounts based on NAMEA (National Accounting Matrix including Environmental Accounts) as the environmental extension. Data are for 2008, the last available year, with a disaggregation of 64 sectors based on the NACE Rev. 2 classification for NAMEA and other economic accounts and with a disaggregation of 64 products based on the Classification of Products by Activity (CPA) 2008.

Scenarios are created according to the following input-output equation:

w=<e> L f

where:

- **w** is a column vector of a specific account (here greenhouse gas (GHG) emissions (104), VA and employment);
- **<e>** is a diagonal matrix of output coefficients of a specific account (GHG/output, VA/output, employment/output);
- **L** is the domestic (105) Leontief matrix: **L=(I-A)**$^{-1}$ where **I** is the identity matrix and **A** is the matrix of technical coefficients (**A=Z<y>**$^{-1}$ where **Z** is the matrix of domestic flows of intermediate inputs and **<y>** is a diagonal matrix of total domestic output).

Input-output tables for EU-27 are in the format of product-by-product while satellite accounts are collected at the industry level. Therefore, in a first step, satellite accounts are allocated to specific products by using the supply table (the vector with information by product is pre-multiplied by **C'**, where **C=V'<y>**$^{-1}$, in which **V** is the supply table and **<y>** is a diagonal matrix of total output).

In a second step, simulated results (by products) are allocated to specific sectors by using, again, the supply table (the vector with information by sector is pre-multiplied by **C'**$^{-1}$).

Scenarios are built by modifying specific elements of the vectors of final demand and emission coefficients (GHG/output).

In the scenarios in Chapter 4, the achievement of a 20 % share of manufacturing in EU-27 GDP has been rescaled to the same share of VA in 2020 results from assuming that the level of demand of manufacturing will increase taking as given the level of demand of services and agriculture so that the share of these macro-sectors will be redistributed at 2020 compared to the reference year (2008). The results of the scenarios include the consequences on a set of economic and environmental variables at EU-27 aggregate level. More details on the what if tool are presented in ETC/SCP 2013 (see also Box 4.2).

(104) GHG emissions are expressed in CO_2-equivalent emissions based on the global warming potential (GWP) of emissions. We aggregate emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). According to the IPCC, the global-warming potential (GWP) is 21 tonnes of CO_2-equivalent for 1 tonne of methane and 310 tonnes of CO_2-equivalent for 1 tonne of nitrous oxide.

(105) By employing the domestic input-output matrix, emissions related to the use of imported goods are not considered.

Annex 4 Classifications of environmental goods (technologies) in international trade

A number of bodies have proposed definitions and classifications of internationally traded environmental goods but these have not been universally agreed (UNEP, 2013). A problem of classification of environmental goods and services (EGS) was first raised in the framework of the Doha Round of negotiations for the liberalization of international trade. The Doha Ministerial Declaration (WTO, 2001) put in place a process for arriving at a list of environmental goods and services in international trade ([106]).

At the time of Doha Declaration, work to identify the scope of environmental goods had already been done at the OECD and APEC (Asia-Pacific Economic Co-operation) and both proposed a list of candidate goods based on a selection of items from the international trade classifications (in particular the Harmonised System [HS]). The lists differed and were somewhat influenced by trade policy considerations, in particular the specific interest of the proposing parties in the case of APEC list. After a rather complicated process stimulated by the Doha Declaration, the WTO arrived at an informal list (WTO, 2005), which strongly reflects trade policy bargaining. The WTO list has been criticized for its lack of selectiveness and its low usefulness in practice (UNCTAD, 2001, Steenblik, 2005). An attempt to consolidate and integrate the APEC list with the list that emerged from the OECD/Eurostat (1999) work on measuring environmental sectors has been done in an Australian paper (Economic Analytical Unit, no year).

The need to arrive at a definition of EGS in international trade emerged again in the recent developments towards a definition and classification of eco-industries.

The Eurostat handbook on the environmental goods and services sector gives instructions on how statistical offices can collect data on the exports of the environmental goods and service sectors (EGSS) (see Eurostat, 2009). Most of the efforts are in the direction of direct measurement (business registers, surveys, etc.) of export generated by the EGSS companies ([107]).

Different selections of EGS have been done in the 2000s by the studies for the European Commission aimed at characterizing the dynamics and the (export) performance of the eco-industries or environmental sectors in Europe. ECOTEC (2002) adopted a selection of traded goods, then extensively referred to by Ernst & Young (2006) and ECORYS (2009) ([108]), that combines two main parts: (i) the trade codes (HS) previously used in the DG Environment/Eurostat study *An Estimate of Eco-industries in the European Union 1994*; (ii) the trade codes identified by the study *The Environmental goods and Services Industry, Manual for data collection and analysis* (OECD /Eurostat 1999, this last being the forerunner of the Eurostat's Handbook 2009). The listed codes, divided in two main themes, mainly represent environmental technologies and renewable energy plants and equipment.

A synthesis of the main features of the different lists based on trade policy or eco-industry lists is presented in Table A4.1.

The existing classifications, as originally produced by OECD, WTO and others, have been reconsidered in ETC/SCP (2012) with a specific focus on imported/exported technologies as representing flows of embodied environmental

([106]) Steenblik (2005) summarises the history of the main lists.
([107]) Services are still a very weak area of analysis of traded environmental goods. See also Eurostat, 2009.
([108]) The ECOTEC (2002) and Ernst & Young (2006) lists are identical. They are composed by the following categories: air pollution control; water pollution control; waste disposal; monitoring equipment; other environmental equipment; solar thermal; photovoltaic; hydropower. The ECORYS (2009) list differs from the ECOTEC/Ernst & Young lists by an additional code in monitoring equipment and an omitted code in both: water pollution control and other environmental equipment.

Table A4.1 Main features of the different lists: summary

	Trade policy lists				Eco-industry lists		
	OECD (2005)	**WTO (2005)**	**APEC (2001)**	**Australian Potential EGS (2002?)**	**ECOTEC (2002)**	**Ernst & Young (2006)**	**ECORYS (2009)**
Number of items/ products (HS codes)	158	480	109	169	26	26	24
Macro categories	3	None	None	None	None	None	None
Sub categories	18	17	9	11	8	8	8

Source: ETC/SCP, 2012.

knowledge. Using this classification, a quantitative picture of these trade flows has been developed by using trade data from COMTRADE and COMEXT databases.

The aim of the ETC/SCP (2012) analysis was to look at trade of EGS as an indicator of international environmental technology transfer so that the role of the EU as a source — and a recipient — of diffusion of embodied green knowledge can be highlighted. This aim is different from the trade policy motivations backing the OECD, APEC and WTO work, as well as from the industrial motivation backing the works by ECOTEC (2002), Ernst & Young (2006) and ECORYS (2009), in which export was included as a component of competitiveness of companies belonging to the EGSS.

The aim then suggested being selective by focusing mainly on the international trade of technological EGS, but also include technological goods that do not refer to the core of eco-industries as generally envisaged by EU studies cited above. The proposed approach in selecting the relevant traded goods has thus then based on the following criteria:

- goods must be 'technological' (machinery, equipment, parts and components, tools, instruments);
- must be included in the ECOTEC, Ernst & Young, and ECORYS list;
- must be included in the OECD list *or* the APEC list (preferably in both);
- must correspond to an existing six-digit HS code (1996 version).

Another issue to be considered is the aggregation. All the existing lists/studies use different aggregations (see above). As a first approximation, the OECD classification (three macro-categories and 18 sub-categories) seems to offer a good starting point: the three categories correspond to the standard distinction between pollution control, cleaner technologies and resource management, which is also at the basis of classifications of eco-industries (but the macro-category cleaner technologies does not have corresponding HS codes thus reducing the macro-categories to two); the 18 sub-categories can be reduced because there are not HS codes corresponding to six of them in the OECD list.

The resulting selection is composed by 74 single HS codes at six-digit disaggregation and two macro-categories: pollution management and resource management ([109]). In short, by combining the features of a trade-policy and an eco-industry oriented lists, the selected list can offer a more comprehensive statistical picture compared to ECOTEC-Ernst&Young-ECORYS approach while not falling into the extremely detailed approach used in trade policy lists ([110]).

([109]) The six categories within pollution management are: air pollution control; waste water management; solid waste management; remediation and cleanup (water); noise and vibration abatement; environmental monitoring, analysis and assessment. The two categories within resource management are: renewable energy plant (further disaggregated into solar energy; wind energy and hydropower) and heat/energy saving and management.

([110]) See ETC/SCP (2012) for further details.

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