GREECO
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The concept of a green economy has been launched as a framework for *operationalization of the principles of sustainable development*. These principles form a global consensus understanding on how the growing populations of the developing world could realise their right to economic development and poverty eradication without depriving future generations of their entitlement to environmental values and natural resources.

The responsibility for transforming the world economy to a low carbon economy is common, but differentiated. In the UN, Europe and other developed countries have agreed to take the lead in developing the low carbon technologies and patterns of production and consumption. The developed economies are responsible for most of the World's production and consumption. They have already consumed most of the capacity of the atmosphere to absorb greenhouse gasses. Most importantly, they - unlike the developing countries – possess the capital and technology muscles necessary for developing the competitive green solutions.

The growth patterns of the European economies in the 20th century do not represent a sustainable model for the growth expected for the 21st century in the developing and emerging economies. It would even be unsustainable to replicate it in the European economies. The 20th century growth model was not able to prosper without sacrificing important ecological qualities such as a stable global climate system, a rich biodiversity and healthy air and water environments. A green economy is an economy that is able to prosper while preserving and even restoring these qualities. It is possible to achieve a high rate of employment and good conditions of life while transforming the economy to a low carbon economy with efficient use of resources such as energy and water, which leaves sufficient space for preserving biodiversity and eliminates the health and life threats of pollution.

The European Union has developed a political consensus on these visions of the green economy. They are reflected in the Europe 2020 strategy and in targeted EU legislation and programmes and they apply to all regions of Europe. However, in the transformations along these lines, the regions face widely differing challenges and potentials – even within the same country. The aim of this report is to describe some of the important transformations and to highlight the differences between regions and how alternative statistical indicators may be used to monitor progress towards a green economy.

Whereas there are consensus understandings on the desirability and feasibility of many key properties of a green economy, there is a variety of perceptions of the pace and policy instruments necessary to transform the economy towards a green economy. The actions of government and civil society at the local and regional level are key to the transformation process. But in the European systems of government, local government have little authority on the general framework conditions for economic activities. Most taxes and subsidies, technical regulation, information on and development of green technologies are decided upon by national government and coordinated in the EU. These institutional frameworks enable investment to take place and drive firms and households towards choosing green solutions. Local governments do, however, have authority on land-use and other decisions within physical planning. National governments also establish financial and regulatory frameworks that local government can use for coordinating and reconciling conflicting local interests. They are to varying degrees responsible for the local supply of power and heat as well as the treatment of wastewater and recycling of waste. The issues of regional governance and institutions, however, are treated in other reports of the GREECO project.

Measuring sustainability

To describe the transformations, it is useful to address more exactly, what is unsustainable about the 20th century growth model. This question was addressed already in the Great Debate on Growth and the Environment that took off in the 60s and became synthesised in the principles of sustainable development.

Quantifying what it takes to transform the European economies requires statistical definitions of what "sustainable development" is. "Social progress" is now widely understood as "sustainable development" in contrast to the conventional measure of GDP per capita, which is insufficient and potentially misleading as an indicator of social progress. The main principles of sustainable development are that neither growth without poverty eradication nor growth that devastate the ecological assets that we share with future generations is sustainable. In other words, progress in the economic dimension at the cost of losses in the social and ecological dimensions is not sustainable development. Neither does emission reductions due to an economic recession count as durable progress in the ecological dimension unless they are continued when the economy recovers.

This report suggests defining unsustainable use of nature as the over-consumption of sources, sinks and space. Continuing over-consumption of nature is ecologically unsustainable just like continuing over-consumption of financial budgets is financially unsustainable. Progress in the social dimension can be quantified as reduction of social exclusion in the form of poverty, risk of poverty, unemployment, inequality in consumption and public service opportunities etc.

Growth and environment

The academic literature addressed the problems of the 20th century growth model, which on the one hand resulted in an unprecedented growth of material well-being, but on the other hand took heavy tolls on nature and did not necessarily include all groups of society in the material well-being. The 20th century industrialism, mass production, mass consumption and the other patterns of consumption and production characteristic for this growth model was in several respects unsustainable and even dysfunctional. This early criticism was important for the development of the green solutions to industrial production, urbanisation, mass consumption that are known today, but still needs to be implemented.

The most unsustainable property of the 20th century growth model was that it linked the use of fossil energy closely to economic growth. It also linked the use of other resources, emissions and waste to economic growth and the extraction, transport, reshaping, construction etc of these very large amounts of material was physically enabled by the abundance of fossil energy. The model derives services such as constantly heated floor space, per and tons-kilometres of transport etc from material standard of living depended on the services derived from these It was aimed at a growing material standard of living derived from ever growing flows of materials and energy through the economy.

The growth model that linked fossil energy with economic growth did not differ fundamentally along the other societal divisions of Europe in the 20th century. Centrally planned and market economies alike pursued fundamentally the same model. Social democratic, conservative and liberal welfare states did not differ in this respect. Democracies and dictatorships shared the same growth model as far as the physical properties is concerned. European countries could differ by important factors such as GDP per capita, inequality and the sufficiency of checks and balances in the financial sector. However, they all shared the same physical links between the growth of GDP and the growth of materials and energy flows through the economy.

These links were determined by the design of the econosphere, the physical interface between economy and nature. The econosphere includes the infrastructures, buildings, machines, transport equipment etc and the material and energy flows they are designed to handle. The econosphere of an economy must be designed differently if the economy should be able to prosper without overconsuming nature as a source of or a sink for material flows. It has been compared to the design of the econosphere of a spaceship, where efficiency means to minimise and recycle the material flows.

The development in the first decade of the 21st century shows that the 20th century growth model is already history in the "old" member-states in important respects. The European economy as a whole now follow a growth model were GDP grows whereas greenhouse gas emissions decline, albeit not necessarily at a sufficient rate. The new member-states deviate slightly from this as GDP growth in these economies occasionally has been accompanied by non-declining or even increasing GHG-emissions.

This delinking of energy use, other resource use, emissions and waste from economic growth is a key objective of the growth model pursued by the EU and its member-states for the 21st century.

The EU 2020 strategy addresses these developments by setting the development of a sustainable, smart and inclusive economy as the goal for policies in the 2010s. The progress towards these goals have been hampered by the cascade of crises from the financial crisis in 2007 to 2008 followed by the great recession in 2008-09, the recovery from which was overshadowed by the sovereign debt crisis and the subsequent austerity policies followed by a second recession in 2012-13.

The transformation of the economy is to a green economy is essentially about *investing* in the transformation of the econosphere and setting institutional frameworks that *enable* these investments.

Employment and the green transformation

The transformation to a green economy has both positive and negative impacts on employment. A low carbon economy does not employ many people in coalmines, refineries, coal power plants etc. Labour is instead required to supply the renewable energy needed for economic activities. A recycling economy does not employ as many people in materials extraction as a throughput economy does. Instead, it employs more people in waste treatment and recycling activities. A region that leaves more space for natural ecosystems will not need farm labour to cultivate that land. It may on the other hand need more labour to provide services for the tourism generated.

Most of the renewable energy will be provided energy sources such as solar and wind that do not require any throughput of fuels at all. Thus, handling of fuels will be reduced to the handling of biofuels for transport that cannot be electrified. In Europe as a whole, more people will probably be engaged directly and indirectly in energy supply since the electricity generating plants and their components as well as the biofuels primarily are produced in Europe, which is not the case for fossil fuels. The jobs will, however, be in other industrial branches mastering other technologies and at other locations. Regions that are specialised in the production and use of fossil energy will loose jobs in these sectors unless they transform to a low carbon economy. Either way, the labour force faces the challenge of specialising in other technologies and the local and regional services for this purpose are crucial. Thus, regional policies aimed at investment in human capital for mastering the new technologies are at the centre of the transformation.

Today, the resources and emissions required for achieving a service such as a constant temperature floor-space amount to only a fraction of the requirements in the 1960s-70s. Roughly, 40% of our energy use in Europe is used in buildings, primarily for heating and cooling. Cost-efficient buildings that use almost no energy for heating are available today and the EU has decided to apply that standard for all new buildings from 2020. With an expected lifetime of a building of 100 years, however, it will take 100 years to renew this important segment of the econosphere. Thus, programmes for retrofitting the building stock inherited from the past century to the energy standards of the present century are being and will be carried through. They represent an important employment potential all over Europe.

Large coal and nuclear power plants dominate the European power and heat sector and a large number of them have reached or will reach retiring age during the 2010s and 2020s. It is a historic chance to replace them by offshore wind farms and other renewable energy technologies and by more energy efficient equipment in the end use of electricity and heat.

The renewable energy production, however, will be located in other regions and so will the transmission and smart grid infrastructures required by the new energy sources. The producers of components of plants and equipment are located in still other regions. At the EU level, it is a small number of jobs involved in the declining and growing parts of this econosphere segment, but in many regions, they may represent a considerable share of the employment.

Many regions with coalmines and/or energy-intensive industries such as steelworks or pulp factories have experienced a decline in these industries whereas the new jobs supplying renewable energy and green solutions emerge in other regions. The prospects for the next decades are bleak as the paper in mass communication is being replaced by digital communication and the European producers face competition from the BRIC countries and North America paying much lower energy prices. To be competitive such industries face the challenges of shifting to less energy intensive niches and/or become much more energy efficient than their competitors. In many instances, this will also increase the environmental living conditions in areas prone to health risks from air pollution.

Many of the European welfare states were successful in including all or most segments of society into the prosperity of the country. In many countries, however, inequality and exclusion from the prosperity have re-emerged since the 1980s. As the transformation process has winners and losers in terms of jobs and growth it can be expected to run more easily if the winning industries, regions and countries help the losing industries, regions and countries with investment in human capital and econosphere that is designed for the green economy. This is not

Development of a sustainable, smart and inclusive economy requires investment in sustainable and smart solutions, in the development of new such solutions and in human resources. Advancing these investments in regions or countries where the recovery does not materialize or is too weak will help lifting the general investment activity of the economy to a level that is required for high level of employment.

Defining sustainability and the green economy

The critical view of the growth paradigm through the Great Debate led to a number of alternative strategic options ranging from zero growth to giving overriding priority to GDP growth. The debate was synthesized in the principles of sustainable development by the Brundtland Commission and subsequently adopted in UN declarations, treaties and government and EU programmes.

The shift from the growth paradigm to the sustainable development paradigm was based on a remarkably broad consensus on balances between present and future generations, between ecology and economy and between the rich and the poor parts of the world. Political consensus at the programmatic level does not necessarily means consensus in practice. In particular, there are marked policy differences as to how fast the long-term visions for the European economies should transform to green economies.

In the political discourse as well as in the academic literature, the green economy paradigm is multifaceted as paradigms are. It includes a different ethics, different perspectives on social progress and different institutional settings and governance principles. Thus, it is difficult to boil it down to a concise definition. Nevertheless, it is used interchangeably with *green growth* and *greening the economy* in the literature and in the documents supporting the policy process. As common definitions are necessary for achieving progress in academic as well as political debates, a set of definitions is suggested below. Based on the review of literature, policy documents and the policy process itself, the following definitions seem to follow the logic established in policy discourse as well as in the scientific literature.

A *green economy* is an economy that is able to *prosper without over-consuming* in any of the economic, ecological or social dimensions. The prerequisite of overconsumption is a budget. The budgets in each dimension are politically defined, but should – as far as possible – be science based. They are defined for the economy as a whole, that is, at the macro level (EU, national or regional).

Green growth is the growth of green solutions in production, consumption and investment at the micro-level. The transformation of the economy as a whole to a green economy requires green growth in a sufficient amount of sectors to eliminate over-consumption at the overall economy scale. But green growth in one sector does not necessarily mean that the rest of the economy is reducing its overconsumption. Thus green growth can occur even if the economy is not as a whole transforming to a green economy.

Greening the economy refers to what governments can do. Governments decide directly upon what to produce, consume or invest in for the part of the economy that is tax financed. For the private sector, governments establish institutions as frameworks for the economic activities. Greening the economy thus includes public investments and physical planning for a green econosphere as well as development of institutional frameworks for private investments and innovation in a green econosphere. They include institutional reform supporting the development of a green economy and governance principles aiming at mediating conflict and broaden the support base for green growth.

Defining *budgets* for the consumption of ecosystem services as well as paving the way for green growth are key elements of such an institutional framework and local government in Europe has a role to play here.

The definition of financial overconsumption has been at the top of the agenda in the EU since the financial crisis.

Carbon-budgets until 2020 for the ETS sector at the EU level and the non-ETS sector at member-state levels have been defined and they could potentially be downscaled to regional levels and expanded to a longer time horizon. Other regional budgets for the consumption of ecosystem services should be defined as well. In the case of renewable energy, many regions appear to have considerable potentials at their disposal before they have consumed the ecosystem service budget.

Budgets for investing in human capital and in good living conditions for the citizens are required for inclusion of those who are excluded or in the risk of being excluded from the formal economy and its social protection. Under-consumption in these areas indicates over-consumption in other areas.

Social progress

There is quite a broad consensus on that GDP growth is a poor and often misleading indicator of social progress. Several attempts have been made to represent progress in these dimensions by indicators that then could be weighed together in one meta-index that – just like GDP growth – could express social progress as a one-dimensional index. These attempts all run into the impossible task of assigning meaningful weights to such different indicators as the share of the population at risk of poverty and the overconsumption of ecosystem functions such as the capacity of the environment to absorb excess nutrients from agriculture. Moreover, the alternative must follow the principles of sustainable development of *simultaneous* progress in the economic, social and ecological dimensions. Thus, there is little reason for defining a set of weights, that is, relative prices, by which points of progress in one index can make it up for loss of one point in another index. A set of sustainability indicators as developed by the EU Commission and EUROSTAT is more informative than the average of all of these indicators.

Ecological balances

Exceeding limit values for air pollutants implies over-consumption of the sink capacity of the troposphere. There are national emission ceilings in Europe, but they are generally much higher than the ecological budget constrained by the limit values. EU targets for emission reductions by country represent emission budgets, but local and regional budgets for the severely exposed areas could facilitate the green transformation in these regions.

The point source emissions of major pollutants are often concentrated in a few regions. This is one of the reasons for the different exposure in different regions. Many of these regions face challenges of restructuring the economy as the large point sources are retired or downscaled.

The use of fossil fuels is an integrated part of the European story of economic growth in the 20th century. It linked CO_2-emissions closely to economic growth. The prospects of reducing CO_2 emissions to sustainable levels are formulated in carbon-budgets for the ETS sector as well for the non-ETS sector in the individual member-states.

The patterns of GHG emission reduction shows that the new member-states (NMS10) reduced their GHG-emissions in the 1990s along with Germany and the UK. In 2000-08, however, this trend was reversed. The CO_2-emissions increased in most regions as they experienced high rates of economic growth. This trend is set to continue in the 2013-2020 period. These higher emissions will then have to be reduced again in the 2020s or later.

The non-ETS sector carbon-budgets can be regionalised if statistical information on energy production and use is available at the regional level. An example of annual regional non-ETS sector reduction rates by NUTS2 regions is provided based on the pattern of annual carbon-budget reduction rates to GDP per capita.

Economic balances

Progress in the economic dimension can be measured by GDP or GNI per capita growth although this indicator is not perfect even just to measure progress in the economic dimension. Two indicators are important in assessing whether the economic growth is financially sustainable. First, only a part of GDP can be spent on consumption – some of it has to be reinvested to make up for the capital consumed. This is the constant total capital approach. Second, the government can run deficits to stabilise the economy, but not infinitely.

The adjusted net savings indicator includes consumption of natural resources in the constant capital stock principle. The European economies, however, have comfortable margins for spending on green investments without getting near economic unsustainability according to this criterion.

Social balances

The demographic prospects of the European countries sets the inclusion of the full potential of female half of the population into the labour force on the agenda in all regions. In some countries and regions – notably in Northern Europe – this agenda has been pursued for two-three generations and in these countries, the employment rate (employed persons per population aged 16-64) has exceeded the EU 2020 target of 75% for several decades.

In other countries and regions the investment in welfare state institutions and human capital that favours a high female participation rate still has potentials of contributing to a the economic development. The problem is how to mobilise the tax revenue required for these investments. Poverty prone

It is important to be aware of the adverse distributional impacts of higher energy costs associated with the transformation of the production and use of energy. The methods developed for neutralising such adverse impacts shows that it is possible to use high energy prices to give incentive to changes without causing energy poverty.

Energy delinking and decarbonisation

The emissions of CO_2 can be decomposed in a number of factors and a model was developed to study the impact of the individual factors. A higher rate of employment ("growth") had a positive impact on emissions in almost all countries. This was offset by a lower intensity of emissions ("decarbonisation") in the energy used. The energy used per employee also had a negative impact on emissions (“delinking”) in most European countries.

The linking of carbonised energy to economic growth has during the 2000s resulted in an increasing share of GDP to be reserved for imports of mineral fuels. The economies of many of the member-states with the lowest per capita GDP are severely drained by this property of their econosphere.

Decarbonisation

The European onshore wind energy potentials have been estimated at the NUTS2 level. The estimates identify the physical, technical and economic potential at different levels of the social value of wind power and the wind power density. The estimates show that onshore wind could contribute considerably to regional income generation in many regions.

A similar study was carried through for PV-energy. The two studies show that these two renewable energy technologies complement each other. The European wind resources are primarily located in the North European wind belt from Bretagne to Finland. The PV energy potential is primarily located in Southern Europe. This points to a new division of labour as producers and consumers of energy and new energy-trade patterns between regions. It makes both local smart-grids and European scale super-grids necessary, both with new technologies for energy storage.

Energy dependency and delinking

Statistics on final energy consumption was collected and used for analysis of energy dependency rates, catch-up potentials and delinking.

Through the 2000s most of the EU15 economies managed to have lower final energy consumption while they had higher employment. In many of the NMS10 the energy consumption increased more than the employment in that period. Both need, however to delink much more in the 2010-20 period to reach the targets for 2020.

The final energy consumption by region increases with income level. It does so, however, at different rates. Transport energy demand is much more elastic to income level than residential energy use and production energy use is in between.

Ecosystem restoration

Two fundamental shifts are important to reverse the trend of declining biodiversity and increasing risks to natural ecosystems. First, the land allocation between economic (urban and agricultural) and nature purposes. Second, the use of the natural ecosystems and in particular the water bodies as sinks.

Spatial patterns of designated nature areas per capita are presented. Many of the regions with low rates of nature areas to population are to be adjacent to each other. Thus, there are quite large regions with homogenous low levels of nature areas per capita.

The limited data reported on the state of the aquatic environment under the Water Framework Directive indicates that measured by area, a less than good ecological state is more widespread than a less than good chemical state.

Green innovation and employment

The statistics on environmental goods and services describes the environmental protection and resource conservation expenditures in the private and public sectors. The employment effects of these expenditures can be estimated, but the definition of environmental expenditures limits the expenditures to only a couple of per cent of GDP of which the waste and wastewater treatment sector is dominating. Transformations such as individual to public transport are, for instance, not included. Thus, this indicator should be interpreted with caution.

The green product innovations measured by patent applications show a traditional east-west and north-south pattern. Low rates of patent applications per employed are found in the east and the south of Europe. The share of green innovations is, however more mixed. In particular in the NMS10.

1. Introduction

1.1. The transformation to a green economy

Local government and administrative bodies as well as civil society and business networks and regional policy authorities are increasingly engaged in the transformation of the regional economies to a "green economies". In some regions, the greening of the economy is even seen as *the* way out of an obsolete industrial structure and as the backbone of the regional development strategy.

This change in policy gives rise to a series of questions that are addressed in this report. First, the question is how a green economy *differs* from the existing economy and what it means to regional policies. A second question is, how to define criteria to determine whether the economy transforms towards a green economy. Finally, there is a question of the *statistical indicator framework* needed by local government to monitor the transformation and the impact of their "green economy-policies".

Statistical indicator frameworks are important when operationalizing policy principles into executable programmes. How to do this in the field of the green economy, is a key question for this report. It discusses how well it reflects the underlying changes in the economy and how it could be improved to meet the needs of the 21st century. It takes up new data on the regional level to analyse regional level challenges of and progress towards the green economy and discusses the strengths and weaknesses of the indicators.

The concept of the green economy did not take form in scientific work, but rather emerged as a political vision from a policy debate.

Thus, the study attempts to integrate definitions from political consensus documents with definitions from the scientific literature and attempts to empirically quantify the "greenness" of the economy. This approach is chosen with the aim of getting closer to an operational understanding of the concept of a green economy at various territorial levels.

The concept of a region is closely linked to the territorial level of government. EU government provides the institutional framework for transformations to a green economy in all of Europe. National government remains the backbone of the European government structure, but in federal states sub-state governments posses powers that are in the hands of national government in other states. Authority is delegated to local government (including municipal as well as regional government) in varying degrees.

This structure of government means that the powers of local governments for changing "their" economies in a green direction are limited and varying. Most of the institutional frameworks are decided at the EU and national levels. On the other hand, they can exert influence on national and EU policies with regional impacts. Thus, the present study also attempts to see the sub-national level changes of the economy in their coherence with EU and national level changes.

For national and local government alike the statistical indicator framework offers the opportunity of identifying and describing challenges and potentials of green transformations. Further, it enables the formulation of policy objectives as quantitative targets to be achieved within specified time-frames. It also enables the monitoring of progress towards - or steps backwards - the targets. The study discusses all three dimensions of the statistical indicator framework for transition to a green economy.

The ambition of report is not to provide a complete conductor's score for how to orchestrate the transition to the green economy at the various levels of government. The ambition is rather to approach a concept of a green economy that is useful in identifying and quantifying what to change and how to change it. The statistical data frameworks are discussed.

The report is organised as follows. Section 2 reviews important debates that preceded the notion of a "green economy". In section 3, the development of the political consensus on the concept of sustainable development is reviewed and definitions of the "green economy", "green growth" and "greening of the economy" are suggested. Section 4 discusses attempts to measure the overall sustainability and "greenness" of economies and section 5 the sustainability indicator framework in the EU. The criteria for sustainability are discussed in each of the three dimensions in sections 6-9. Section 10 describes the physical interface between nature and the economy, the econosphere and sections 11-13 analyses changes towards a low carbon econosphere. Section 14 is about delinking of other flows ("dematerialisation") and section 15 restoration of natural ecosystems. These changes require innovation of new green technical solutions. Indicators on these are reviewed in the sections 16-18.

The relevant policy issues are addressed in each of the sections. Policies and institutions in specific sectors are addressed in other reports of GREECO project.

2. Discourses on the green economy

2.1. The Great Debate on Growth and the Environment

The "green economy" is not a scientific concept with a concise and academically agreed definition. It is more a way of framing how we turn the abstract principles of sustainable development to more operational green transformations of the economy and green policies to guide them. Nevertheless, it is rooted in real problems of ecological-economic and social nature and these problems have, been addressed in the academic literature, even before they could be labelled "green economy"-problems.

The birth of the academic discourses on the unsustainable properties of the 20th century European growth model – that is, the negation of the *green economy* – can be dated to the Great Debate on Growth and the Environment (GDGE)[1] that unfolded from the 1960s through the 1980s. Not that the themes had not been addressed before, but exactly in that period, the transformation to the industrialised and technology based oil-economy accompanied by heavy investments in human capital took place. It is worth noting that this transformation took place in the east as well as in the west. It was not restricted to either market or centrally planned economies.

Remarkable academic works such as "Silent Spring" (Carson 1962) did not only identify the loss of ecological values due to the modern patterns of production and consumption. They also devised an "other road" to expansion of output – in this case agricultural - while allowing the preservation of ecosystems and species. It involved the use of biological pest and insect control in agriculture along with

[1] The scientific and public debate on these questions was coined "The Great Debate on Environment and Growth" by Freeman (1978)

other methods. This alternative was not called a "green economy" by then, but it definitely was an early outline of a green agricultural economy.

The economic potentials of the modern economies allow the human populations to grow beyond the biological carrying capacity of the preindustrial economies. Factoring in the "population bomb" in the future pressure from economic activities would multiply the pressure already exerted in the 1960s - let alone if the poor majority of the world population should attain a standard of living just near that of Europe and the North America in the 1960s (P. Ehrlich 1968; J. P. Holdren and Ehrlich 1974). Or put in another way, the challenges for the technological development for coping with the impact of the growing world population was far beyond what the growth economies could deliver (P. R. Ehrlich and Holdren 1971; John P. Holdren and Ehrlich 1972).

2.2. The throughput of physical flows

The economic literature also provided some new views on the interaction between the economy and the nature in which it is embedded. The prevailing understanding of the economy was a set of aggregate economic activities that transformed inputs of labour and capital to outputs of consumption and investment goods that were finally used for their purpose.

In the mainstream of economic literature, natural resources were regarded as *land,* but mainly in its capacity of an asset in a unique or un-replicable form of capital providing the owner with some degree of market power, materialising in a *land rent*. Other natural resources from oil to fisheries may also involve a rent, and from an economic point of view, maximizing the resource rent over the lifetime is the focal point of interest.

The mainstream economic literature addressed the *rent maximisation* from renewable resources like fisheries and subsequently, the economic optimality of only harvesting a sustainable amount of these resources (Gordon 1954; Hardin 1968). The *depletability* of non-renewable resources had mainly been addressed from the perspective of how fast to deplete them so as to maximize the rent (Hotelling 1931).

In this paradigm, the physical flows of resources through the economy are only relevant to economic development to the extent that they are linked to an economic rent.

Pollution problems were similarly identified as external to the market transactions, thus requiring other institutional solutions to be resolved (Coase 1960; Pigou 1950). It was, however, mainly viewed as events occurring randomly and in isolation. Ayres and Kneese (1969) demonstrated the pervasiveness of the environmental problems and helped the public towards recognition that pollution is *systematically* linked to the ecological-economic structure of the 20th century industrial economy. Ayres and Kneese (1969) found that the prevailing approach to economic analysis of ecological-economic problems could lead to erroneous conclusions. This was due to the treatment of the problems as "exceptional and minor" rather than "inherent and general part of the production and consumption process" and analysed with a partial rather than a general equilibrium approach. This methodology risks leading to the recommendation of marginal changes where more fundamental changes of the materials and energy flows are socially preferable. The institutional economist (Kapp 1975) was another early voice among economists pointing to the pervasiveness of environmental costs of economic activities throughout the economy.

Whereas the rent of natural resources enter the circular flows of economic values, the physical flows enter the economy through the natural resource extraction (entry point) and leaves it as waste and emissions (exit point). Every stream though the economy consumes nature as a source and a sink. As all streams has a physical extension and we use infrastructures, plants, buildings, machines and transport equipment to handle them, they also take up space and use nature as land.

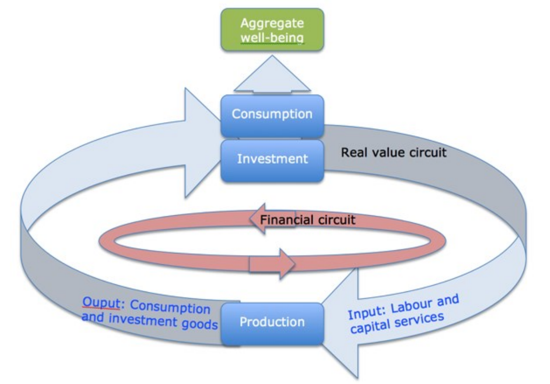
One of the front-runners for a new paradigm, incorporating the natural science perspective on the economy, was the economist Georgescu-Roegen who pointed to the fact that the flow of energy and matter resembles the *throughput* of oil through pipelines and refineries to their ultimate combustion. Energy and matter originate from *sources* that are finite. They are separated and united in new ways in various processes that make them more useful to us, but eventually they end up in nature used as *sinks*.

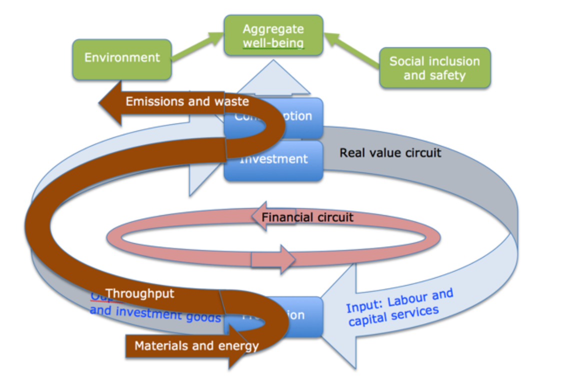
In this perspective, it is necessary to expand the standard model of the economy with circular flows of economic values with the throughputs of physical inflows of materials and energy and the outflows of waste and emissions. Including the finiteness of nature as a source as well as a sink into the conceptual framework of an economy is necessary for understanding its production opportunities (Georgescu-Roegen 1972; Georgescu-Roegen 1971; Georgescu-Roegen 1970).

George-Roegens referred to the mechanical physics expressed in the fundamental laws of thermodynamics, the law on energy conservation and the entropy law. According to the law on energy conservation, all the matter and energy involved the economic activities must come from somewhere and end up somewhere. According to the entropy law, the economic process transforming natural resources to final products is physically an irreversible process defining the non-renewable properties of the resources and thus the necessity for the economy to conform to its nature basis.

The differences between the mainstream economic growth paradigm prevailing in most of the 20th century and the economic paradigm integrating the boundaries of nature are depicted in figure 1.

Economic activities are linked in a real value circuit of valuable goods and services, where labour and capital are inputs to the production processes. The outputs of the production processes are goods and services for either consumption or investment. These activities in turn regenerate the labour force and capital that is suitable for production. In economic thinking, the *raison d'être* of the entire real value circuit is to contribute as much as possible to the wellbeing of man. The financial circuit enables the real value circuit and runs in the opposite direction of the value circuit.





The circular real and financial value flow paradigm	The circular value flow with throughput of materials and energy flows paradigm

Figure 1. Competing paradigms for understanding the growth and environment problem

The new paradigm recognises that the economic processes consist of physical flows as well as value circuits. The paradox is that "all the economic process does is to transform valuable matter and energy into waste, is easily and instructively resolved. It compels us to recognize that the real output of the economic process (or of any life process, for that matter) is not the *material flow* of waste, but the still mysterious *immaterial flux* of the enjoyment of life." (Georgescu-Roegen 1979, p353). We derive the services that are important for our well-being from the physical flows, but it is services generated from the physical flows rather than the flows themselves that are important.

The easy access to relatively inexpensive fossil fuels was and is crucial for the feasibility of the throughput economy of the 20th century. The flows of fossil energy constitute in itself a large part of the material flows of the industrial economy. At the same time, the massive energy supply required for the transport and conversions of the physical flows are provided by the large supply of the fossil fuels. Thus, the end of the era of cheap oil also has consequences for the cost-advantage of the material flow based services viz-a-viz stock and recycling based services.

2.3. Substituting different forms of capital

The unsustainability of the physical structures built-in to the throughput growth model leads to the question of the capacity of the economy to adapt to the changing natural environment as its energy and materials resources and its life and health support functions become scarcer.

The positions to this question as far as non-renewable (typically mineral) resources are concerned range from the substitutability-optimism of Goeller and Weinberg (1976) to substitutability pessimists pointing to the fact that we are using rapidly reserves that have been built up through dozens of millions of years. The optimists point to the wide variety of technological options to provide the services we need, using very different materials in the solutions and to the option of engaging in "land-fill-mining" when the reserves become scarcer.

From an economic point of view, it is important to note that scarcity of resources is a relative concept. The kinds of materials that are used in the economy will not be fully removed from the earth crust – most of them are present in too low concentrations to warrant extraction. Only a fraction of the material present in the earth crust will be used. This fraction is determined by the value of the best alternative in combination with the energy, labour, capital and land cost of extracting, transporting, processing and storing the materials and the products made from them. These costs, however, may increase dramatically as the deposits that were easy to get to become depleted.

Under a longer-term view, it is probably economically preferable from a societal perspective to use the materials efficiently and recycle them comparing to paying high costs of landfill mining or a costly substitute at a later point of time. There is an economic aspect relating to the discounting of future values by the present and an ethical aspect relating to the cost burden postponed to future generations. For renewable resources and environmental values, there is an additional ethical imperative of securing the existence of the life forms involved for posterity.

The question of whether a level of consumption based on non-renewable resources could be sustained as the non-renewable resources are depleted was answered in the economic literature with reference to substitutability. The response to this question was that if the resource flow in question can be replaced by a more competitive alternative solution, there is no theoretical problem to solve - only the technical challenge of replacing it. If the resource flow, however, is indispensable in some amount, but in proportions that always can be marginally substituted by capital, an economy based on non-renewable resources can go on as long as this substitution can take place (Solow 1974). For the environmental values that are consumed directly, however, such substitution may not be possible.

(Dasgupta and Heal 1979) concluded that the substitutability of exhaustible resources at present seems sufficient to not be concerned of the exhaustible resource constraint, but they also warn, that the substitution can be considerably more difficult in the future when the resource inputs are much smaller in relation to the capital inputs. The critical assumption behind this result is, that if flows from an exhaustible resource enter the macro production function as labour or capital does, it will be possible to substitute natural resource inputs by manufactured capital, but not necessarily without government interference.

Thus, according to the mainstream economic thinking at the time of the great debate, economic growth would not end because we would run out of oil or other natural resources as long as substitutes are available. Many other contributors to the debate focused on the substitutes for high volume throughput solutions of the growth model.

2.4. The spaceship economy

One of the mental models used to describe the green economy before the concept emerged was the metaphor of the *spaceship economy*. Kenneth E. Boulding, at the time the president of the American Economic Association used it in the essay "The coming of the spaceship earth" discussing the transitions from the open earth to the closed earth economy:

"The closed earth of the future requires economic principles which are somewhat different from those of the open earth of the past. For the sake of picturesqueness, I am tempted to call the open economy the "cowboy economy," the cowboy being symbolic of the illimitable plains and also associated with reckless, exploitative, romantic, and violent behaviour, which is characteristic of open societies. The closed economy of the future might similarly be called the "spaceman" economy, in which the earth has become a single spaceship, without unlimited reservoirs of anything, either for extraction or for pollution, and in

which, therefore, man must find his place in a cyclical ecological system which is capable of continuous reproduction of material form even though it cannot escape having inputs of energy.

The difference between the two types of economy becomes most apparent in the attitude towards consumption. In the cowboy economy, consumption is regarded as a good thing and production likewise; and the success of the economy is measured by the amount of tile throughput from the "factors of production," a part of which, at any rate, is extracted from the reservoirs of raw materials and noneconomic objects, and another part of which is output into the reservoirs of pollution. If there are infinite reservoirs from which material can be obtained and into which effluvia can be deposited, then the throughput is at least a plausible measure of the success of the economy. The gross national product is a rough measure of this total throughput. It should be possible, however, to distinguish that part of the GNP which is derived from exhaustible and that which is derived from reproducible resources, as well as that part of consumption which represents effluvia and that which represents input into the productive system again." (Boulding 1966).

Another way of approaching the same *problematique* is to ask how to maximize the well-being without increasing the throughput. Daly (1977) referred to the concept of steady state economics originally suggested by the classical economist John Stuart Mill. According to this view, nothing can grow forever. At some point, economies must enter into a phase of steady state, i.e., a mode where it reproduces itself in the same physical proportions. Even in this mode, however, the *quality* of the individual economic activities can improve and thereby increase the well being of the citizens. Such an economy grows in the quality – and thus economic value – of things rather than in the volume and weight of things.

2.5. Limits to Growth

These and similar criticisms was systematically reviewed in a comprehensive set of scenarios produced with the World Model in the *Limits to Growth* report to the Club of Rome (D. L. Meadows, Meadows, and Randers 1972). They questioned the feasibility of the vision of a world where the by then poor populations of the world would have a standard of living comparable to the wealthy populations in Europe and North America. The economy viewed from a natural science point of view relies on the "sink" and "source" functions of nature and these functions would be insufficient to sustain the future world population.

In addition to the physical properties of the economy, the study pointed to the ethical obligations arising from the fact that our economic activities seriously affect the environmental and resource conditions of the future generations and the fact that we know it.

It also involved a series of governance issues. First, such global problems can only be understood through scientific models. Collective action through democratic processes thus, requires a very broad knowledge of the mechanisms governing the interplay between nature and economics.

Second, the policy process at the international level is usually even slower than the policy process at the national level. Just like a car has a braking distance when bringing it to a halt, the speed of the policy process defines a "braking distance" of the societal trend subject to the policy. If the societies do not react several decades in advance of the prospective scarcity, the outcomes can be violent and catastrophic. In the absence of long term planning and global response to insights gained from scientific models, humanity would respond to limits like other species in their ecosystems with overshooting and collapse.

The most heated question of the Great Debate, however, was the question of *Zero Growth*. Should economic growth be an objective of economic policies at all or should the objective be *not* to grow?

The Limits to Growth report was ambiguous in this question. In the first report, the conclusion was that only the scenarios where a reproduction level of two children per family was achieved and where per capita consumption was kept on the 1975 level, produced sustainable outcomes (D. L. Meadows, Meadows, and Randers 1972, pp168f). It was argued, that "Bringing a deliberate, controlled end to growth is a tremendous challenge, not easily met." (D. L. Meadows, Meadows, and Randers 1972, p176). It was also clear from the context, that this was a desirable goal.

In its comments to the report, the executive committee of the Club of Rome recommended the developed countries to "encourage a deceleration in the growth of their own material output while, at the same time, assisting the developing nations in their efforts to advance their economies more rapidly" (D. L. Meadows, Meadows, and Randers 1972, p198). In other words, the committee did not recommend zero growth, but less growth in industrial countries linked with more growth in developing countries.

The Zero Growth proposition was met by severe criticism from many sides. Most important is that a Zero Growth strategy cannot solve the problem of unsustainable ecological-economic *structures*. If the level of, e.g., CO_2-emissions is too high, maintaining it at the same level, will still be unsustainable. Second, a very large share of the global population consists of poor people and this is unsustainable. This means that they have too little material wealth and sustainability means that they produce and consume more material wealth (although not exactly as was the case in Europe in the 20th century).

In the follow-up report "Beyond the Limits" 20 years later, the authors of the Limits to Growth report unreservedly dissociated themselves from the Zero Growth proposition: "Sustainability does not mean no growth". The founder of the Club of Rome, Aurelio Peccei, adds: "Some of those ...accuse the [*Limits to Growth*] report of advocating ZERO GROWTH. Clearly, such people have not understood anything, either about the Club of Rome, or about growth (D. H. M. D. L. R. J. Meadows 1992, p210).

Many of the predictions in 1972 turned out to be highly relevant. The competition of the emerging economies of China and India for non-renewable and still more depleted global oil resources have led to oil prices 8-10 times the level in the 1990s. It does not prevent the global economy from growing, but fuelling it by oil or the price-linked natural gas is not always the least expensive solution. The time it takes for the international society to reach a global agreement on curbing greenhouse gas emissions shows how relevant the "braking system" is to understand these problems and our ability to respond to them.

2.6. The synthesis of the debate: Sustainable Development

Against the backdrop of the environment and growth debate, the UN commissioned the World Commission on Environment and Development (WCED) to develop strategies and perceptions that could serve as frameworks for addressing the rapid deterioration of the environment on an international scale.

The conclusion known as the *Brundtland report* (World Commission on Environment and Development (WCED) 1987) represents a synthesis of the Great Debate with the suggestion that *sustainable development* should replace plain economic growth as the overall objective of economic strategies and policies:

"1. Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:
• the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and
• the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs" (World Commission on Environment and Development (WCED) 1987).

This concept of sustainable development can be seen as a synthesis of The Great Debate. The WCED recommends "sustainable development" as a broader societal goal than "economic growth" that previously was the overriding criterion for social progress. One of the practical implications of this is that government and other societal bodies should be made directly responsible for not only the economic but also the ecological and social sustainability of their policies, programmes, etc. (p314).

Economic growth is far from absent in the sustainable development vision presented by the WCED. To the contrary, it is stated that sustainable development requires growth. First, in the developing countries for overcoming poverty and, second, in developed countries as a prerequisite for growth in the developing countries (p51). It is however not the overriding priority over ecological and social concerns.

Rather than looking at the relation between economic growth and environmental pressure as given and unchangeable the WCED advocated for changing the *quality* of growth towards more equality, less poverty, preservation of natural resources, etc.

The long-range outlook for energy demand and supply did however give rise to deep concern. Not as much because of the shrinking reserves as because of the environmental effects of fossil fuel burning and nuclear power technology. The recommendations of the commission were, first, to strengthen the international efforts for development of safe and sustainable energy sources, notably renewable ones, and, second to buy time by reducing energy consumption by 50% in 50 years.

The concern of the WCED for the availability of mineral resources is more related to their importance for the economies of developing countries than for the global supply of the minerals as raw materials. The developing countries are characterized by being largely dependent on exports of primary commodities for foreign currency earnings. Then, exhaustion of national reserves of minerals will be also exhaustion of national sources of foreign currency. The solution according to the WCED is to promote diversification of the economy into industries that gradually can take over this role.

It has been customary in economic literature to refer to the WCED definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987; p43). This is often interpreted as comprising only the intergenerational equity dimension, but two other aspects are just as important. The Commission refers explicitly to physical sustainability and the limitations of the environment and it stresses that "the concern for social equity between generations, a concern that must logically be extended to equity within each generation" (p43).

Thus, the sustainability concept of the WCED is not restricted to the intergenerational dimension, but to the entire triangle of ecological limits, intergenerational equity and *intra*-generational equity. To this, we can add economic growth in "places where such needs are not being met" (p44). Elsewhere, growth is consistent with sustainable development provided it respects the broad sustainability principles and non-exploitation of others.
Population policies, energy saving policies, and peace reinforcing policies are also important constituents of sustainable development. The commission does, however, also emphasise, that beyond the general principles, interpretations of sustainable development may vary from country to country.

2.7. Anthropocene

From a natural science point of view the traditional distinction between nature and culture becomes still more blurred. Human economic activities even interfere with natural cycles and thus impact and to some extent control changes in climate and biodiversity and generally in the spheres that make up the natural environment of humans (bio-, hydro-, cryo-, litho- and atmosphere). Such changes define the geological time-periods of earth history and human activities are traditionally considered too weak to interfere with them.

Scientific research is, however, increasingly documenting how the economic activities interfere with the natural cycles such as the hydrological cycle and the cycles of carbon, nitrogen, phosphorous, metals and other materials and the environmental balances involved. This has led to the suggestion that the Holocene epoch by the time of the industrial revolution was relieved by the *Anthropocene* (Crutzen 2002a; Crutzen 2002b; Crutzen 2005; P. J. C. Steffen 2003).

The understanding of the present epoch as *anthropocene* implies that the human economy is not just a part of the biosphere, but has a physical side that independently affects all of the other spheres. We return to the characterisation of that side below.

In particular, the second half of the 20th century, also referred to as the *great acceleration*, was characterised by decisive interference with the natural cycles and the survival conditions of natural forms of life (W. Steffen et al. 2005).

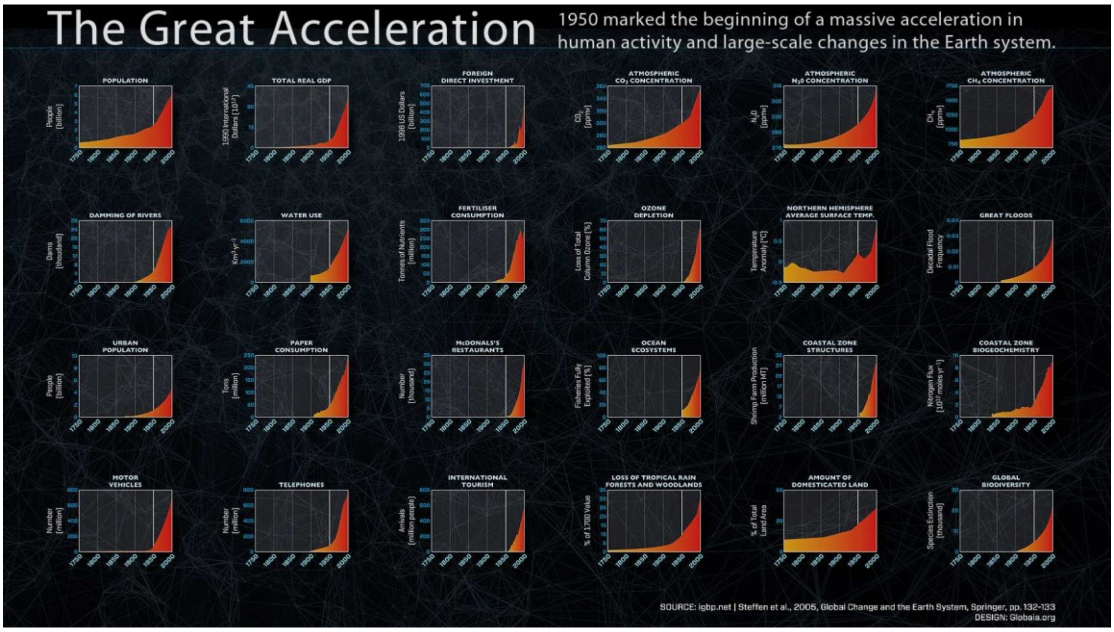


Figure 2. Selected indicators on material and energy flows and space consumption, 1750-2000.
Sources: (International Geosphere-Biosphere Programme (IGBP) 2014) and Steffen et al. (2005).

Figure 1 shows how the changes of selected indicators of global flows of materials and energy and global land use patterns have unfolded since the industrial revolution. The acceleration in the second half of the 20th century is closely linked to the unprecedented economic growth the world has experienced since WW2.

Most of the accelerating volumes of materials and energy flowing through the world economy until the end of the 20th century were and is set into motion by Europe and other industrialized economies. The weight of the throughputs of materials through the "old" EU countries (EU15) alone was 6-6.5 billion tons annually through the 00s until the financial crisis and 5.5-6 billion tons in the years 2009-11 (measured as DMC cf. figure 28).

2.8. The econosphere – linking nature and the economy

The broad character of the concept of a green economy makes it desirable to define more exactly the structures of the economy that must be changed to achieve an economy that is able to prosper without drawing too heavily on its natural resource basis and environment. The understanding of the throughput economy, the notion of anthropocene, the great acceleration and limits to growth tells us that the physical interface between nature and the economy cannot continue growing. Economic values that are not depending on the

It has very little to do with the major controversies on economic structures that dominated the 20th century. The experience from the 20th century was that centrally planned and market economies alike engaged in building supply chains and infrastructures that are ecologically unsustainable. The profound differences between Nordic welfare state economies the southern economies and the economies of the new member states have immense importance to the social welfare of the populations in the countries, but the ecological-economic trade-offs are similar in both types of economies. The financial sector and its regulation have differed widely between countries, with fateful consequences for the economy of the countries, but without significance for differences in ecological over-consumption. A wide variety of solutions to the balance between free markets and government regulation is found in Europe, but irrespective of the way, nations handle this balance, the physical patterns of production and consumption that need to be changed are similar.

The green transformations are about breaking the close links between production of useful services and commodities on the one hand and large throughputs of materials and energy flows accompanied by use of large land areas for these purposes on the other hand. It is often referred to as *delinking* the materials and energy flows from economic growth, *dematerialisation* and *decarbonisation*.

In the longer term, it is only possible with a different *physical interface* between economy and nature than the throughput based model of the 20th century. The flows of fossil fuels constitute the primary physical condition for the feasibility of the materials flows such as those shown in figure 2. Fossil fuels themselves make up a considerable part of the .

The 20th century European growth model was built on a progressively more pervasive use of fossil energy to fuel the economy. Fossil fuel technologies equipped productive units with unrivalled physical power and enabled them to specialise in highly productive niches. The mix of fossil fuel consumption, however, changed through the century and at the end of the century and in the first decade of 21st century, an increasing share of the energy consumed was natural gas and renewable rather than coal and oil.

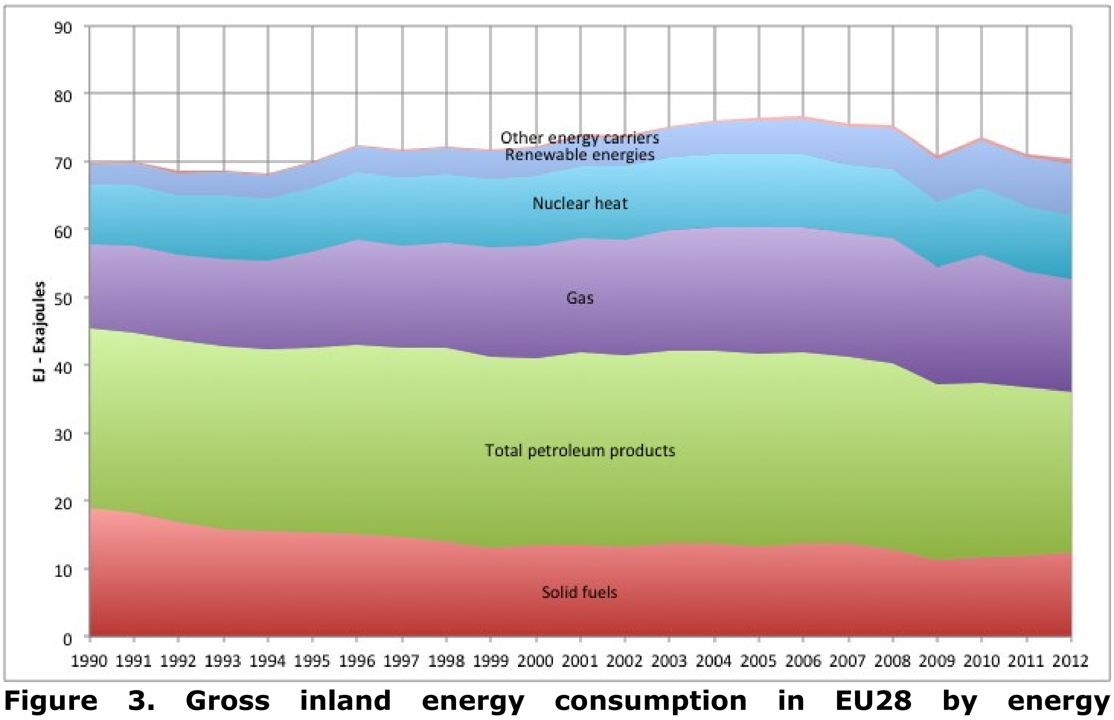


Figure 3. Gross inland energy consumption in EU28 by energy commodity, 1990-2012. Exajoules.
Source: Author's calculations based on EUROSTAT (European Commission 2014a).

The relief of coal by oil and later in the century by natural gas resulted in a slow "decarbonisation" of the economy. The ratio of emissions to primary energy supply was declining. This was due to a higher energy content per ton of carbon than coal and natural gas a higher energy content per ton of carbon than oil (Grübler and Nakićenović 1996). Figure 3 shows how this process continues into the 21st century. In addition to this, renewable energy, is supplying an increasing share of the energy consumption in the EU. The energy consumption itself has dropped due to the great recession 2008-09 and the 2012-13 EU-recession. The net result is that the consumption of fossil fuels was lower in 2012 than in the year 2000 despite a peak in fossil energy consumption in 2006. The composition of the fossil fuels has changed too.

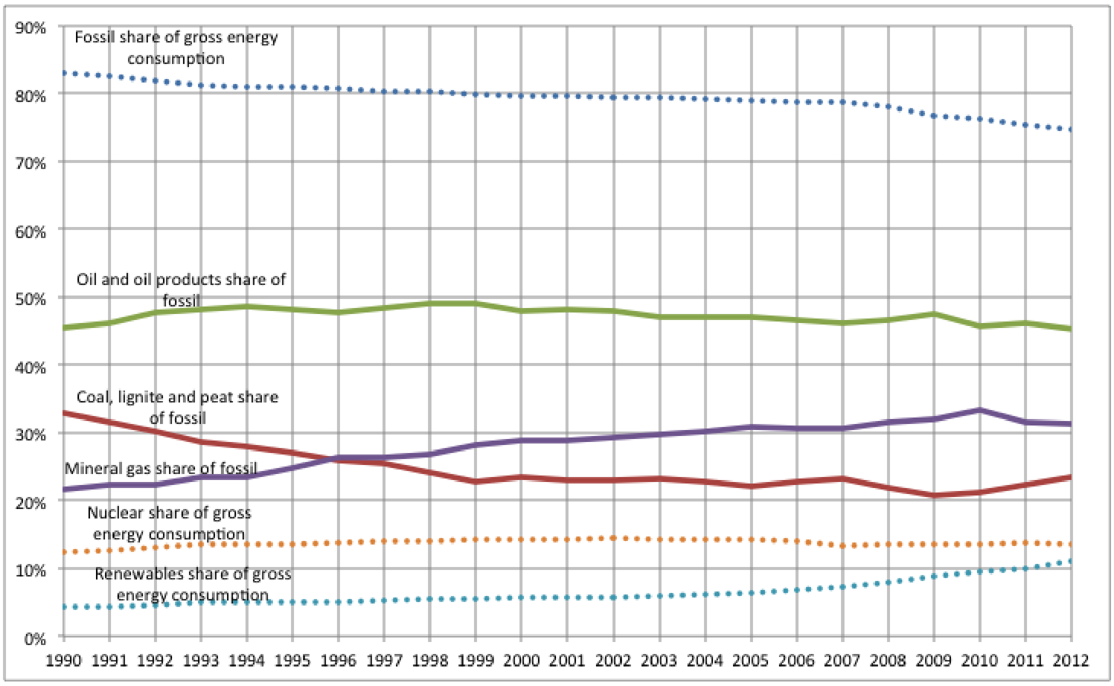


Figure 4. Share of fossil, nuclear and renewables in gross inland energy consumption and of oil, coal and gas in fossil fuel consumption in EU28, 1990-2012. Per cent.

Source: Author's calculations based on EUROSTAT (European Commission 2014a).

Figure 4 shows that the share of fossil fuels in the gross energy consumption of the EU has declined persistently throughout the period 1990 to 2012. In the 00s this share was primarily replaced by renewable energy. The mix of fossil fuels changed as well towards fuels with fewer emissions per energy content. During the 90s the share of coal declined in favour of first of all mineral gas, but also oil. During the 00s the share of coal in fossil fuel use did not change as much and the 2012 share is approximately unchanged compared to the 2000 share. The mineral gas share, however, continued to decrease whereas the oil share declined. Change from coal or oil to mineral gas or from coal to oil contributes to the decarbonisation of the EU energy consumption.

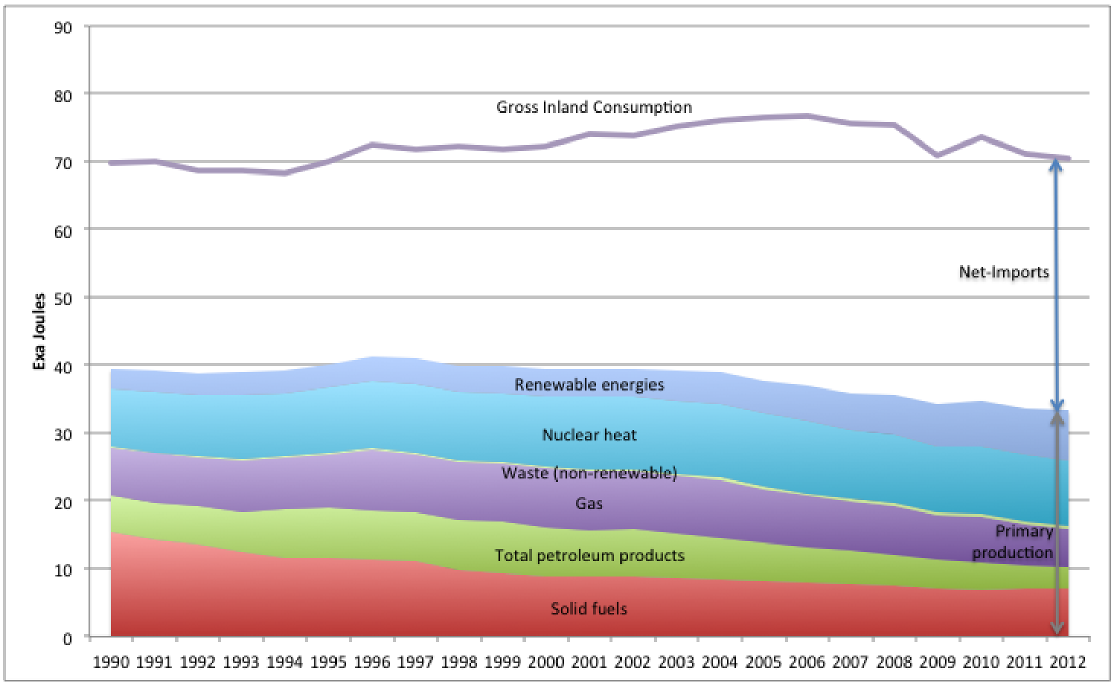


Figure 5. Primary energy production and consumption in the EU28, 1990-2012. Exa Joules.
Source: Author's calculations based on EUROSTAT (European Commission 2014a).

The recent energy history of the EU appears from figure 5 and shows that the production of primary fossil fuels is declining. The endowment of Europe with fossil fuel resources was never very generous compared to other continents, but Europe was early in using the available resources. As a result, the primary production of fossil fuel resources is now in decline. Opening new sources of shale gas will slow the decline, but hardly be sufficient to halt it or even reverse it (International Energy Agency (IEA) 2012). The nuclear energy capacity is expanding in some member-states, but for EU28 as a whole, it is not likely to make up for the dwindling fossil fuel production. Renewables are expanding, but as can be seen from figure 5, a much higher pace of renewable energy capacity growth is necessary to make up for the decline of fossil energy.

Energy from indigenous – that is EU-domestic – sources is important for security of energy supply and in particular to avoid the geopolitical imbalances following from depending too much on few energy supplying countries outside the EU.

The renewables that will relieve fossil fuels, however, comes primarily as electricity (wind in the North, solar in the South). This does not present a major problem in the building sector, but it does in the transport sector. In any case, the transformation entails the electrification of final energy use.

The transformation of the physical interface between nature and the economy required for a green economy follows some major trends illustrated in the **table 1**.

Table 1. Major dimensions of the green transformations of the energy econosphere.

	Non-renewables	**Renewables**		
Non-combustibles	Nuclear (uranium, thorium …)	Hydro, wind, ocean, geo-thermal, solar...	↑	*Elec-tri-fica-tion*
Combustibles	Fossil fuels: Coal, oil, natural gas	Biomass, biofuels, micro-biological fuels		
	→ *Sustainable supply*			

The energy econosphere is changing from non-renewables to renewables and from combustibles to non-combustibles. This means that the supply of energy can become more ecologically sustainable, more secure and without the price of geopolitical dependency. At the same time, a large part of it comes as electricity and thus a parallel transformation of the energy sector and the final energy use is necessary.

The share of electricity in final energy use is increasing already and the EU Commission expects it to reach around 27% in 2050 in a Business-as-usual scenario. In low carbon scenario, however, the share will be around 10 percentage points higher (European Commission 2011a).

Among the energy and materials flows, the oil flow is probably the most important. On average 92 million barrels leave the oilfields on a daily basis in a continuous flow from sources to sinks (International Energy Agency (IEA) 2013a). The so-called Well-to-Wheel chain of oil-based energy-flows - that still today fuels 93% of global motorised transport (International Energy Agency (IEA) 2012) - is maybe the most difficult set of physical interface structures to replace.

With the current policies, the share of transport fuelled by oil will be reduced to 89% by 2035, but this must still be regarded as an over-consumption of the absorptive capacity of the atmosphere. The IEA estimates that a reduction to 77% by 2035 is required to stabilise the GHG concentration in the atmosphere at 450 ppm and keep global warming below 2°C (International Energy Agency (IEA) 2012).

In rough numbers, it means that 16% of the world transport vehicle fleets and their supporting infrastructure must be replaced by vehicles and infrastructure using electricity and biofuels before 2035. The corresponding flows of oil must be replaced by flows of other energy carriers – electricity, gasses, biofuels - and supporting infrastructures.

The Well-to-Wheel chain cannot deliver the transport within the ecological balances, in particular when considering the need for transport of a 9 billion World population without poverty, but with continuous growth in productivity. Even with very optimistic assumptions on progress in fuel economy, it would hardly be consistent with a 80-95% reduction of the GHG emissions. A green economy providing the transport services within the balances must rest on totally different sets of energy and materials flows, vehicle fleets and infrastructures.

Rather than a Well-to-Wheel chain it will be a Wind-to-Wheel chain (or Solar-to-Wheel) with intermediate storage links.

The EU Commission has prepared scenarios for how this change of the transport system may take place in Europe (European Commission 2011d). According to these scenarios the replacement of oil based by renewables based transport in European cities could be completed in 2035. This will require the rate of transformation of the transport system in Europe to be much higher than elsewhere.

The thus transformed transport system will be able to deliver more transport services (vehicle-, ton- and person-kilometres) than today, but leaving a third of the otherwise extracted oil and the related CO_2-emissions in the ground.

Similar sets of energy flows and infrastructures and capital equipment designed to handle them will be replaced by green alternatives in other supply chains of the economy. The building stock now providing its floor space heated by natural gas, gasoil or coal will be replaced by a "near-zero-energy" building stock as new "vintages" replace older. Their heating technology will probably make use of electricity with heat pumps. The electricity sector delivering the energy from wind, solar and other energy sources will have to be organised with a much more flexible demand-side, "smart-grids", and integrated in much larger European "supergrids".

These coherent sets of flows, infrastructure, end-use equipment and technologies providing the *interface between nature and the economy* have been called the *econosphere* (Boulding 1966). This term is useful for describing that the transformation of the economy to a green economy involves more than shifting from coal to gas and shifting from less to more fuel-efficient cars. These steps are important and necessary, but a green economy also means that over a longer period a shift to an entirely different econosphere is necessary. Otherwise the economy cannot deliver the high level of economic well-being to all and still keep the ecological balances.

A related term is *socio-technical systems*, which is often used in analyses of the same phenomenon. The econosphere can be perceived as the total of all socio-technical systems making up the physical basis of the economy. The term "econosphere" is preferred here because it is more about the physical link between economy and nature and has a more macroscopic meaning.

The econosphere is not a term in the conventional economic vocabulary. In the mainstream of economic analysis, the economy is described in terms of a real value circuit and a financial circuit. In the real value circuit, production activities convert inputs of labour and capital services to outputs of consumption and investment goods. They are consumed and invested respectively in consumption and investment activities. The reincarnated labour force and capital stock deliver new inputs etc. The financial circuit runs in the opposite direction and keep the real value circuit running.

From a natural science point of view, the econosphere is the *total anthropogenic materials and energy flows between the four spheres (lithosphere, atmosphere, hydrosphere and biosphere) and the fixed capital and systems transporting and processing them.* Figure 1 illustrates how the econosphere complete the mainstream economics paradigm to an interdisciplinary paradigm including the natural science as well as the economics perspective on the economy.

The econosphere thus consists of

- the capital stocks used for extraction of materials and energy, transport storage, processing, conversion and final use.
- The flows of energy and materials through it
- The areas allocated to the above activities and to function as sink for the eventual exit of the materials as waste and emissions

The types and volumes of materials and energy carriers are determined by the fixed capital, invested in the economy: Buildings, infrastructures, plants, machines, transport vehicles. They are designed to deliver particular services by using particular fuels and to process particular types of materials in particular volumes. A car is designed to use a specific fuel – mostly petrol or diesel – deliver its vehicle kilometres. A house is designed to use a specific amount of a specific energy carrier to deliver its 150 heated square-meters. The energy sector and its infrastructures are designed to deliver these energy carriers within its capacity limits.

The case of the global transformation of the Well-to-Wheel chain to a Wind&solar-to-Wheel chains illustrates that there are different levels of "green". It is also green to remember to turn of the light or to get the bicycle rather than the car when fetching bread from the bakery. However, eventually, the economy cannot stay within its limits without a profound transformation of the physical interface between the economy and nature. The concept of the econosphere is useful in this distinction.

EU and individual member-states have developed a series of programmes scheduling the transformations by setting specific targets to be reached at specific years. For the energy sector transformation the pace of renewal is set according to the climate concerns. The European Union has since the 1990s pursued a goal of limiting global warming to 2°C. A global agreement about that was achieved at the COP15 summit in Copenhagen 2009 and it involves the replacement of the present econosphere by an econosphere that enables maybe twice the present economic prosperity, but only 5-20% of the present emissions.

The EU target for reduction of greenhouse gas emissions by 2020, however, is only 20%, which is very modest compared to the overall goal. According to the integrated energy and climate policy 30% emission reduction is the preferable level of ambition, but as long as other large emitters such as the US and China do not make similar concessions it would be at the cost of international competitiveness and thus loss of economic values without gains in global balance in GHG emissions. The COP19 in 2015 is set to finally reach an agreement with targets and commitments.

The Covenant of Mayors initiative, which now has almost 5000 signatories – cities and municipalities – is committed to (at least) realising the 20% target by 2020 in their geographical area. This is, however, an inadequate pace of decarbonisation, which is already being overtaken by national frameworks in many countries and is likely to be so in all EU countries.

In some countries, longer-term strategies are taking shape or have already been implemented. The United Kingdom and Scotland have adopted climate change acts in 2008 and 2009 respectively to ensure a time consistent and continuously progressing reduction of greenhouse gas emissions to a sustainable level through the first half of the century. In Germany, the "Energiewende" is pursued with a focus on developing a long-term institutional framework for achieving 80% renewable energy in 2050. In Denmark, a climate change act is under preparation aiming at a 100% decarbonisation of the economy by 2050. In Sweden, a roadmap is being prepared aiming at eliminating greenhouse gas emissions totally in 2050. Regions in countries with such programmes for green transformation will have to target a more ambitious pace of progress towards a green energy economy.

The replacement of the physical basis of the economy does not only concern the production and use of energy. Other unsustainable flows of materials and energy and unsustainable "consumption" of areas similarly involve major redesigning and refurbishing of supply chains and of the capital stocks and systems supporting them. They can be grouped in two types of transformations, one called "dematerialisation" and the other called "ecosystem restoration". Together with the "decarbonisation" and "energy delinking" processes, they constitute a more efficient use of resources in the sense that less tons, cubic-meters, megawatt hours etc. are required for achieving a given level of economic prosperity. Green solutions, however, do not in every case require higher costs of capital. For instance, when an environmentally harmless substitute for a chemical substance entailing environmental risks exists, the costs of

2.9. Key economic properties of the green transformation

Against this backdrop, we may assume some core properties of the green economy and the transformations towards it.

First, the feasibility of the necessary substitutability of the unsustainable flows of energy and materials has now been demonstrated in many areas. Whereas the early debate was based on a profound uncertainty of whether it would be physically and technically feasible to replace fossil fuels and other unsustainable flows by renewable technologies, smart devices, recycling and other green solutions, today these solutions have been demonstrated and their feasibility as a physical basis for the economy has been established. Green growth is a reality on the markets.

Second, the adaptation of the economy to a low carbon and generally a low materials flow economy can be summarized in some main types of transformation:

- substitution of harmful substances with harmless substances
- substituting capital for energy and resource use in the production of commodities and services
- using capital and labour for recovering and recirculation of energy and recycling of materials

Third, substitution of unsustainable flows requires capital. Renewable energy resources are captured by, e.g., capital invested in wind-farms, replacing non-renewable energy resource flows such as steam-coal for power generation. Worn-out batteries with contents of heavy metals can be separately collected and the heavy metals recovered and recycled if an adequate recycling infrastructure is established. More sophisticated capital equipment enables the use of energy and materials in doses that are more accurate and to eliminate "useless energy" such as lightening of unused rooms and machines running idle.

Fourth, the capital requirements depend on the sequence and time horizon of transformation. A shorter time horizon makes the overall transformation more expensive, whereas stretching the transformation period is likely to make it less expensive. This is due to the learning economies, the dynamic economies of scale, involved in the transformations. On the other hand, a low rate of, e.g., the energy conversion sector in the near future implies a higher rate later on with a correspondingly higher capital requirement.

Fifth, the socially desirable pace and sequencing of the transformations will depend on the socially acceptable and preferable *trade-offs* between consumption growth and investment in the transformations. High rates of investment in energy savings may allow for lower energy bills and higher consumption opportunities in the future. High rates of investment in offshore wind and PV-electricity implies less income left for consumption in the long run as long as these electricity sources are more expensive than fossil fuel based electricity. On the other hand, both will replace imports of fossil fuels with investment goods that are mainly produced in Europe. Thus, there is an employment effect of advancing future investments in transformation that could outweigh negative effects of higher electricity costs in the future.

Finally, the *institutions* that serve as frameworks for the replacement of the unsustainable with the sustainable solutions will determine the actual pace and sequence of the transformations. Long-term ecological budgets are important institutions with which society literally can recognise the scarcity of the services provided by nature. Implementing them in long-term legislation reduces the uncertainty faced by innovators of whether there will be a market at all for the innovations when they are ready. Climate acts with emission budgets until 2050 have, e.g., been adopted in the UK, Scotland and Denmark.

2.10. Notions of a green economy

A number of books have addressed the issue of a green economy. They offer different perspectives on it, but have that in common that they see the green economy as a paradigm. A paradigm shift that involves a whole new set of ethical principles, it involves integrating understanding from different disciplines on what is feasible and what is desirable, it involves a broad range of institutional reforms and governance principles and many other aspects.

An early book on the green economy included the first of a series of five "blueprints" (Pearce 1989) based on the understanding that environmental losses were a result of mismanaged economies. The book attempted encircling an economic understanding of the newly coined concept of "sustainable development". It was defined as either a set of sustainability indicators that all are increasing or an increasing aggregate measure of per capita utility or well-being. The book explored, in particular, the economic approach of non-declining stocks of capital (cf. below).

A contemporary book relating to the sustainable development took a critical view on the neoclassical foundations of the environmental economics developed in the "blueprints" (Jacobs 1991). Jacobs defined sustainability as the maintenance of environmental capacities at levels, which at least prevent future catastrophes and which at least gives future generations the opportunity to enjoy a measure of environmental consumption equal to that of the present generation" (p86). The task is then to define the levels that do not lead to "catastrophes" and the environmental consumption that the present generation enjoys.

Ekins (2000) suggested that sustainable development should be understood in its economic, environmental and social dimensions adding ethics as a fourth dimension. Ekins used the constant capital approach with the addition of the notion of "critical capital" that is, indispensable or unique environmental assets. This approach embraces the notion of constant capital as well as the notion of a level that avoids "catastrophe". Ekins also provided a more in depth review of key environmental economic problems such as green national accounts, double dividend of environmental taxes and the environmental Kuznets curve.

An even more critical and anti-capitalist perspective was offered by Milani (2000). He defined the ten principles of the green economy including ecological and other principles. A key principle is to recognise that it is the services produced – not the materials and energy used to produce them - that are of value to us. Thus, "eco-designing" the physical structures of the economy to use less physical flows while still providing the necessary services is a prerequisite for a green economy.

Rifkin (2011) develops a similar vision of the third industrial revolution that we are entering now. Whereas the first industrial revolution was based on coal and steam engines, second industrial revolution was based on electricity and oil. The third industrial revolution will be based on renewable energy, a distributed production of it integrated in any building and a flexible use of it enabled by ICT and hydrogen and other storage technologies that allow effective exchange and storage of this energy. This energy system allows the full electrification of automotive transport. Programmes for supporting and guiding this revolution of the physical and energy basis of our economy are already taking shape in the EU.

2.11. Zero Growth, Degrowth or delinking and decarbonisation?

The "Zero Growth" vs. "overriding priority of GDP growth" debate (cf. above) was settled by the formation of a shared vision of sustainable development. In the 00s, however, an alternative paradigm emerged along similar lines. The political slogan of *degrowth* or *décroissance* is offered as an alternative to *sustainable development* and the *green economy*. *Degrowth* is not a scientific concept, but a is a political slogan with theoretical implications" (Latouche 2010, p519). It is as much about *disbelieving* in the growth society as it is about the economy itself. This has given rise to a semantic debate since the French *décroissance* carries connotations to both meanings, whereas the English translation to degrowth doesn't (Latouche 2010). An alternative could be *agrowth*, resembling *atheism* (van den Bergh 2011).

The *degrowth* paradigm aims like the *green economy* at an economy, which operates "within its ecological means", that is, without ecological over-consumption. This leads to "degrowth of the ecological footprint in the North (and thus of the GDP) is a necessity" whereas the opposite is true in the South (Latouche 2010, p521). On the other hand it is reassured that "degrowth is not negative growth" (Latouche 2010, p522).

According to the "sustainable development" growth or zero or negative growth is not the question. The question is what should grow and what should be reduced.

The debate, however, continues and it is probably due to the ambiguity of the definition of "growth". In natural science, the concept of "growth" means the increase in volume, mass or numbers or matter over time. The concept is strictly reserved for the *accumulation of physical quantities* in space and over time. The economics concept of growth is different. In economics, it is in principle about the *value* of the production (or of the use of the output in consumption and investment). The value of production could very well be higher even when the weight and volume of the output and its energy requirement drastically reduced.

The concept of *growth* is, however, very often used without reference to whether it is about physical quantities or qualities and usefulness and not used without reference to whether the finally consumed products involve heavy upstream physical flows or not. See e.g., (See, e.g., Jackson 2009).

Herman Daly is one of the contributors to the debate who has made it very clear, that *"by "growth" I mean quantitative increase in the scale of the physical dimensions of the economy; i.e., the rate of flow of matter and energy through the economy (from the environment as raw material and back to the environment as waste), and the stock of human bodies and artifacts. By "development" I mean the qualitative improvement in the structure, design, and composition of physical stocks and flows, that result from greater knowledge, both of technique and of purpose. Simply put, growth is quantitative increase in physical dimensions; development is qualitative improvement in non-physical characteristics"* (Daly 1987, p323).

This distinction between the growth of throughput, of materials and energy flows on the one hand and of value creation, of GVA/GDP on the other hand gives rise to the question of whether the growth of GDP is possible at all without growth of material throughputs. It is probably the most fundamental assumption of the degrowth paradigm that growth of GDP without growth of the material throughputs is not possible.

Considering the throughput growth model, there are definitely good reasons for aligning growth in value with growth in physical flows – and growth in employment. The throughput growth model linked all of these together and growth in GDP was paralleled by growth not only in employment, but also in physical flows. It is fair to say that the growth potentials of the model rested on precisely these flows and, in particular, the flows of fossil energy that constituted a prerequisite for the feasibility of all the flows.

The economy of the 21st century, however, is not necessarily bound to the same growth model. It is possible to grow in different ways now. Near zero buildings, for instance, and electric vehicles of the 21st century require no flows of fossil fuels as their counterparts in the 20th century did.

In the transition from the 20th century model to green economy the GHG-emissions (or other physical flows) can be strongly or weakly linked to GDP and the delinking or relinking can overshadow the change in GHG emissions caused by GDP growth. The figures below show some European experiences in the 1990-2011 period.

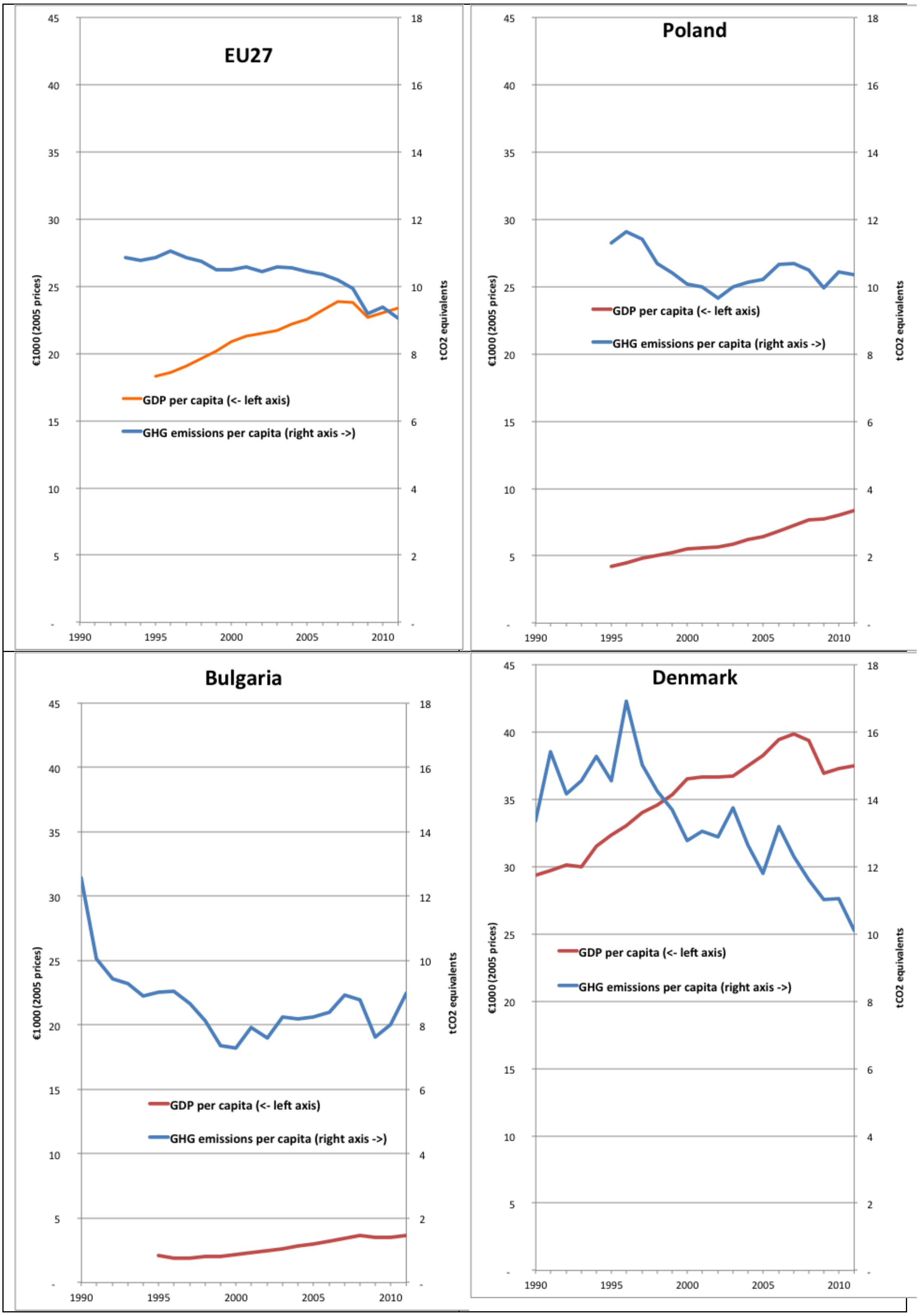


Figure 6. GDP and greengouse gas emissions per capita in EU27, Poland, Bulgaria and Denmark 1990-2011. €1000 (2005€) and tCO2-equivalents. Source: Author's calculations based on EUROSTAT statistical database nama_gdp_k, env_air_gge, nama_aux_pem (resident population, domestic concept), accessed 05.01.14.

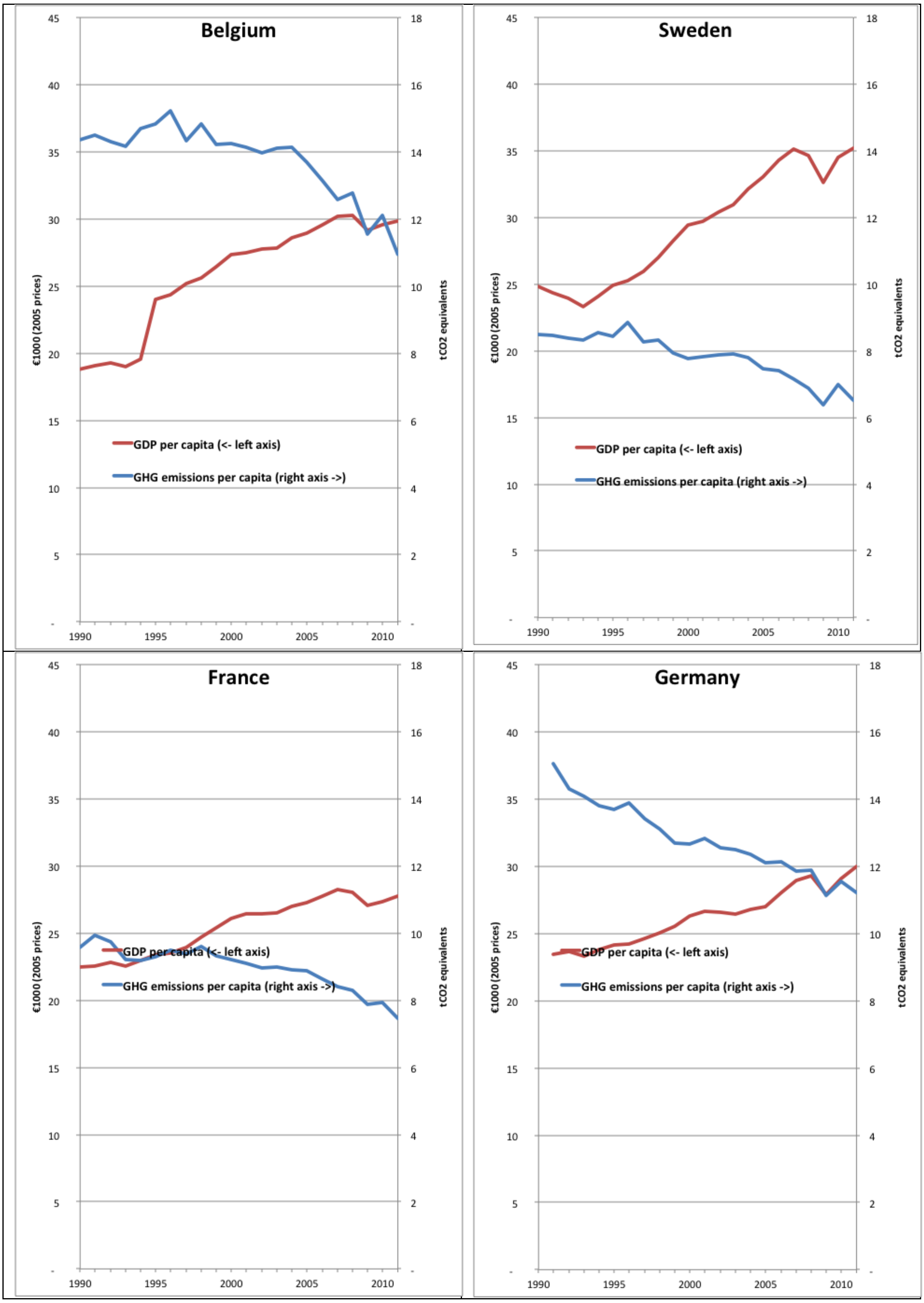


Figure 7. GDP and greengouse gas emissions per capita in Belgium, Sweden, France and Germany 1990-2011. €1000 (2005€) and tCO2-equivalents.

Source: Author's calculations based on EUROSTAT statistical database nama_gdp_k, env_air_gge, nama_aux_pem (resident population, domestic concept), accessed 05.01.14.

The diagrams in figure 6 and figure 7 show that the relation between emissions of greenhouse gasses (GHG) and GDP in the period of 1990-2011 was far from a simple proportionality. For the EU27 as a whole the GHG emissions declined while the GDP increased (both measured per capita). It does, however, cover different developments in different member states.

In Poland and Bulgaria as well as in other new member-states, the GHG-emissions declined through the 1990s, but hen started to rise whereas the GDP grew from 1995 onwards.

In EU15 member-states such as Denmark, Belgium, Sweden, France and Germany the pattern is like the overall EU27 pattern: Increasing GDP, but declining GHG emissions – at least from 1995 onwards.

The impact of the financial crisis, however, is common for all of the economies. The large drop in GDP from 2008 to 2009 and recovery from 2009 to 2010 was followed by a parallel drop in GHG emissions 2008-09 and growth 2009-10.

The level of per capita GHG-emissions differs between EU15 countries with high levels in countries like Denmark, Belgium and Germany and lower levels in countries like Sweden and France with high shares of non-fossil energy. The per capita GHG emission of Poland and Bulgaria are not particularly high, but related to the very low levels of per capita GDP, it is higher than in the EU15.

The real challenge of the transformation to a green economy is to achieve progress in all three dimensions simultaneously. In the great debate on environment and growth in the 1970s it was a widely distributed premise that it was impossible. It was a choice between growth as in the industrialised economies with massive ecological losses or no growth. The concept of sustainable development and now the green economy is also a statement of its feasibility. Economic prosperity in ecological balance is possible.

In the European economies, energy use is closely linked to economic growth and energy is to a high degree carbonised, that is, fossil. This is because the fixed capital stock was and is designed to use fossil flows to produce its services such as transport. This carbonised system of fixed capital and supply chains (the econosphere) effectively links economic growth to growing flows of fossil fuels.

A green economy is characterised by a different design of the econosphere. As the fixed capital stock of oil-, gas, and coal boilers, combustion engines, heat wasting buildings etc. are replaced by wind turbines, photovoltaics, heat pumps, electro-motors, near-zero-energy buildings etc., the econosphere reduces the energy required to deliver energy services ("energy delinking", "energy efficiency") and reduce the carbon content of the energy used ("decarbonisation"). A decarbonised and energy efficient econosphere enables even an expanded provision of energy services such as measured by heated square-meters of floor area or vehicle-kilometres without over-consuming natural resources and sinks. Economic growth becomes delinked from growing CO_2-emissions. The EU has agreed on policies in this direction, but the pace of the transformation is debated.

Similar transformations of the sets of material flows and capital equipment designed to handle them take place in, for instance, the flows of nutrients through agriculture and food consumption, the flows of chemicals implying environmental risks and the flows through products to municipal waste. Enclosing substances in circular supply chains, redesigning the dosage and substituting hazardous with safe substances are key green innovations. As the sets of capital equipment and material flows are replaced by green solutions, it is possible to deliver a high level of production without over-consuming natural resources and sinks.

2.12. Rebound effects and the Environmental Kuznets Curve

The energy consumption – and fossil energy consumption in particular – closely related to economic growth of the developed or industrialised economies in most of the 20th century. In the last two decades of the century, however, the growth of fossil fuel use and energy consumption seems to have been less closely linked to GDP growth. This delinking is interpreted partly as a response to the oil crises in 1973-74 and 1979-80, but not necessarily, a response led by government.

The nature of the mechanisms behind linking and delinking has been debated in the scientific literature under the headlines of "rebound effect" and "Environmental Kuznets Curves (EKC)".

The rebound effect is a type of market mechanism based on the observation that more resource efficient solutions in production and consumption do not necessarily lead to less resource use. Firms and households buy technical solutions to provide the services they need for their production and wellbeing. When such solutions become more resource efficient, they can deliver the same or more services with less resource use.

It is also called *Jevons' paradox* referring to the observation of the 19th century economist William Stanley Jevons in his inquiry on the coal question. He noted that the progress in the energy efficiency of steam machines did not lead to lower coal demand, but instead to investment in more and more powerful steam machines (Jevons 2001; Jevons 1965).

When combustion engines in cars, for instance, has become more fuel efficient due to improved injection technology, it enables the car owners to reduce their purchase of petrol for a given amount of transport services. Nevertheless, it also enables car owners to buy larger and heavier cars with larger engines without increasing the petrol bill. Or to increase their consumption of transport services without increasing their petrol expenditures.

In typical cases, where the cost of technological progress are not included in the resource flow itself such responses are even what must be expected as illustrated below.

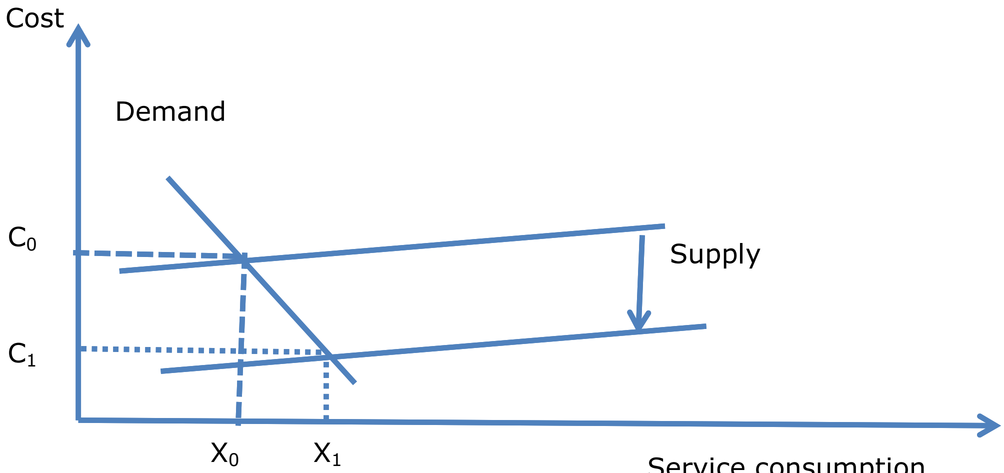


Figure 8. Direct rebound effect.

The figure shows the market for services such as transport (measured vehicle kilometres, passenger kilometres or ton kilometres). For simplicity, we assume that there are no maintenance costs depending on the amount of transport. The new technology shifts the fuel cost per kilometre (C_0) downward to C_1 enabling the car fleet to reduce the petrol bill from the area of the C_0X_0 rectangle to the area of the C_1X_0 rectangle. However, due to the lower costs of the transport service, the users of the vehicle fleet want to consume more kilometres or transport heavier loads or more passengers. The result is more kilometres and a fuel bill of C_1X_1. The market strikes back and the final impact on the fuel demand is uncertain.

The literature on rebound effects distinguish between direct and indirect effects (Sorrell and Dimitropoulos 2008; Sorrell, Dimitropoulos, and Sommerville 2009). The effect shown in figure 5 is the *direct* rebound effect.

Carbon leakage represents similar effects. Recently, the coal-to-gas shift in the USA led to a redirection of the coal supply towards Europe causing gas-to-coal shifts in Europe. If such mechanisms are not controlled, progress in emission reduction in one country will have limited impact on global warming. As all countries reduce their oil demand, the global demand for oil will at some point peak and turn downwards. Unchecked, this would lead to lower fossil fuel prices and the transformation would come to a standstill halfway in the process. Consequently, fossil energy taxes and tradable allowances are indispensable for the transformation in the long run.

Indirect rebound effects can occur to the extent demand responses do not convert all of the potential gain to a higher demand for the energy services. If the demand for car transport is saturated – that is, the relevant section of the demand curve is close to vertical -, then the users will spend the budget, they otherwise would have spent on petrol, on other goods that also may entail unsustainable use of sources, sinks or areas.

Another indirect effect can occur upstream in the supply chain. When a significant share of the car fleet of an economy consists of electric cars, the energy efficiency of car transport will be dramatically improved because most of the energy in petrol is lost to the surroundings as waste heat from the combustion process. Electric vehicles eliminate this loss because they do not combust anything. However, they do also generate a demand for electricity. If that electricity is supplied by, e.g., coal power plants this demand will generate a similar loss of waste heat from coal combustion in the electricity sector. Then, the final impact on the gross inland energy consumption will be uncertain.

Finally, the market also strikes back with another form of carbon leakage. If the costs of emission reduction reduce the competitiveness of industries relative to their foreign rivals, the latter may gain larger shares of the international markets. This means that the production may just be relocated rather than transformed. The formula for competing with competitors that pay lower prices for energy, water etc. is to become correspondingly more resource efficient. Government policies supporting such industry responses to input prices are likely to be successful.

Any strategy for transformation of the econosphere must consider such rebound effects. In general, government regulation can counter such feedback effects by applying additional administrative, economic or informative instruments. The direct rebound effect shown in figure 5 can be neutralised by raising the cost of resource consumption using the new technology. In Europe and Japan, for instance, the fuel taxes were raised significantly in the 80s and 90s, whereas in the US they were not. This difference has been used to explain the very different ways the same car technologies were used in Europe and in the United States. In Europe smaller fuel efficient cars became more popular, whereas in the United States heavier cars with more horsepower became more popular in the 1990s and the first half of the 00s.

The major economic instruments engaged to drive transformation and mitigate rebound effects include taxes, subsidies, tradable allowances and support of innovation. Warnings have been raised that tradable allowance markets such as the ETS may also in itself cause carbon leakage within the system. If one country gets its ETS firms to reduce emissions by more than the allowance price justifies, these firms will sell the allowances to other firms that will increase their emissions ton by ton. This mechanism will work in an efficient allowance market where the supply of allowances is the effective cap on emissions.

However, the ETS market is not efficient because the supply of allowances exceed the demand by more than 2 billion tons. This surplus is not expected to diminish before 2020 and the Commission have decided to postpone allowances for 0,9 billion tons from 2014-16 to 2019-20 (European Commission 2014f). This "backloading" is, however, not expected to cause a strong price incentive. The transformation in the ETS sector is, however, also driven by the wide gap in energy prices between European industries and their competitors in the USA and China and by national and regional energy planning and environmental regulation. In a longer time perspective, an efficient market is a possibility and the strategies for countries that want to advance faster towards a low carbon economy should consider such effects.

Changes in the market price can be more important than the changes in taxes and allowance prices. The price increases on fossil fuels through the 00s have been much larger than the changes in taxes and allowance prices in Europe and have provided larger incentives for shifting from fossil fuels to renewables and resource efficiency. The oil price increased from the lowest level in the 1990s of about $10 per barrel to around $100 per barrel through the 2000s. This increase, of course, has the same effect of neutralising rebound effects. In general, price as well as tax increases induce innovation in fuel and other resource efficiency. There is, however, no reason to expect that the long term trend in the oil price will be exactly what is needed to drive the transformation to a transport econosphere able to deliver the transport services the economy needs within its carbon budget.

The market price adjusted by taxes is not the only instrument available to governments to counter rebound effects. In the US as well as in the EU and Japan governments also use standards for fuel efficiency and exhaust to drive the transformation and counter the rebound effects.

Regulation of final energy use (transport, buildings, production processes) for advancing the long-term shift from combustibles to electricity has little success if not accompanied by a parallel set of policies for transforming the power and heat sector from fossil energy to renewables. Thus, the indirect rebound effects are countered in the EU by instruments such as the emission trading system and regulation of emissions to air from large boilers.

In sum, the following conclusions can be drawn:

- Rebound effects occur and are predictable from basic economic models
- Curbing GHG emissions will lead to lower demand for fossil fuels which are likely to cause lower prices giving rise to rebound effects
- Governments have instruments at their disposal for countering them
- Economic instruments are natural choices to counter adverse effects of technology-induced lower costs of services based on unsustainable flows
- But technical regulation, information and innovation support also mitigate such effects
- The transformation of final energy use from fossil energy to electricity and heat only leads to the targeted decarbonisation if accompanied by a parallel transformation of the power and heat sector from fossil to low carbon energy

The Environmental Kuznets Curve (EKC) debate is related to this as it is based on observations of some pollution problems describing an inverse U shaped curve over the history of industrialisation and urbanisation of economies. The observation is similar to an observation made by the economist Simon Kuznets on measures of inequality, thus the name (Kutznets 1955).

The questions debated are whether the EKC really can be considered a statistical regularity according to standard criteria of statistics and, more generally, how we can understand the variation of environmental pollution in the course of economic development.

The original and subsequent empirical findings have been criticised for not meeting standard statistical criteria. Few curves do, but the general pattern is that the growth of emissions and polluted environment follows the growth of income in an economy. There are, for instance, patterns of development of urban air pollution that are common to European economies, but they can be explained by the uniform use of regulation, urban planning concepts with heavy industry relocated from centre to periphery and that kind of government responses (Stern 2005; Stern 2004).

The conclusion is that the available evidence does not support the view that economic development requires high rates of environmental pollution in the beginning and automatically evolves into a greener economy as it matures. This curve is definitely a strategy that a developing country can choose, but it can also choose a sustainable development strategy implementing the green solutions already developed in other countries.

Against this backdrop, the following analyses of delinking processes are formed within a view that they do not evolve automatically from the maturity of European economies or from the technological development in general. They require long-term government policies with the use of a palette of technical standards, economic incentives, information and innovation supportive frameworks. Such policies have been pursued to varying degrees by European governments through the recent decades. They now seem to pay off by providing decision makers a wide range of green solutions that are approaching cost-competitiveness compared to fossil and other unsustainable solutions.

Regional administrative bodies are usually not entrusted with government authorities that enable them to do use such instruments, but central governments can establish an institutional framework, that is useful for regions in furthering green transformations of the regional economy.

2.13. The global governance agenda

The academic and public debate was paralleled by an increasing political awareness of the necessity of political action at local, national and even global levels. The use of DDT, for instance, was increasingly recognised to result in *Silent Spring* and other environmental damage and through the 1970s it was successively restricted and banned in many developed countries[2].

Regulation and growing international concern for the environmental consequences of economic growth had already led to actions such as the formation of international cooperation on nature conservation and interdisciplinary research on "Man and Biosphere" (UNESCO). Also more direct measures had been taken such as the ban of DDT in the US to be followed by European and other countries.

The United Nations Conference on the Human Environment in Stockholm in 1972 marked a comprehensive global effort to address these problems associated with the industrialisation and urbanisation processes that were shared by the industrialised countries, but also the environmental problems of the developing countries. For developed and developing countries, respectively, the conference found uniform problems and recommended uniform solutions. It was followed by the 1992 World Summit in Rio, the 2002 implementation conference in Johannesburg and the Rio+20 Conference in Rio in 2012.

These conferences mainly addressed the question of governance and formation of institutional frameworks for a more balanced development. In the 1970s after the Stockholm conference there was a wave of adoption of environmental protection laws and establishment of environmental ministries in Europe. Whereas these institutions were national, they also had international relevance as the technologies causing the environmental pressures were international and as the pollutants released to the environment flew across borders. At any level of government, the transformation to a green economy calls for implementation of the same principles for good governance as in other societal transformations: enforcement, proportionality, accountability, transparency, participation etc.

The global environmental challenges were also considered, but the scientific evidence was generally too weak to warrant the formation of strong global institutions for addressing them[3].

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[2] Whereas it is still used in malaria control in many developing countries.

[3] The Study of Critical Environmental Problems (SCEP) (SCEP project team 1970) prepared in the advance of the conference identified a series of global environmental concerns including DDT, heavy metals and other toxics into the environment, the overdose of nutrients into fresh water and brackish water systems and oil spills at sea. Moreover the study addressed the questions of anthropogenic

One of the important scientific inputs to the Stockholm conference came from a panel of experts formed at a seminar in Founex, Switzerland – thus, "The Founex report" – analysing the topic of development and environment. The message of the report was, in brief, that whereas the environmental problems in the developed countries were "the outcome of a high level of economic development", the environmental problems of the developing countries "reflect the poverty and very lack of development of their societies" (Almeida 1971). In addition to this, the report argued that the developed countries had a responsibility to assist the developing countries in solving these problems. This approach became influential in the formation of the north-south consensus in the declarations and action plans from the Stockholm Conference. It led subsequently to the principle of common but differentiated responsibilities at the subsequent conferences.

The north-south consensus on uniting the seemingly contradictory goals of economic development in the developing countries and shrinking the impact of the global economy on nature remained the key challenge for the subsequent Rio Summit in 1992, the Johannesburg Summit in 2002 and the Rio +20 Summit in 2012.

3. Sustainability and the green economy

3.1. Defining the green economy

The vision of a green economy reflects a future where economic prosperity goes hand in hand with conservation of ecological values and a society in social balance. Beyond this understanding, however, there is little consensus on what a "green economy" really is.

The concept has been used in scholarly publications, but there is no scientific consensus on an unambiguous and concise definition. The meaning of the concept has primarily evolved from the international political discourse on sustainable development. It is, however, supported by science-based studies underlying the strategic decisions and orientation of international and national policies.

3.2. The emerging consensus on a green economy

The green economy was literally put on the agenda of the world community by the decision of the United Nations general assembly on organising in 2012 the United Nations Conference on Sustainable Development "Rio+20". The conference agenda contained two themes: a) "a green economy in the context of sustainable development and poverty eradication" and b) "the institutional framework for sustainable development" (UN 2010).

The United Nations Environmental Programme (UNEP) provided a range of important analyses and strategy papers in the years leading up to the conference. The green economy concept as such a framework for development was defined by UNEP as

"*a green economy as one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities.*

climate change due to small particles in the atmosphere, due to fossil fuel combustion and due to supersonic systems of transportation (SST).

In its simplest expression, a green economy can be thought of as one which is low carbon, resource efficient and socially inclusive. In a green economy, growth in income and employment should be 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. These investments need to be catalysed and supported by targeted public expenditure, policy reforms and regulation changes. The development path should maintain, enhance and, where necessary, rebuild natural capital as a critical economic asset and as a source of public benefits, especially for poor people whose livelihoods and security depend on nature" (UNEP 2011, 9).

This definition is not in any important respect different from the definition of sustainable development provided by The Brundtland Commission (World Commission on Environment and Development (WCED) 1987) and the documents agreed upon at the Rio summit in 1992, the Rio Declaration and the Agenda 21 (United Nations (UN) 1993). The concept of the *green economy* reflects aspirations to *operationalize* the sustainability principles.

These principles include balances between the present and the future generations, between social, ecological and economic concerns and between global interests and national self-interest. They represent a paradigm shift from the after-war growth model with its overriding priority of the growth production of any kind.

The paradigm shift includes a remarkably broad consensus on *why* a green or sustainable economy is necessary, on *which properties* characterise the green economy and on *how* the process towards a green economy should be governed. Accordingly, the concept of the green economy has an ethical component, a physical component and a governance component.

The ethical component is expressed in the principles of inter- and intra-generational balances. In the words of the Brundtland commission we are able to meet "the needs of the present without compromising the ability of future generations to meet their own needs" and "in particular the essential needs of the world's poor, to which overriding priority should be given" as stated in the conclusion (World Commission on Environment and Development (WCED) 1987).

This ethics "requires that those who are more affluent adopt life-styles within the planet's ecological means - in their use of energy, for example." (World Commission on Environment and Development (WCED) 1987).

The replacement of "economic growth" by "sustainable development" was embraced by the United Nations Conference on Environment and Development (UNCED) in 1992, the Rio Summit. It agreed on 5 documents that had a considerable impact on the development in the following 20 years. The two general documents, The Rio Declaration (United Nations Conference on Environment and Development (UNCED) 1992) and Agenda 21 (United Nations (UN) 1993), laid down the consensus principles of sustainable development and a detailed catalogue of ways to put them into practice. Three conventions provided the framework for the global cooperation on climate change, forests and biodiversity.

The Rio Declaration (United Nations (UN) 1993) similarly states that "The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations." "Environmental protection shall constitute an integral part" of and "eradicating poverty" is "an indispensable requirement for sustainable development" (Principles 3-6).

This “3 dimensional” concept of sustainable development is unfolded in more detail in the Agenda 21 document of the Rio Summit (United Nations (UN) 1993). It contains details on the *social, economic and ecological*[4] dimensions. It is evident from the documents that social progress is *sustainable development* in its three dimensions rather than simply *economic growth.*

The consensus documents emphasise that poverty eradication and the ecological values that the present generation share with future generations are essential components of sustainable development. Thus, it can be inferred that the consensus excludes the principle of economic growth as an overriding priority to which ecological and social concerns necessarily must give way. Practically all governments have adopted the concept of sustainable development as the overarching ambition for society and understanding of social progress. The broad definition of what sustainable development is and what it is not, however, leaves the concept open to a variety of national interpretations.

Since the 1992 Rio summit the EU, its member states and regional authorities have attempted to implement the principles of sustainable development, as have governments around the world. The 2002 UN summit in Johannesburg confirmed the principles of sustainable development and adopted the Johannesburg Plan of Implementation (United Nations (UN) 2002). The green economy can be seen as way to generalise this experience with technologies and ecological responses and institutional frameworks for related information and innovation as well as technical and economic regulation of ecological-economic patterns. In this sense the green economy is the *operationalization* of the principles of sustainable development.

The Rio+20 conference in 2012 recognised the importance of advancing the consensus on the principles of sustainable development towards more operational *goals* for sustainable development (United Nations (UN) 2012). In its final document “The future we want” it defined the “green economy in the context of poverty eradication and sustainable development” as an economy that “should contribute to eradicating poverty as well as sustained economic growth, enhancing social inclusion, improving human welfare and creating opportunities for employment and decent work for all, while maintaining the healthy functioning of the Earth’s ecosystems” (United Nations (UN) 2012, 9). Moreover, the final document emphasises “that fundamental changes in the way societies consume and produce are indispensable for achieving global sustainable development” (United Nations (UN) 2012, 39).

The shift of emphasis from *principles* of sustainable development to the *goals* of a green economy reflects a recognition that the natural environment that we pass on to the future generations depends on the physical structures of the economy we pass on. Future generations that may be twice as numerous as the present cannot preserve the environmental qualities unless they inherit an economy with physical structures that allow satisfaction of material needs without overconsuming nature as source and sink.

The operational setting of goals, objectives and targets is left to the subsequent series of conferences. They will relieve and build upon the results of the

[4] Called ”environmental” and ”Conservation and management of resources for development” in the document, but called ”ecological” to represent ”source” and ”area” as well as ”sink”.

Millennium Development Goals (MDG) and are insofar primarily concerned with the developing and emerging economies. They are also concerned with the transformation of the developed economies. For the EU they are described in the EU Strategy for Sustainable Development and the Europe 2020 strategy for smart, inclusive and sustainable growth. The EU Commission provides an overview of Rio+20 implementation actions in the EU and internationally and includes them in the proposal for the 7th environmental action programme (European Commission 2013n; European Commission 2012a).

The European Commission and UNEP characterize the green economy as "patterns of consumption and production (that) are sustainable and enable all citizens to have access to resources while conserving the quality and quantity of the world's shared resources. This implies primarily the decoupling of economic growth and well-being from energy and resource consumption" (European Commission 2011c). As elaborated in more detail below, the coupling of energy and resource consumption is built-in in the fixed capital stock of infrastructure, buildings, plants, machines, means of transport. Thus, in economic terms, sustainable or delinked patterns of consumption and production is to a high degree a matter of investment.

The transformation of the economies towards a green economy involves investment in new production capacity and new technologies across a broad range of industrial sectors. As a response to the 2008 financial crisis and the ensuing investment crisis and recession, the UNEP and others advocated for a *green new deal*, advancing such investments to break the negative spiral of the crisis and hasten the recovery (Barbier 2009; United Nations Environmental Programme (UNEP) 2009). The EU Commission shared some of these views in its recovery plan from 2008 (European Commission 2008c), but it is, of course, the member states that control the government budgets required for realising the green new deal. The fiscal consolidation strategy from 2011, however, pulled in the opposite direction.

At a ministerial level meeting in 2009, the OECD countries reached a consensus on developing a common response to the dual challenge of their ecologically unsustainable economies and the collapse of the economically unsustainable growth in the preceding years. The following year, an interim report was presented (Organisation for Economic Co-operation and Development (OECD) 2010) and in 2011, the strategy "Towards Green Growth" was published. It explained the need for a green growth strategy: "The world faces twin challenges: expanding economic opportunities for a growing global population, and addressing environmental pressures that, if left unaddressed, could undermine our ability to seize these opportunities" (OECD 2011a).

According to the accompanying report on green growth indicators "green growth is about fostering economic growth and development while ensuring that the 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" (OECD 2011b).

The United Nations Division on Sustainable Development (UNDESA) has reviewed 50 similar publications and 32 national strategies on the green economy, green growth and a low-carbon economy. The definitions on a green economy differ considerably, but they share some common elements:

"**Social:** Human well- being; social equity; socially inclusive; reduced inequalities; better quality of life; social development; equitable access; addressing needs of women and youth.
Economic: Growth in income and employment; public and private investments; resilient economy; economic growth; new economic activity.
Environmental: Reducing environmental risks and ecological scarcities; low carbon; resource efficient; reduce carbon emissions and pollution; enhance energy and resource efficiency; prevent loss of biodiversity and ecosystem services; within ecological limits of the planet; environmental responsibility; finite carrying capacity" (Division for Sustainable Development (UNDESA) 2012, 60).

It is important to note that in all definitions of "sustainable development" and "green economy" the economy should "contribute to" or "ensure" progress in a range of dimensions *simultaneously* or at least in parallel in the long run. None of the definitions use the word "or" when listing the functions that a green economy should be able to deliver. Thus, the it is fair to conclude, that sustainable development and progress towards a green economy is generally perceived as simultaneous progress in all three dimensions – economic, ecological and social.

There are more institutional frameworks and societal conditions that are often brought into the discourse on a green economy. They include broader goals such as peaceful international relations and a highly developed democracy with comprehensive citizen participation. These aspects are, however, beyond the scope of this report.

The above definitions depict a shared vision of a 21st century green economy. It can be inferred that unlike the typical industrial economy of the 20th century, the green economy is *inclusive* and able to *prosper without over-consuming* the sink, resource and space budgets provided by nature. This is only possible if its system of fixed capital and supply chains (the econosphere) is designed for minimizing the consumption of the resources, sinks and spaces of nature.

This does not in any important respect differ from the principles of sustainable development agreed upon in the documents of the Rio Summit in 1992. On the contrary, the concept of the *green economy* reflects the *operationalization* of the sustainability principles. These principles include balances between the present and the future generations, between social, ecological and economic concerns and between global interests and national self-interest.

3.3. "Green economy", "green growth" and "greening the economy"

The concepts of *green economy*, *green growth* and *greening the economic policies* are used interchangeably in the literature and in the public debate. This is no wonder since they are not scientific concepts with clear and unambiguous definitions. Based on the review of literature, policy documents and the policy process itself, the following definitions seem to follow the logic established in policy discourse as well as in the scientific literature.

A *green economy* is an economy that is able to *prosper without over-consuming* in any of the economic, ecological or social dimensions.

The notion of overconsumption requires a *budget*. The budgets in each dimension are politically defined, but should – as far as possible – be science based. They are defined for the economy as a whole, that is, at the macro level (EU, national or regional). The economic bubble leading up to the financial crisis in 2007 is a

recent example of the unsustainability of over-consumption in the economic dimension.
The throughput economy of the 20th century is not able to prosper without over-consuming the source, sink and space budgets of our environment.

Progress in the social dimension is mainly about inclusion. Equal rights is central in the self-perception of what it is to be European and the European welfare states have with varying degrees of success pursued equal opportunities for all. Still, large groups of the European societies are detached from the formal economy or marginalised by poverty, discrimination, severe unemployment and inadequate access to health, education and social services. Obviously, the problem of inclusion also have a strong link to the economic dimension: The share of the population that is in risk of being marginalised is also a risk to society to fail to obtain its contribution to the value created by society. Inclusion, on the other hand, is obtained by investment in human resources of the population at risk of marginalisation. In this economic sense, marginalisation reflects under-utilisation of human resources and inclusion reflects the successful investment in human resources.

The *green transformation* is the transformation of the econosphere and its sectors to a green economy.

If the green economy of the 21st century is structured differently from the throughput growth model, then there must logically be a transformation of the latter to the former. An economy in ecological balance requires a different econosphere with flows of renewable energy instead of fossil (and in some countries nuclear) energy, flows of substances with low instead of high environmental impact, recycling rather than flows through the econosphere, reforming the use of land designated to economic and nature purposes and other transformations of the physical structures.

***Green growth* is pursuing green solutions as business cases.**

It is innovation in firms and the diffusion of these innovations among users and development of institutional frameworks that are conducive to green innovation and diffusion. The transformation of the economy as a whole to a green economy requires green growth in a sufficient amount of sectors to eliminate over-consumption at the overall economy scale. But green growth in one sector does not necessarily mean that the rest of the economy is reducing its overconsumption. Thus green growth can occur even if the economy is not as a whole transforming to a green economy.

***Greening institutions and policies* refers to the changes in institutions and policies enabling and driving green transformations and green growth.**

The definition of budgets, targets and timetables is fundamental for effective policies. For the private sector, governments establish institutions as frameworks for the economic activities. Institutions such as the Common Agricultural Policy (CAP) or the tax system are being reformed to structures that support green growth and green transformations. Governance principles of institutions with a transformative purpose such as those established by the renewable energy directive are adapted and improved. For the public or tax financed sector, governments decide directly upon what to produce, consume or invest in. Greening of the institutions of the economy thus includes public investments and physical planning for a green econosphere as well as development of institutional frameworks for private investments and innovation in a green econosphere.

In the scientific report, it is found expedient to distinguish between "green economy", "green growth" and "greening the institutions of the economy" as defined above because they refer to different ontologies or objects of change. In the public debate, however, "green economy" is often used as an all-embracing concept including all of the above as well as green perceptions of and attitudes towards the relation between the economy and nature. Thus, the studies in volumes 3-5 use the latter definition.

3.4. EU and the green economy

The understanding of social progress as a multidimensional development including sustainable balances in the ecological and social as well as in the economic dimensions is reflected in the Europe 2020 strategy (European Commission 2010c). GDP growth is not a target, but targets are set for the prerequisites for GDP growth - education, R&D and competitiveness. In the social dimension, poverty reduction and the rate of employment are targets. In the ecological dimension, the headline targets are the 20-20-20 targets of the energy and climate policy package of 2009 and the strategy includes a flagship initiative on resource efficiency as well.

The dimensions are overlapping. Resource efficiency has crucial effects on competitiveness and education is the main key to poverty reduction and a higher employment rate. A high rate of employment makes an economy more capable of financing the investments needed to reach the other targets.

The flagship initiative on resource efficiency is an umbrella for the main processes of econosphere transformation that needs coordination on the EU level. The roadmap for the flagship initiative *Resource Efficient Europe* is a comprehensive catalogue of changes towards circular flows of materials and energy, elimination of waste in resource use and containment of environmentally harmful flows in closed systems (European Commission 2011e; European Commission 2011f; European Commission 2011g). It explores the technical and economic feasibility of various ways to a green economy – along with various conceptions of a green economy.

The green economy is described in the roadmap as follows: "The Vision: 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" (European Commission 2011e, p10).

The flagship initiative focuses on selected sectors of the economy where EU coordination of the green transformations is required. They include the energy sector, the transport sector, other final energy use, agriculture and fisheries (and the related bio-economy), biodiversity and water.

4. Analysing social progress

4.1. GDP as a measure of well-being

One of the rising concerns in the 60s was the rising social costs, which were associated with the economic growth, but not accounted for. This theme was addressed early in the Great Debate and it was pointed out that GDP is poor measure of economic progress because these costs are unaccounted for and their growth may even outpace economic growth (E.g., Mishan 1971).

One of the first and most comprehensive attempts to quantify these costs and adjust the GDP to a more informative measure of economic progress was the study by Nordhaus and Tobin on the question of whether growth had become obsolete (Nordhaus and Tobin 1972). Recognising that GDP is a poor indicator of general well-being and even of economic well-being, they decomposed it into components, which were directly related to human well-being and components that were not. The positive impact of household activities was added to the former and the negative impact of urbanisation was subtracted. The result was a Measure of Economic Well-being (MEW), which, however, could not confirm the suspicion that the social costs of economic growth outweighed the benefits. It turned out to develop in parallel with GDP.

Daly (Daly, Cobb, and Cobb 1994) explained the parallel development by the missing social dimension of the index. Including a measure of inequality in an "Index of Sustainable Economic Well-being" with a weight of 50% produced a much different development. Whereas there is no doubt that social balance is an important component of social progress, it is difficult to find a scientific basis for the weight and the index.

Another observation that questioned the use of GDP as an overall measure of social progress was the *Easterlin paradox* (Easterlin 1973). Easterlin found that the average feeling of happiness as revealed by regular happiness surveys did not follow GDP. Surveys studying such broad questions such as the respondents' feeling of happiness can be subject to serious framing bias, but the Easterlin paradox was confirmed by several studies in the following decades.

Such considerations provided the background for the consensus on sustainable development as a strategy for economic development and as a conceptual framework for indices of social progress. The most extreme versions of the alternative frameworks for social progress that were propagated in the growth and environment debate of the 1970s and 1980s can be characterised as "maximum economic growth at all costs" and "zero growth for conserving ecological values". They represent a dilemma in the choice of strategy that is rejected by the sustainable development concept. The national accounts framework with its income and production aggregates is clearly insufficient to reflect social progress or sustainable development as defined above.

4.2. Adjusting and synthesizing indices

Against this backdrop, several attempts have been made to develop better measures of social progress. The EU Commission has engaged in this work with a comprehensive set of initiatives (European Commission 2013a; European Commission 2013b; European Commission 2013c; European Commission 2009a) and has commissioned the Stiglitz-Sen-Fitoussi-report on the issue (Stiglitz, Sen, and Fitoussi 2009).

The Commission provides a compilation of indices developed to satisfy this need for better measures of social progress. The indices comprise indicator frameworks on the three dimensions – economic, ecological and social – and attempts to integrate the three dimensions in aggregate well-being measures. The well-being indicators can be categorised in four groups.

Indicators of *well-being relevant consumption opportunities of the present* take departure in the gross national income and adjust it for fixed and natural capital consumption, defensive expenditure etc much along the lines set out for the MEW and ISEW above (Daly, Cobb, and Cobb 1994; Nordhaus and Tobin 1972).

Indicators of changes in the *productive capacity of the future* involve the balance between savings, investments in human capital and the use of man-made and natural capital. These indicators follow the capital stock approach operationalizing the sustainability concept in a way similar to portfolio management. The adjusted net savings approach below belongs to this group of indicators (The World Bank 2011).

Indicators of *poverty and exclusion* of groups of society from the private consumption opportunities, public services and ecosystem services are important for assessing the actual well-being impact of larger consumption opportunities. The shares of the population at-risk-of-poverty, severely materially deprived citizens, long-term unemployed and low educated citizens indicate the result of marginalisation mechanisms. Income and wealth inequality measures can indicate the share of the population that is included in the economic growth.

Indicators of *subjective well-being* are derived from surveys of happiness and satisfaction. Time-use studies with values of well-being assigned to the various categories of time use also represent an approach to quantify subjective well-being.

Composite well-being indices attempt to combine the above indicators in a single dimension measure of economic or overall well-being. The Human Development Index (HDI) and the Human Poverty Index (HPI) discussed below are prominent representatives of this class of indicators.

4.3. Human development index and Human Poverty Index

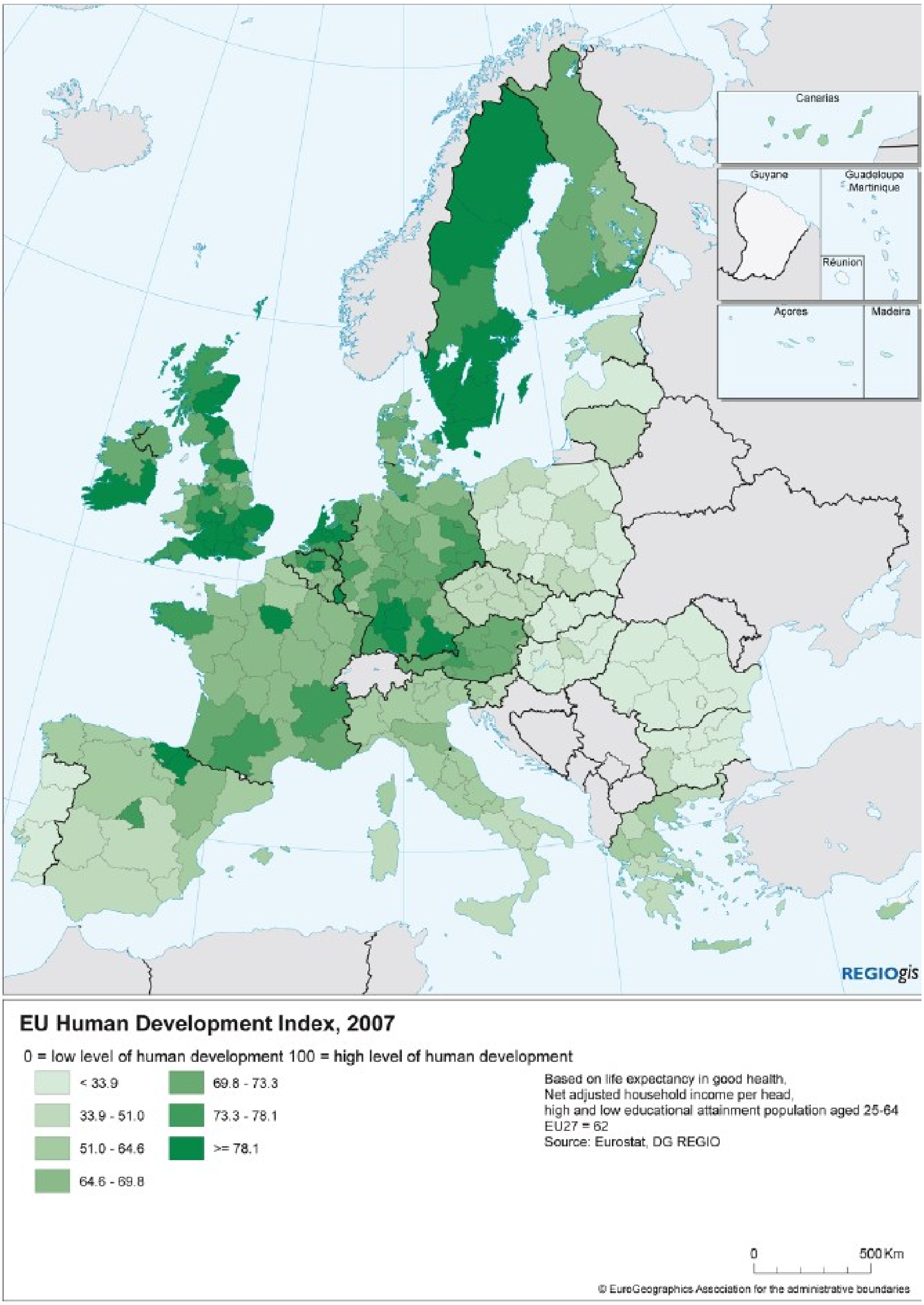
The United Nations Development Programme (UNDP) has published a series of human development indices on health, education and income levels of almost all countries since 1990 (United Nations Development Programme (UNDP) 1990). The annual publications also ranks countries according to an aggregate Human Development Index in which the three sub-indices for health, education and income enter with equal weights.

The HDI is computed as the geometrical mean of the three indices with equal weights, that is,

$$\text{HDI} = \text{Longevity index}^{(1/3)} * \text{Education index}^{(1/3)} * \text{GNI per capita index}^{(1/3)} \quad (1)$$

From 2010 onwards the formulas for calculation of these sub-indices have been revised. In particular, the education index was formerly composed by indices of literacy and enrolment, but from 2010 by years of schooling.

The index has been calculated for European NUTS2 regions with indices of low and high education. The result is shown in map 1.

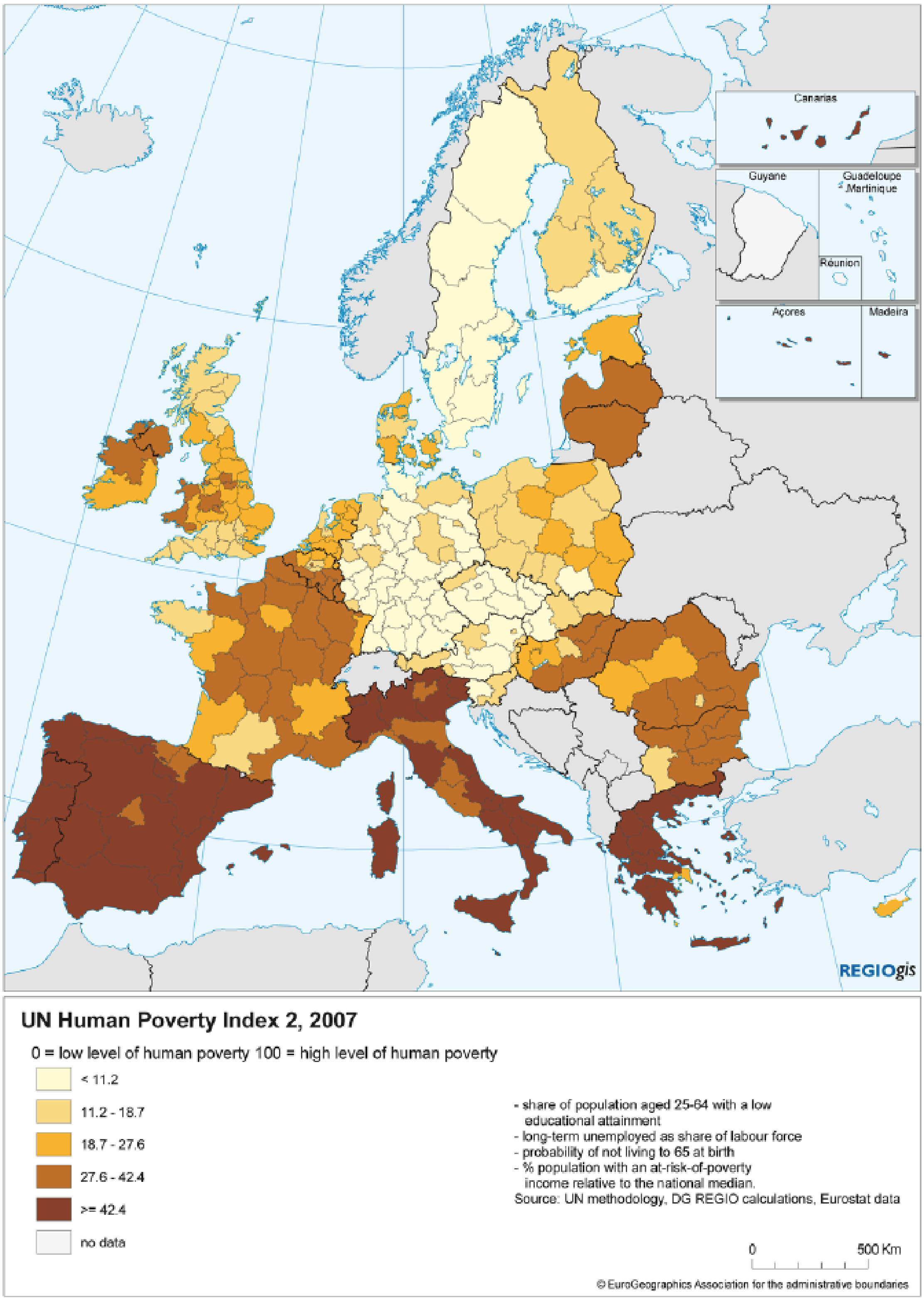


Map 1. Human Development Index (HDI) by NUTS2-regions, 2007.
Source: (Bubbico and Dijkstra 2011, p4)

The regional patterns of the HDI share similarities with the regional patterns of GDP or GVA per capita and derived indicators. This is because the HDI is composed by a GNI per capita index and indices of education and life expectancy that are closely correlated with GDP per capita.

It is important to note that different regions of an economy have different potentials for achieving a high HDI. Metropolitan regions host universities, head quarter functions of corporations and similar government functions and all kinds of specialised services that require highly educated staff. This is not the case for rural and peripheral regions. Thus, it is neither expectable nor socially desirable that rural and peripheral regions should score as high as metropolitan regions in education and income level. Thus, for providing information of how a region performs, the HDI index of a region should be related to its potentials and should be compared to peers by the individual sub-indices.

The HDI does not reflect economies with strong social exclusion processes. The UNDP has developed a Human Poverty Index (HPI) for this purpose and it has been calculated for European NUTS2-regions. The result is shown in map 2.



Map 2. Human Poverty Index 2 (HPI2) of NUTS2 regions, 2007.
Source: (Bubbico and Dijkstra 2011, p5).

The HPI2 for NUTS2-regions is composed by indices of longevity, low education, share of population with income less than 60% of the median and the long-term unemployment. All of these four sub-indices are assigned the same 25% weight. Map 2 reveals patterns that are to some degree similar to those of map 1. This is not surprising as the two indices share two sub-indices and as the other two sub-indices are correlated with GDP per capita. However, the pattern of "trade-off" between the HDI and the HPI2 differs between the new member states (NMS10) and the EU15. At a given HDI value, the NMS10-regions have much lower HPI2 values than the EU15 regions (Bubbico and Dijkstra 2011).

4.4. Composite indices

The HDI and HPI2 indices do not include sub-indices reflecting the ecological dimension, but they highlight the problem of weighting in composite indices.

The mathematics of composite indices inevitably involves weights assigned to the individual indices. In some cases, the sub-indices are assigned equal weights because there is no empirical basis for assigning a specific weight. In these cases, however, a specific weight is assigned like 1/3 in equation (1) above. Thus, assigning equal weights is not the same as assigning no weights, but assigning random weights, depending on the number of sub-indices in the calculation.

This has important consequences for the impact of changes in the sub-index on the composite index. This is because the weights are relative prices, terms of trades for changes in the sub-indices. In the case of equation (1), a one-point change in one sub-index like longevity can be offset by a one-point change in the education index.

There are two problems with this method. First, it assumes that decline in one index can be offset by progress in one or more of the other indices. In equation (1) any decline in the health and education indicators can be offset by a higher GNI and still show a higher level of human development. Second, even if such substitutability is warranted the "exchange rate" between the indices is arbitrary. If nothing else is known about the importance of progress in health vs education vs income, it is most likely not constant, but changes over time and by region and country. A more in depth analysis of the implicit price on health and educational standards is provided by (Ravallion 2010).

The concept of sustainable development reflects a consensus on progress in all three dimensions – not in one dimension at the cost of decline in another dimension cf. section 3.2. Economic growth at the cost of important ecological values that we share with future generations would not meet this criterion for sustainable development or social progress. Economic growth without poverty eradication would not be social progress either. A composite index can reflect developments where progress in one dimension can offset decline in another, but not sustainable development.

In cases where different sub-indices reflect the same development and run in parallel, they can be combined to composite indicators. This is, for instance the case for indicators of consumer confidence and for innovative activity. This is particularly useful if there are data gaps or delays in some of the sub-indices.

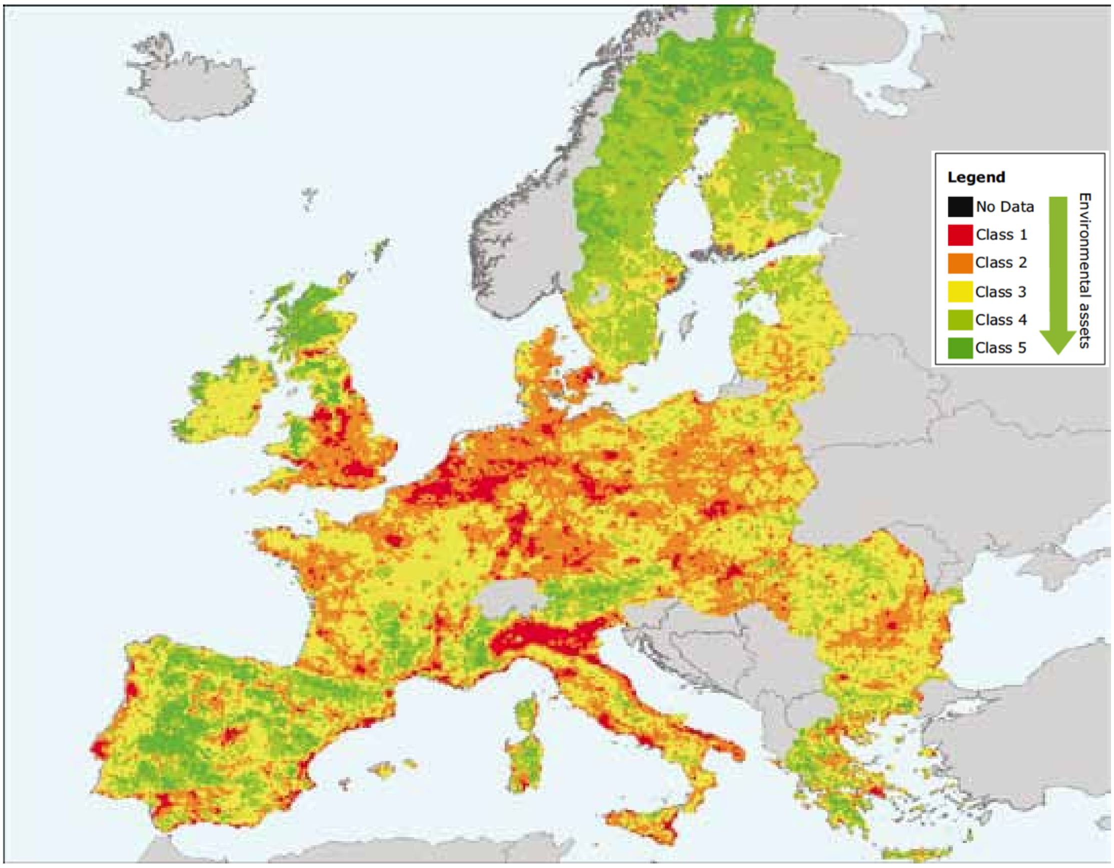
In cases where substitution between the sub-indices is warranted, the appropriate weights must reflect the values and the importance of progress in the sub-indices as assessed by the users. The OECD has developed a "Better Life Index" where each user has to set her own weights to 11 sub-indices (Organisation for Economic Co-operation and Development (OECD) 2013). Operationalizing such solutions for policy decisions in a regional context would require continuous collection of poll data from a representative sample of the citizens of the region on the relative importance of the sub-indices. This would probably involve difficulties as many citizens may lack the mathematical skills required for assigning weights to a large set of indices.

4.5. Composite environmental index

Another attempt to contribute to a broader understanding of social progress is a measure of environmental quality developed in the framework of an EEA project (EEA 2011). It includes 5 sub-indices:

(1) FARO — EU Rural typologies
(2) High Nature Value farmlands;
(3) proximity to natural areas (CLC semi-natural classes, N2000, CLC water);
(4) PM10 (air quality);
(5) degree of soil sealing

Based on these indices, a map of a composite index on environmental assets is produced.



Map 3. Composite environmental asset index.

Source: (EEA 2011).

The map in map 3 shows a spatial pattern similar to the pattern of population density. This is because air pollution and the degree of soil sealing are positively correlated and nature and farmland negatively correlated with population density.

If such an index was used operationally by assigning targets to the composite index, then a region would show progress towards a green economy even if the number of premature deaths due to air pollution was increasing as long as the share of farmland classified as "high nature value" was also increasing. This would be in conflict with the fundamental policy principle of EU environmental policy that rejects not accept "significant negative impacts on and risks to human health and the environment" (European Commission 2002b) regardless of the landscape qualities in other parts of the region or country.

4.6. A multidimensional indicator framework

Compared to a composite index, a multidimensional indicator framework provides a more informative framework for policy decisions on the transformation of economies to green economies. Some statistical material is available at the regional level and is reviewed in the following. There is, however, not any scientific basis for assigning constant weights to the individual indicators. If weights are derived from running opinion polls, they must be expected to change according to the shifting challenges of to the economy and the corresponding shifts in political priorities. That would, however, complicate the interpretation of changes in the index over time.

With the above definitions on a green economy, social progress means achieving progress simultaneously in all three dimensions – economic, social and ecological. It is not about progress in one dimension at the cost of decline in another dimension. This is challenging - in particular in the ecological-economic nexus where the 20th century economies were characterised by trade-offs between environmental qualities and economic growth.

In the social-economic nexus, it is not as challenging to achieve synergies because economic growth often provides opportunities for the poor to work themselves out of poverty and leave the "vicious circles" of poverty. This is, however, not automatically ensured if growth is not inclusive. Investment in human resources is needed for including otherwise marginalised groups of the population.

The multidimensional framework has also been the preferred framework for statistical indicators on sustainable development used by the EU Commission (European Commission 2013d), the EEA (EEA 2012) and the green growth indicators used by the OECD (OECD 2011b). The EU indicator framework further differentiates between "headline" and other indicators.

5. Sustainability indicators in the EU

Progress towards a green economy is to some extent mainstreamed into the programmes for economic development at the various territorial levels. At the EU level a comprehensive set of sustainable development indicators have been developed. More than 100 indicators are used to monitor whether the development is sustainable and progressing towards a green economy. 11 of these indicators have been selected as headline indicators. They are shown in Table 2.

Table 2. EU Sustainable Development headline indicators

Theme	Headline indicator
Socio-economic development	Growth rate of real GDP per capita
Sustainable consumption and production	Resource productivity
Social inclusion	People at-risk-of-poverty or social exclusion
Demographic changes	Employment rate of older workers
Public health	Healthy life years and life expectancy at birth, by sex
Climate change and energy	Greenhouse gas emissions Share of renewable energy in gross final energy consumption
Sustainable transport	Energy consumption of transport relative to GDP
Natural resources	Common bird index Fish catches taken from stocks outside safe biological limits: Status of fish stocks managed by the EU in the North-East Atlantic
Global partnership	Official development assistance as share of gross national income
Good governance	No headline indicator

Source: (European Commission 2013d).

The *headline* indicators shown in table 2 reflect some of the high priority aspects of sustainable development, but beneath each of them a large body of sub-indices are calculated for monitoring the field.

The 10 broader fields for action are encompassing the economic, social and ecological dimensions of social development. The dataset enables a policy process informed about whether progress takes place in all three dimensions, which is required for the development to be sustainable. Moreover, it allows monitoring and analysis of the physical flows and production machinery in the material part of the economy as well as the impact of environmental and social living conditions on our quality of life.

Individual governments as well as the United Nations, the OECD and other organisations have developed similar datasets with the same intentions under the headline of "sustainable development" or "green economy". These datasets are highly overlapping, but they have also inspired the GREECO project.

This orientation has been further sharpened in the set of targets of the Europe 2020 strategy. It pursues growth that is smart, sustainable and inclusive and supported by reforms of economic governance. A leaner set of *headline targets* quantify these overall priorities:

1. **Employment:** 75% of the 20-64 year-olds to be employed
2. **R&D / innovation:** 3% of the EU's GDP (public and private combined) to be invested in R&D/innovation
3. **Climate change / energy:** greenhouse gas emissions 20% (or even 30%, if the conditions are right) lower than 1990, 20% of energy from renewables and 20% increase in energy efficiency
4. **Education:** Reducing school drop-out rates below 10%, at least 40% of 30-34–year-olds completing third level education

5. **Poverty / social exclusion:** at least 20 million fewer people in or at risk of poverty and social exclusion

The instruments and targets relating to **economic governance** are mainly laid down in agreements such as the stability and growth pact and the recent fiscal compact.

It is worth noting that the smart, sustainable and inclusive growth is not measured in euros, but in employment, education, innovation and competitiveness. This must be seen as the logical inference from the broad consensus about replacing *GDP growth* by *sustainable development* as the overarching societal goal. As in all government programmes, the exact targets and goals can be debated as well as the adequacy of the instruments engaged to reach the targets.

The EU flagship initiative on resource efficiency points to Resource Productivity as a provisional lead indicator. It is, however, recognised that it is a very crude indicator measuring flows in tons rather than by their ecologically harmful potential. Thus, it must be supplemented with a host of other indicators.

The Europe2020 headline targets constitute an important starting point for regional indicators on the green transformations of the economy. They are differentiated across member-states according to their national level priorities and would be even more differentiated at the regional level. The intention of the GREECO project, however, is not to develop exact targets for regional development.

The goals and priorities at sub-national territorial levels are formulated in the Territorial Agenda 2020 (TA2020).

The TA2020 objectives include:

1. Promoting **polycentric** and balanced territorial development
2. Encouraging **integrated** development in cities, rural and specific regions
3. Territorial integration in **cross-border** and transnational functional regions
4. Ensuring global **competitiveness** of the regions based on strong local economies
5. Improving territorial **connectivity** for individuals, communities and enterprises
6. Managing and connecting **ecological, landscape and cultural values** of regions

These objectives are not operationalized in specific targets, but they add territorial dimensions to the economic development pursued in the Europe 2020 strategy.

The development of cross-border cooperation around the Baltic Sea and the river Danube, for instance, are highly focused on coordinating investments in the natural capital of these regions and safeguarding the environmental qualities shared by them.

The Common Strategic Framework (CSF) for the EU structural funds was developed through 2012. It aims at concentrating the investment efforts of the structural funds in the following fields:

1. Strengthening research, technological development and innovation;
2. Enhancing access to, and use and quality of, information and communication technologies:

3. Enhancing the competitiveness of small and medium-sized enterprises, the agricultural sector (for the EAFRD) and the fisheries and aquaculture sector (for the EMFF);
4. Supporting the shift towards a low-carbon economy in all sectors;
5. Promoting climate change adaptation, risk prevention and management;
6. Protecting the environment and promoting resource efficiency;
7. Promoting sustainable transport and removing bottlenecks in key network infrastructures;
8. Promoting employment and supporting labour mobility;
9. Promoting social inclusion and combating poverty;
10. Investing in education, skills and lifelong learning;
11. Enhancing institutional capacity and an efficient public administration

The Common Strategic Framework aims at aligning the allocation of structural funds with the overall Europe 2020 objectives. Allocating investments following such priorities is likely to generate progress along the headline targets of Europe 2020. The role of the structural funds and the Cohesion funds in the green transformations could be further strengthened if the future budget includes the proposed earmarking of 20% of the budget for climate action.

The allocation of funds along these lines is followed up by a set of monitoring prescriptions. The member states are to establish performance frameworks for each priority for the years 2016 and 2018 and targets established for 2022.

"Milestones are intermediate targets for the achievement of the specific objective of a priority, expressing the intended progress towards the targets set for the end of the period. Milestones established for 2016 shall include financial indicators and output indicators. Milestones established for 2018 shall include financial indicators, output indicators and where appropriate, result indicators. Milestones may also be established for key implementation steps." They must be

- "relevant, capturing essential information on the progress of a priority;
- transparent, with objectively verifiable targets and the source data identified and publicly available;
- verifiable, without imposing a disproportionate administrative burden; and
- consistent across operational programmes, where appropriate."

Based on the above indicators, the EU Commission has developed a selection of performance indicators for monitoring the performance of member-states compared to the EU average and the lowest and highest value of the indicator in the EU (European Commission 2013e).

A similar set of indicators could be developed for regions, but it is important to recognise the fundamentals of regional economics. Whereas, national economies typically embrace all or most of the spectrum of products and services, skills and organisations, natural resources and infrastructures, this is not the case for NUTS2 regions and definitely not for NUTS3 regions. Regional economies are typically more specialised than national economies. They are even organised in hierarchies where the highest earning specialists tend to locate in and around metropolitan agglomerations.

Thus, far from all regions have the potentials of being among the top performers in all "disciplines" and it would not even be socially desirable. Achievements in resource efficiencies, renewable energy production etc. should thus always be seen in relation to what it is possible to achieve. This point will be elaborated in the review of various indices below.

6. Economic, ecological and social balances

6.1. Budgets and overconsumption

The notion of "balance" in all three dimensions is key to measuring the "state of sustainability" or how "green" an economy is. Lending from the vocabulary of economic accounting, keeping a long-term balanced *budget* is the indispensable condition for an economic activity to be viable. That is, the resource use must be financed. If there is a deficit in one year, it must be balanced by a surplus in another year. Otherwise, the deficits can only go on until the wealth or capital is gone or as long as some outside donor wants to finance the activity. This is the basic condition for the economic viability or financial sustainability of firms and projects as well as households and governments.

A household *over-consumes* when it spends more than its budget and thus generates a deficit. This goes for firms and governments as well. It is the core of the economic perception and measurement of sustainability and viability. It is the approach used to define the fiscal sustainability of government and the robustness of financial institutions in the attempts to restructure the financial circuits in Europe after the financial crisis.

This simple kind of metric is useful in analysing ecological sustainability as well.

Resource budgets are well known in renewable resource management. A fish resource is not sustainably managed if more fish is harvested than the fish population can regenerate. The source budget depends on the natural regeneration. In the case of non-renewable resources, the consumption of natural assets is mirrored in a compensating budget for investment in man-made assets.

The sink-function of nature is over-consumed or over-used if the impacts on human and ecosystem health lead to losses of ecological qualities that are unacceptable. In any case, nature provides a potential or "budget" for its economic use as source, sink or area. Using nature beyond the potential use means that natural assets are ultimately lost. It compromises the ability of future generations to meet their needs.

In defining the sink budget, a key challenge for regional as well as national government is to distinguish between acceptable trade-offs and unacceptable ecological losses. The unacceptable ecological losses are politically defined as, e.g., depleted ozone layer, global warming more than 2°C and exposure to pollution in excess of the adopted limit values. A number of scenarios are possible within such budgets limits. E.g., the installation of technical plants in a natural landscape often makes the landscape less attractive. This includes wind-turbines and high voltage transmission lines. In some cases, the loss of landscape values would be unacceptable whereas in other cases the loss of landscape qualities in one location can be offset by other land-use changes making the landscape more attractive and by restoration of landscape qualities in other locations. In these other cases, ecological losses are acceptable if adequately compensated by investment in other assets.

In the United Kingdom, the Climate Change Act of 2008 provides the stable long-term framework for a transformation of the economy by providing 4-year CO_2-emission budgets. Other countries consider similar institutionalisation and official recognition of the scarcity of the environmental capacity as a sink. It has also been suggested as a framework for a global climate agreement (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen (WBGU) 2009).

A land resource is not sustainably managed if it allocates more land to economic purposes - and thus less to the natural ecosystems - than required to maintain the desired level of biodiversity. The land budget available for economic activities is limited by the areas required for sustaining healthy populations of species and natural ecosystems.

Progress in the social dimension cannot be reduced to a zero sum game of taking from the rich and giving to the poor. In the long run, it is about including groups of society that otherwise were at risk of being marginalised or even isolated from the formal economy. The use of national income for investing in human capital – education, health, welfare – also affects the rate of participation of the population in the economy and the productive potential of participating population. Under-investment in human capital is the flipside of overconsumption of consumption goods.

Key balances important for the green economy include:

- *Ecological balance*: Potential (sustainable) vs. actual use of nature as source, sink and area for economic activities.
- *Economic balance*: Consumption opportunities vs consumption (=savings requirements vs savings) of the economy and public budget balance
- *Social balance*: Marginalisation vs inclusion of population groups and investment in future inclusion

It is important to note that the balance requirements concern relevant time scales as well as. Public budget deficits are for instance necessary for stabilising economic development during recessions. How ever, they do have to be reversed to surpluses at some time. Ecosystems are resilient and able to absorb and recover from temporary shocks, but not necessarily from a perpetual environmental pressure.

7. Ecological balances and budgets

7.1. Tropospheric air pollution budgets

The environmental living conditions are important to a broader concept of well-being than the consumption opportunities measured by, e.g., GDP per capita. Among these are concentration rates of particulate matter, ozone, heavy metals, acidification and eutrophication.

Pollutants often have more than one adverse effect and often work together in causing environmental damage. Important air quality pollutants include ozone (O_3) and particulate matter (PM) (respiratory disease) and ozone has negative effects on vegetation and on the durability of some materials. Nitrogen oxides (NO_x) from fossil fuel combustion as well as from agriculture cause eutrophication and acidification – terrestrial as well as aquatic - along with SO_2 pollution. Acidification causes materials erosion as well.

The EU has introduced limits for tropospheric air pollution. They are based on the long term ecological balance of the EU economies with the atmospheric environment expressed in the environmental action programme objective of "achieving levels of air quality that do not give rise to significant negative impacts on and risks to human health and the environment" (European Commission 2002b). This ecological balance principle is measured by the distance of the air quality to certain limit values (European Commission 2008b). They are maximum values for significant negative impacts that are considered safe or intermediate maximum values in a longer-term transition to safe limit values. They are often higher than the limit values recommended by the WHO.

Based on the considerations of the distance to these values and the time span over which ecological balance is to be achieved, it is possible to set national emission ceilings for SO_2, NO_X, NMVOC and NH_3 that are compatible with the limit values. For most countries, notably some the new member states, there is a wide margin from the emission levels to the ceiling. This follows two decades of dramatic reductions of emissions of these pollutants in the EU15 countries and is partly explained by the economic recessions since 2008.

Table 3. Deviation of emissions in 2011 from national emission ceilings 2010. Per cent (negative = ceiling above emission).

	NH3	NMVOC	NOX	SO2
Austria	-6%	-21%	40%	-53%
Belgium	-9%	-28%	19%	-44%
Bulgaria	-55%	-46%	-53%	-54%
Cyprus	-43%	-31%	-9%	-46%
Czech Republic	-18%	-34%	-21%	-36%
Denmark	-1%	-6%	-1%	-75%
Estonia	-64%	-32%	-41%	-27%
Finland	20%	-16%	-9%	-48%
France	-14%	-30%	24%	-32%
Germany	2%	1%	23%	-14%
Greece	-16%	-39%	-14%	-50%
Hungary	-28%	-27%	-35%	-93%
Ireland	-6%	-21%	9%	-44%
Italy	-7%	-11%	-5%	-56%
Latvia	-71%	-49%	-48%	-97%
Lithuania	-65%	-25%	-54%	-75%
Luxembourg	-31%	4%	338%	-56%
Malta	-48%	-75%	-2%	-12%
Netherlands	-7%	-22%	0%	-33%
Poland	-42%	-19%	-3%	-35%
Portugal	-48%	-2%	-30%	-71%
Romania	-24%	-32%	-49%	-64%
Slovakia	-38%	-51%	-35%	-38%
Slovenia	-16%	-25%	-1%	-60%
Spain	8%	-10%	10%	-33%
Sweden	-9%	-26%	-2%	-56%
United Kingdom	-2%	-37%	-11%	-35%

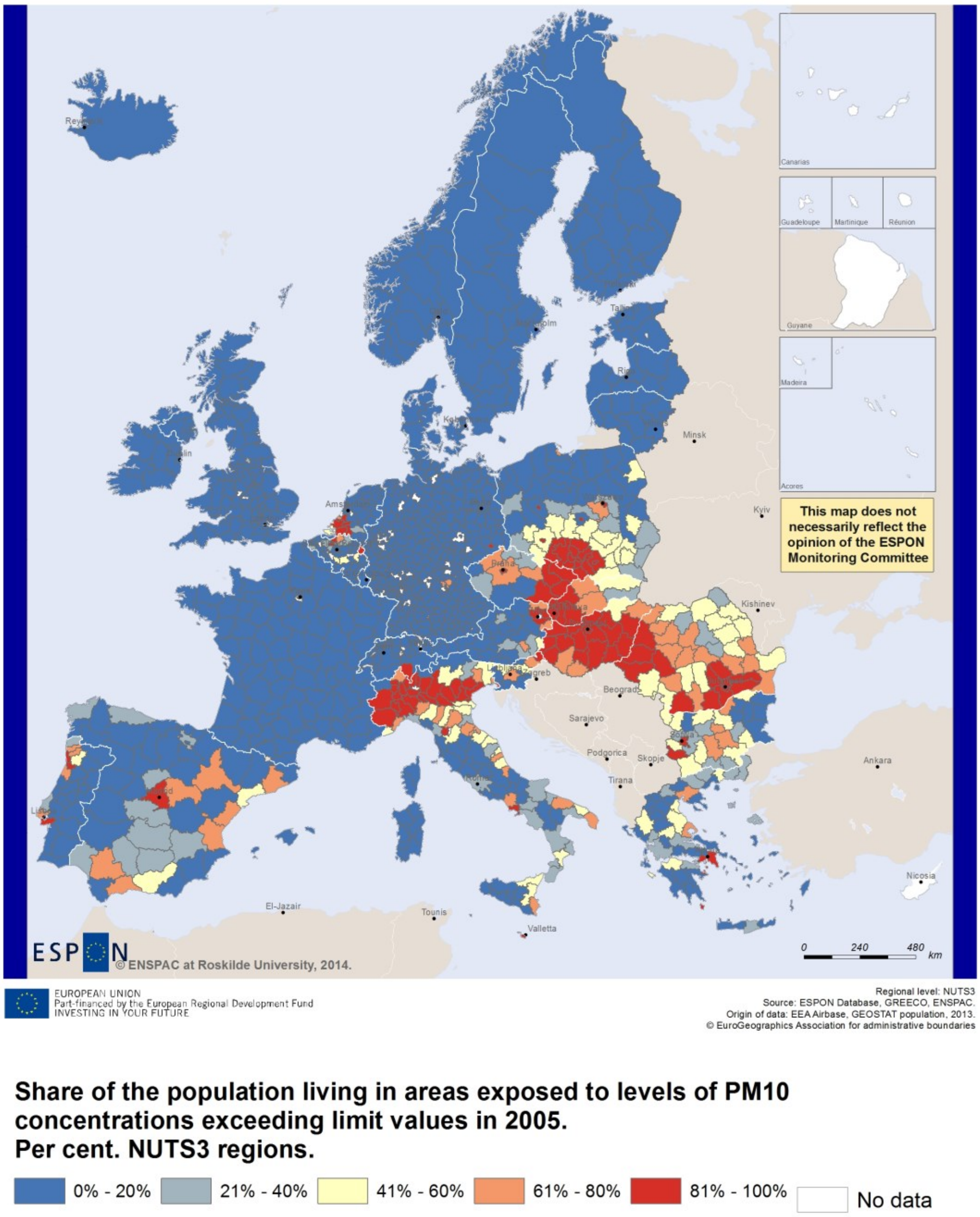
Source: Author's calculations based on the EEA emission data viewer (European Environment Agency (EEA) 2013a).

Despite dramatic reductions of emissions through the recent decades, the pollution problems generated by these emissions persist in parts of Europe.

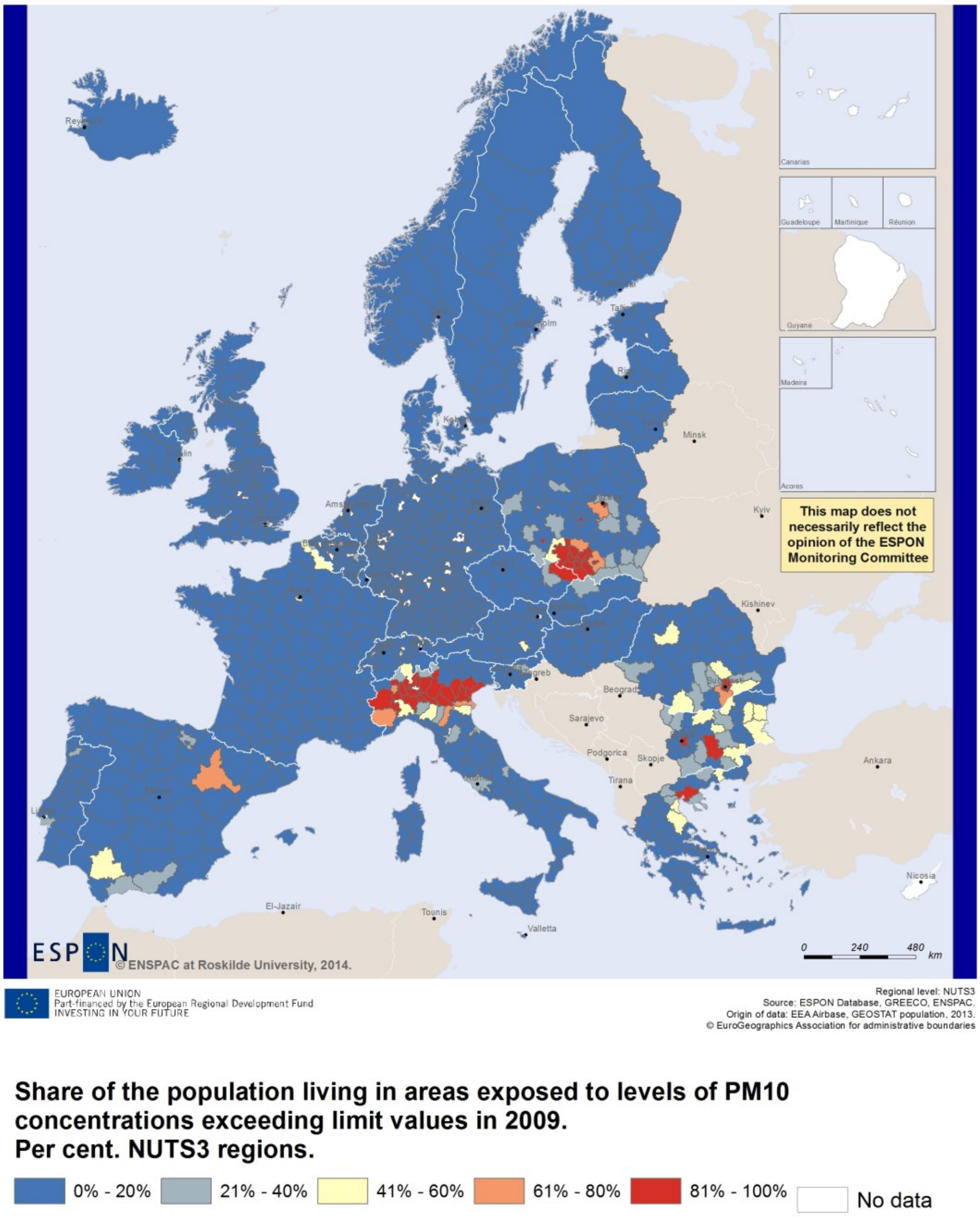
The European environmental policy has particular focus on the pollution with particles and ozone. The GREECO project processed the data from the monitoring network by the European Environmental Agency (EEA) in cooperation with the

Dutch institute NERI. Based on these results it was possible to estimate the share of inhabitants in NUTS3 regions that have been exposed to pollution beyond safe levels in 2005, 2009 and 2010.

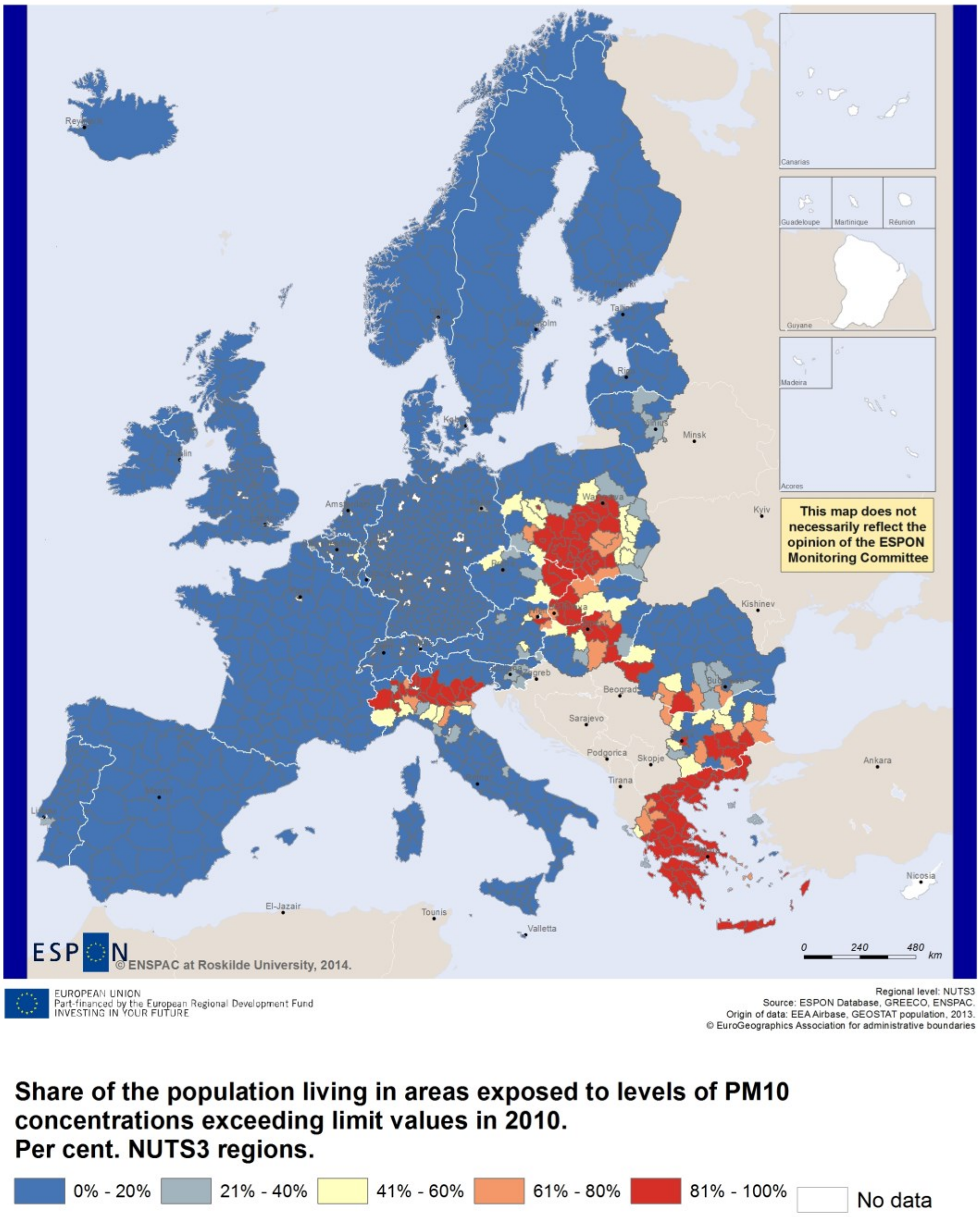
The spatial patterns of the problem with PM10 pollution (concentration of particulate matter with a diameter of less than 10µ) seems to be linked to more to geography than to GDP, but following fluctuations of GDP.



Map 4. Share of population living in areas exposed to concentrations exceeding limit values in 2005. Per cent. NUTS3 regions.
Sources: Author's calculations based on GIS data collected and processed for the ETC/ACM (Rijksinstituut voor Volksgezondheid en Milieu (RIVM) 2013) and related to population shares according to the GEOSTAT 2006 population grid (European Forum for GeoStatistics 2012).



Map 5. Share of population living in areas exposed to PM10 concentrations exceeding limit values in 2009. Per cent. NUTS3 regions.
Sources: Author's calculations based on GIS data collected and processed for the ETC/ACM (Rijksinstituut voor Volksgezondheid en Milieu (RIVM) 2013) and related to population shares according to the GEOSTAT 2006 population grid (European Forum for GeoStatistics 2012).

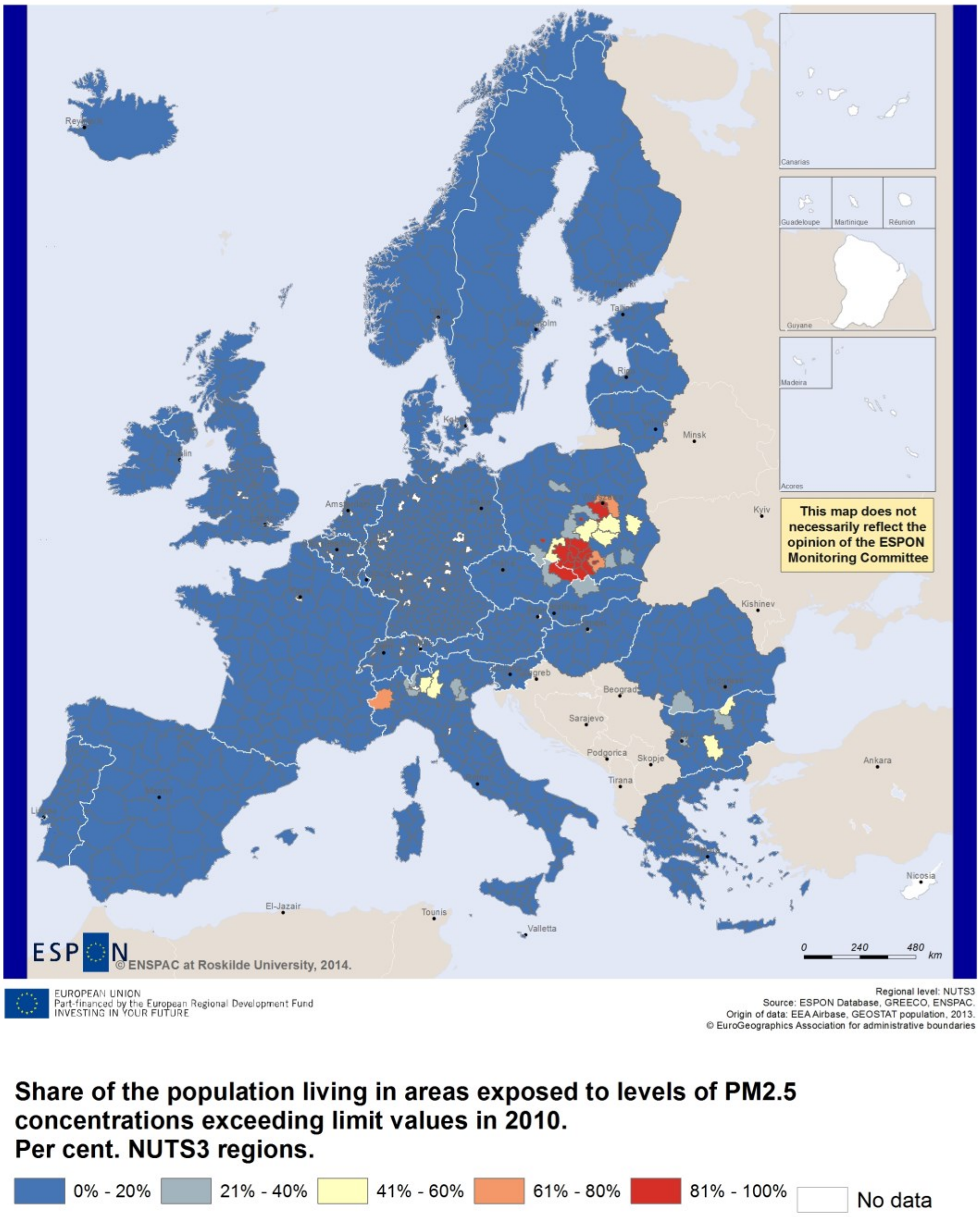


Map 6. Share of population living in areas exposed to PM10 concentrations exceeding limit values in 2010. Per cent. NUTS3 regions.
Sources: Author's calculations based on GIS data collected and processed for the ETC/ACM (Rijksinstituut voor Volksgezondheid en Milieu (RIVM) 2013) and related to population shares according to the GEOSTAT 2006 population grid (European Forum for GeoStatistics 2012).

Some of the PM10 pollution shown in map 4, map 5 and map 6 is transported from other regions, but in the regions with high risk, such as northern Italy and south of Poland, most of the emissions are of local origin. There is not a clear link between the level of environmental risk and the level of GDP at the European scale. A number of factors contribute to explaining the geographical location of the high-risk regions. The regions mentioned as well as the scattered pattern of urban regions are characterised by a concentration of energy intensive production plants and transport. Many of these locations are also located in valleys with air-sheds that are locked or only replaced at a slow rate.

The changes from high-risk levels in 2005 to lower risk levels in 2009 and again higher risk in 2010 could indicate that the risk levels pulsates around these regions in parallel with the economic cycle. Even in the deep recession of 2009, however, the pollution problem was still severe in these regions.

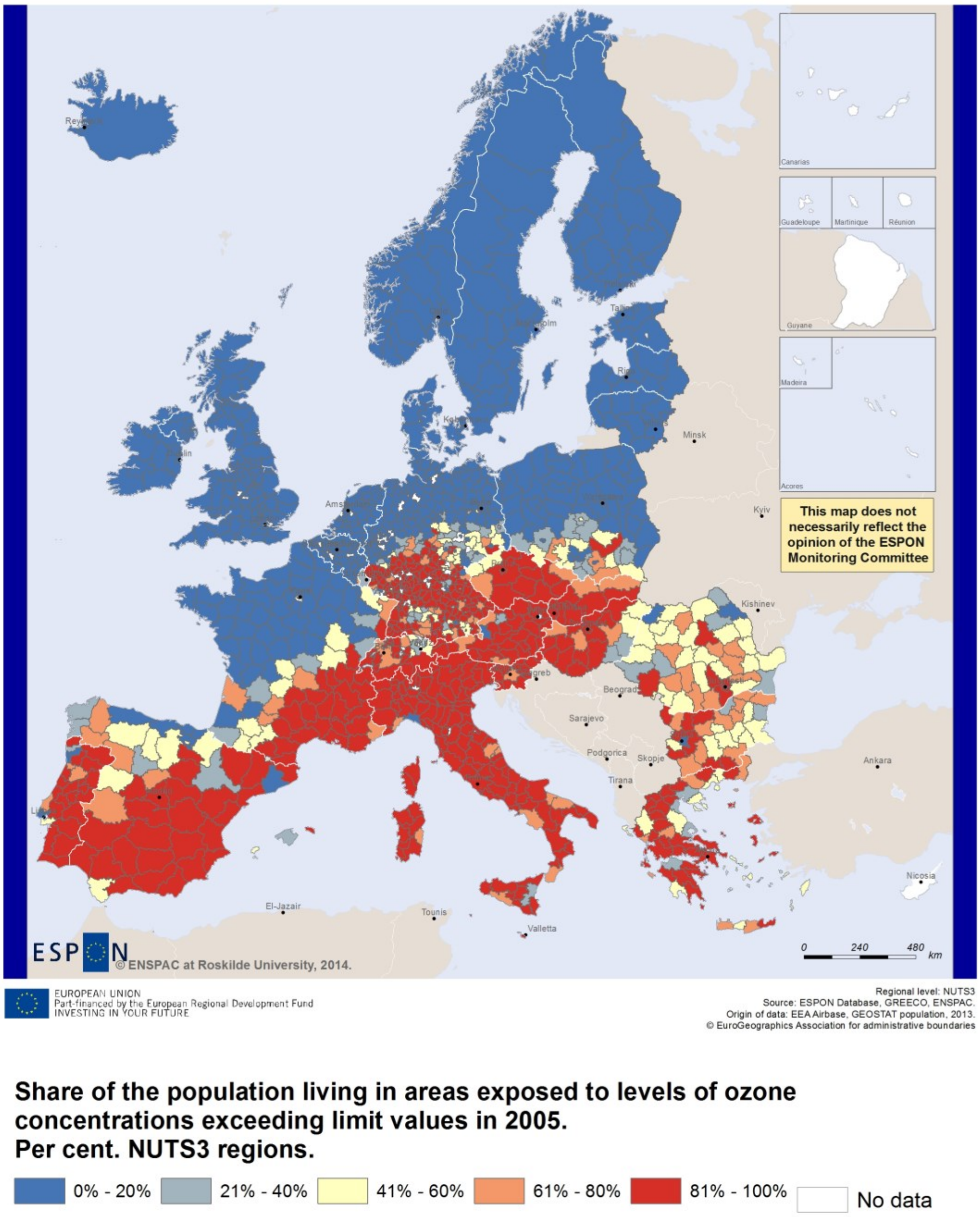
From 2010, limit values have been introduced for the concentration of the very fine particulate matter called PM25 (diameter less the n 2.5µ). Map 7 shows the exposure rates in NUTS3 regions.



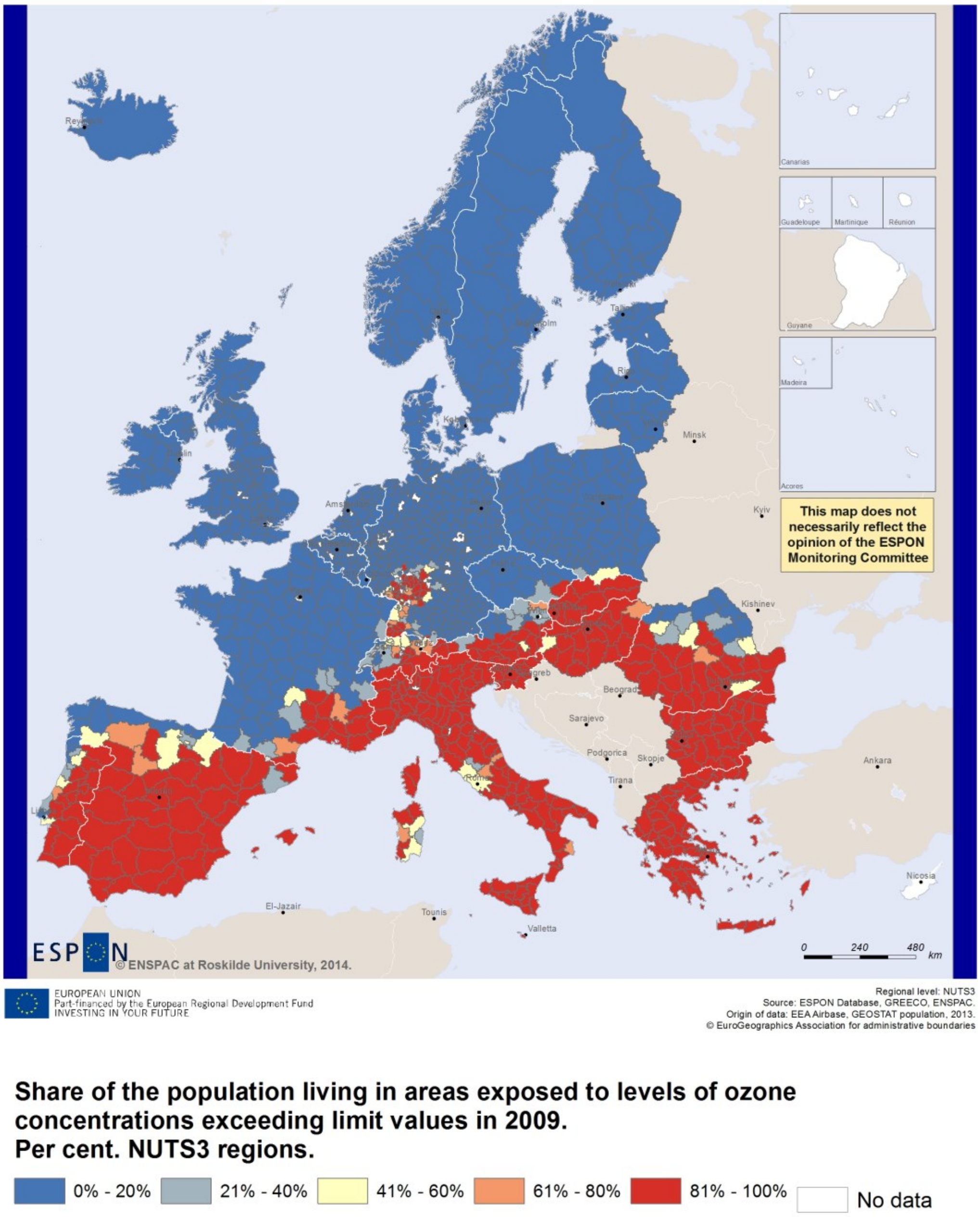
Map 7. Share of the population living in areas with PM2.5 concentration levels in exceeding limit values. 2010. Per cent.

Sources: Author's calculations based on GIS data collected and processed for the ETC/ACM (Rijksinstituut voor Volksgezondheid en Milieu (RIVM) 2013) and related to population shares according to the GEOSTAT 2006 population grid (European Forum for GeoStatistics 2012).

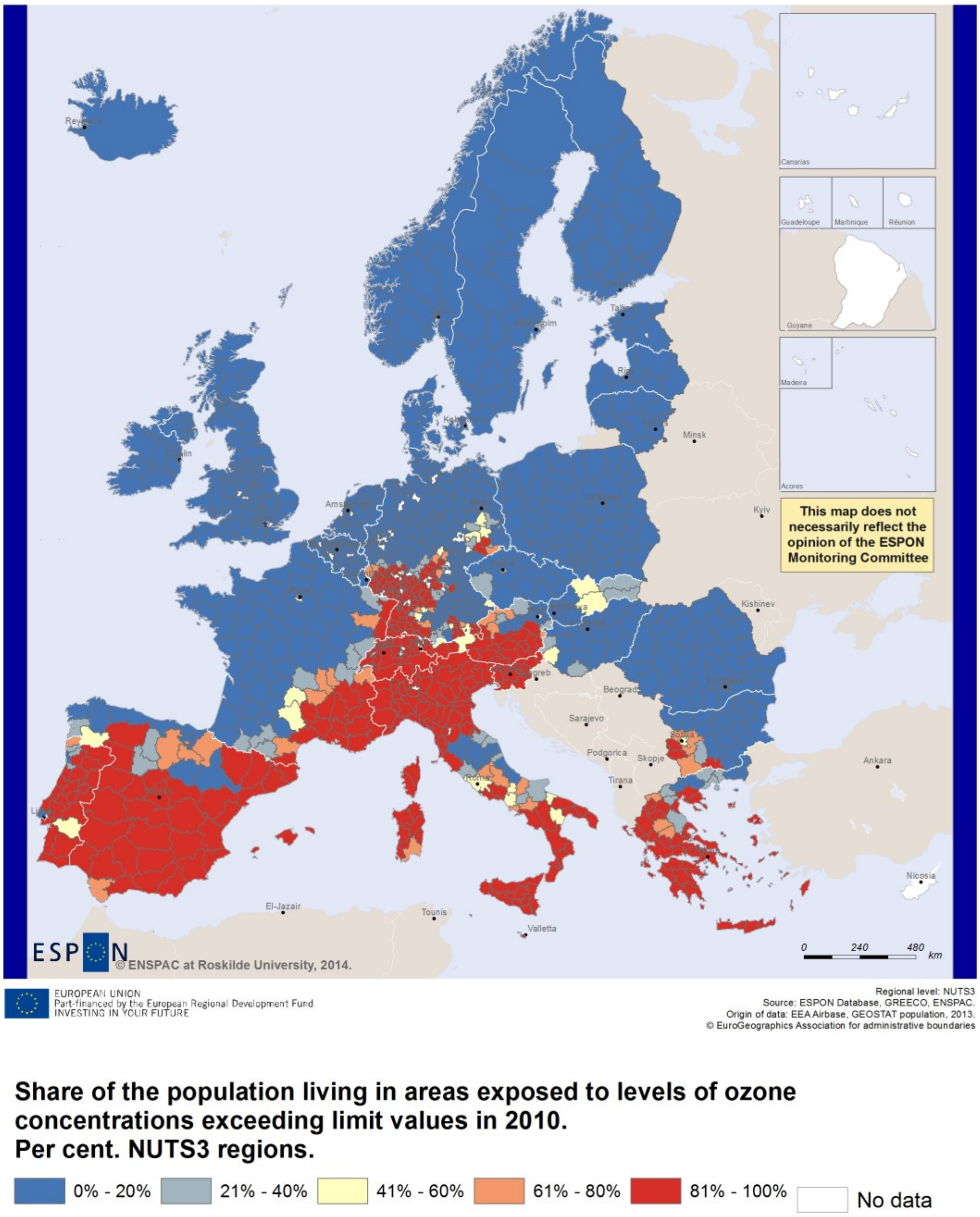
Another problem is the ozone problem. Sunlight is a decisive factor for ozone formation and the risk of exposure to elevated level is mainly a problem for the south of Europe.



Map 8. Share of population living in areas exposed to ozone concentrations exceeding limit values in 2005. Per cent. NUTS3 regions.
Sources: Author's calculations based on GIS data collected and processed for the ETC/ACM (Rijksinstituut voor Volksgezondheid en Milieu (RIVM) 2013) and related to population shares according to the GEOSTAT 2006 population grid (European Forum for GeoStatistics 2012).



Map 9. Share of population living in areas exposed to ozone concentrations exceeding limit values in 2009. Per cent. NUTS3 regions.
Sources: Author's calculations based on GIS data collected and processed for the ETC/ACM (Rijksinstituut voor Volksgezondheid en Milieu (RIVM) 2013) and related to population shares according to the GEOSTAT 2006 population grid (European Forum for GeoStatistics 2012).



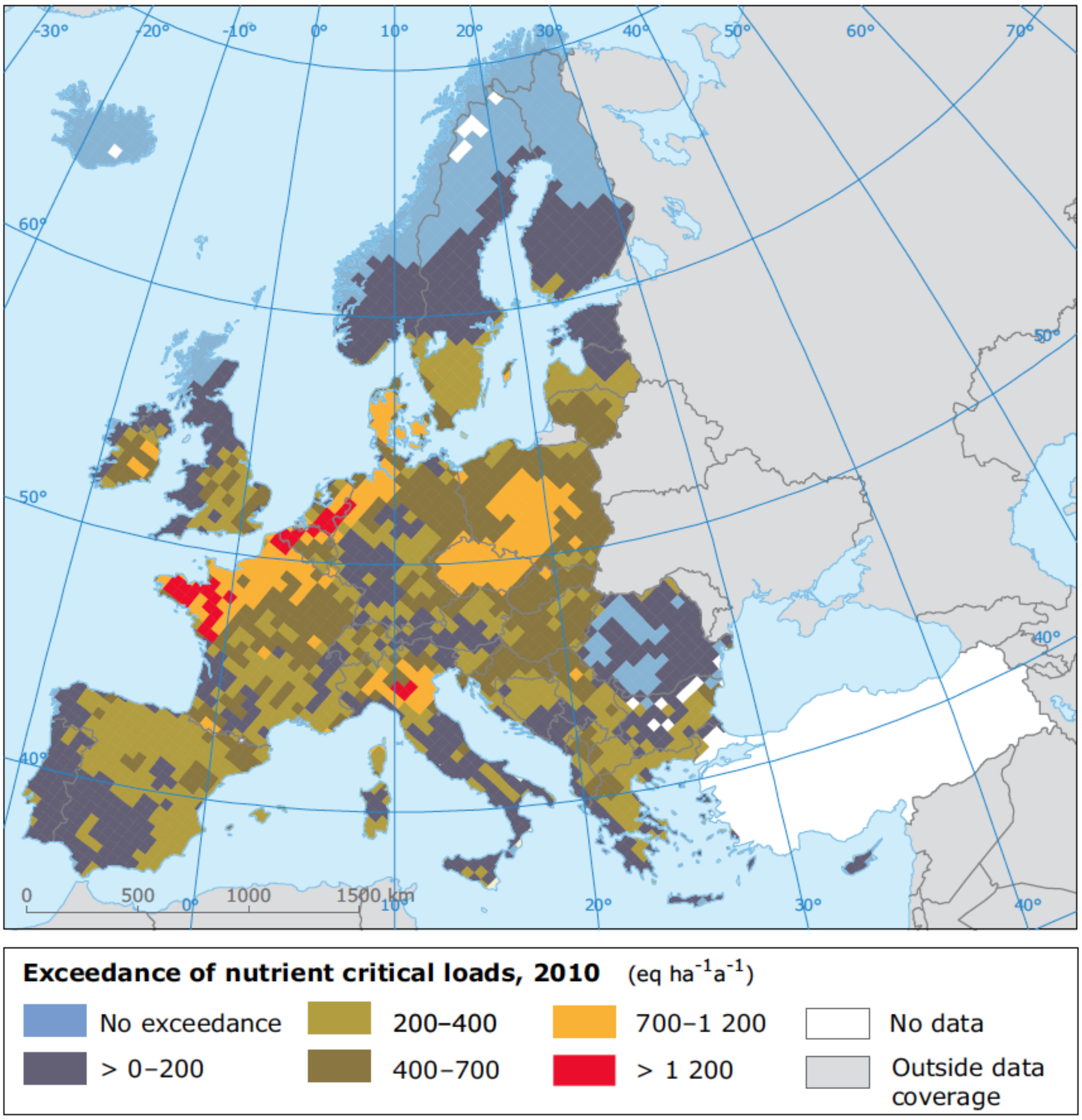
Map 10. Share of population living in areas exposed to ozone concentrations exceeding limit values in 2010. Per cent. NUTS3 regions.
Sources: Author's calculations based on GIS data collected and processed for the ETC/ACM (Rijksinstituut voor Volksgezondheid en Milieu (RIVM) 2013) and related to population shares according to the GEOSTAT 2006 population grid (European Forum for GeoStatistics 2012).

The geographic pattern of the risks of being exposed to elevated levels of ozone is not only related to the geographical patterns of emissions levels. As shown in map 8, map 9 and map 10 they are as much linked to solar irradiation.

The common EU goal of eliminating significant health risks is obviously more distant in some regions than in others. Reinforced efforts that could advance the implementation of green solutions in these areas are thus justified. Local and regional level emission budgets could facilitate the development of effective strategies at the regional level. They should, however, be integrated with carbon budgets (below) to the extent they concern fossil fuel combustion.

7.2. Exposure of nature and crops beyond critical loads

One the important achievements of European environmental policy is the reduction of areas exposed to acidification by 80% from 1990 to 2010 (European Environmental Agency (EEA) 2012). Despite the reduction 10% of the natural ecosystems areas was subject to acidification in 2010, mainly from agricultural emissions of nitrogen(European Environment Agency (EEA) 2010). These emissions are also responsible for eutrophication of terrestrial and aquatic environments. Map 11 shows the spatial patterns of deposition exceeding the critical load.



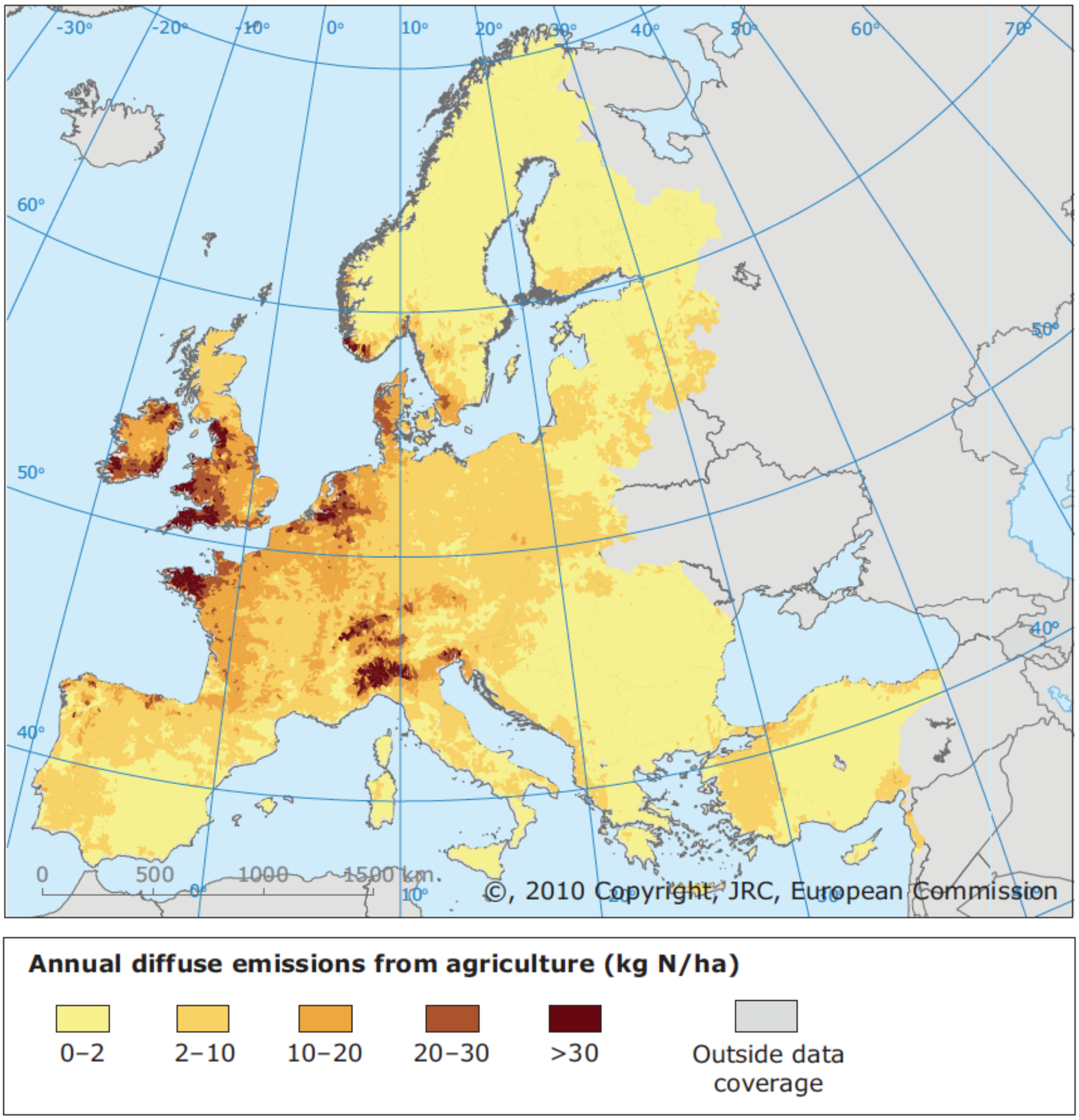
Map 11. Exceedance of critical loads for eutrophication due to the deposition of nutrient nitrogen, 2010 (Neq /ha/year).
Source: (European Environment Agency (EEA) 2010 p63).

Map 11 shows that the critical loads are exceeded in most of Europe by deposition of nutrients. Important polluting activities causing these emissions include NO_X from fuel combustion and ammonia, NH_3, from agriculture. The same conclusions as to the above air pollutants apply to the indicators for conforming agricultural activities and activities involving combustion to these boundaries. Regional budgets would help the transformation of the economic activities causing the pollution problems to green economic activities delivering their services without causing these pollution problems.

7.3. Nutrient cycle balances

The land (including water areas) left to natural ecosystems is also used as a sink for the materials flowing through the econosphere.

Diffuse sources of nitrogen from agriculture to freshwater represent a second important interference with the nitrogen cycle. The spatial patterns are shown in map 12.



Map 12. Annual diffuse nitrogen emissions from agriculture.
Source: (EEA 2012).

The diffuse nitrogen run-off from agriculture is not a severe problem to any agricultural area in Europe. Rather the high rates of emission are predominantly concentrated in areas with high livestock density. Such concentration may be desirable for economic reasons and it can be made sustainable by enclosing the flows of nitrogen in controllable circular chains. In this respect the industrialised animal production in agriculture does not differ from industrial production.

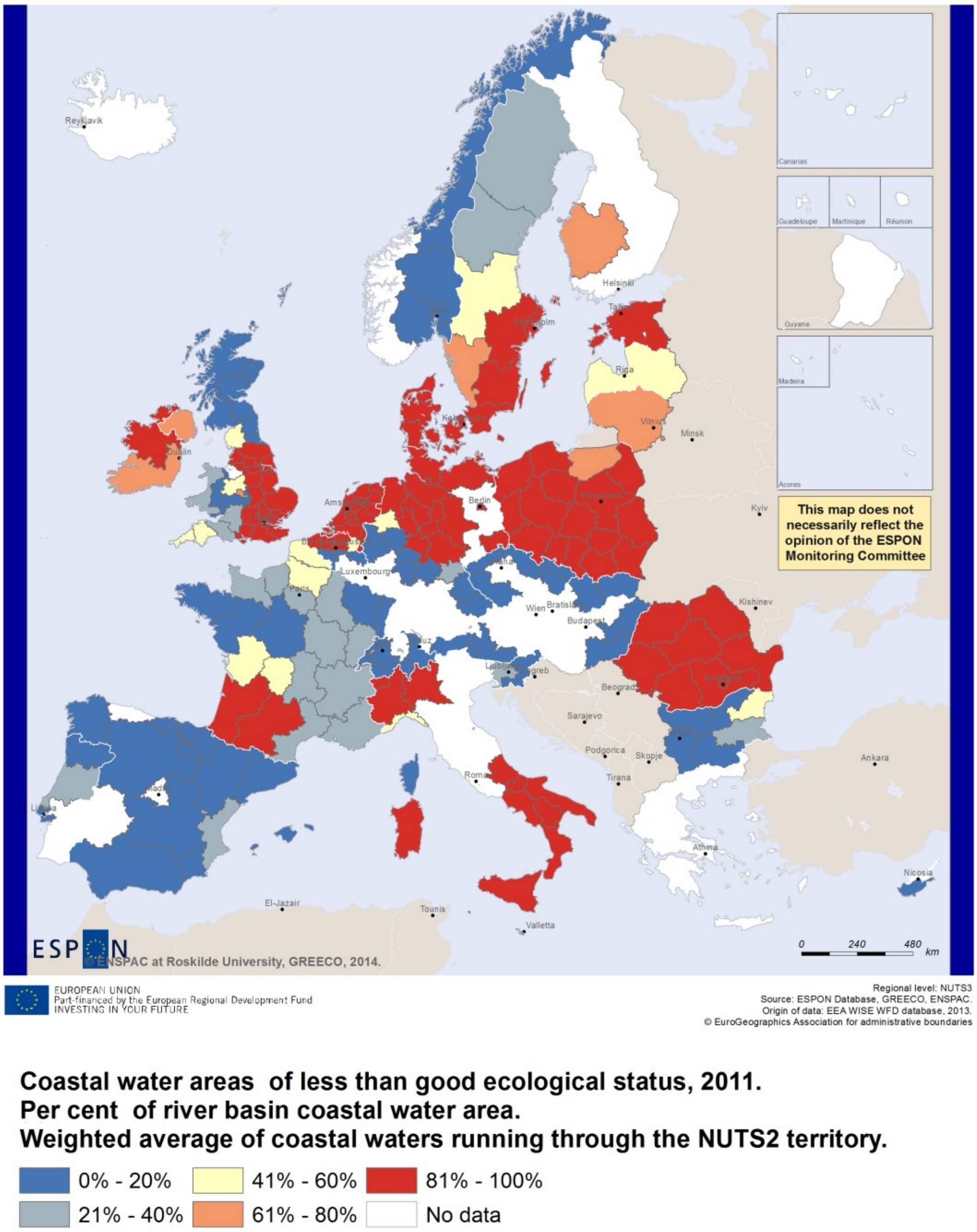
The European Nitrogen Assessment recommends the definition of regional or local nitrogen budgets. The atmospheric nitrogen deposition and the nitrate leaching to the aquatic environment cause eutrophication of ecosystems and thus degrade their ecological status to less than good.

7.4. Water quality

The status of ecosystems related to freshwater areas is the primary purpose of the Water Framework Directive (European Commission 2000). The Commission has developed a set of agri-environmental indicators that could form the basis of the post 2013 CAP, which will use agricultural subsidies as means to achieving environmental goals. These indicators are, however, not generally available at sub-national territorial levels.

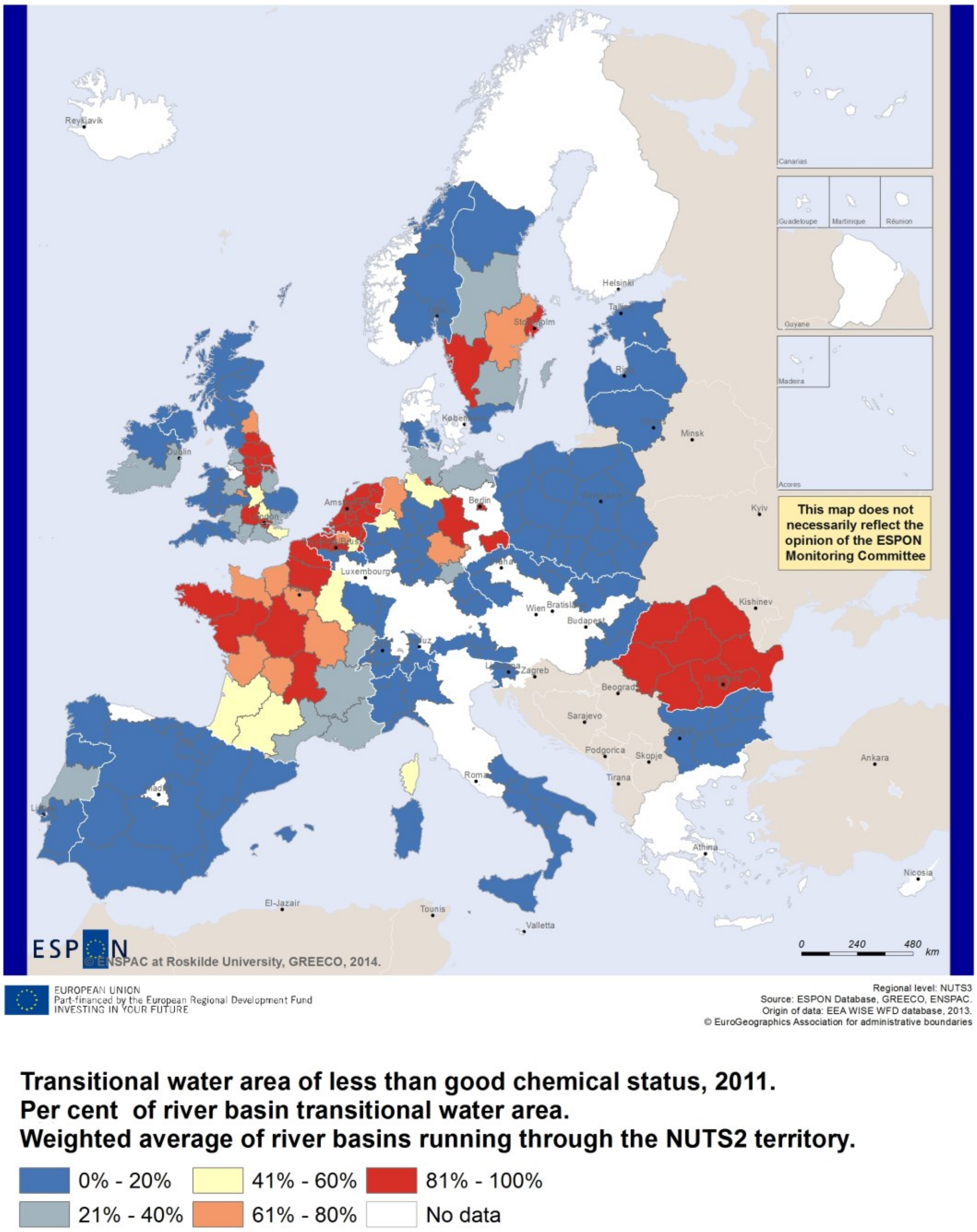
The target for water quality set by the water framework directive is at least a "good" chemical and ecological status of all water bodies in the EU. The scale for the status of water quality is high, good, moderate, poor and bad. The water bodies are classified in coastal, transitional, lakes and rivers. The ecological status depends on factors such as nutrient run-off from agriculture and household wastewater whereas the chemical status depends on discharge of heavy metals and other harmful substances. In some regions a naturally high background occurrence also plays a role.

It is not straightforward to assign water bodies to the individual regions. The firms and households of the region may use different services of the aquatic ecosystems of the river basins as polluters (upstream), pollutees (downstream) or both. The indicator explored here builds upon the data on the share of the water bodies of the river basin that are classified as having less than good status. The value assigned to each region is then the average of the values for the river basins that run through the region, weighted by the area of the region, they occupy.



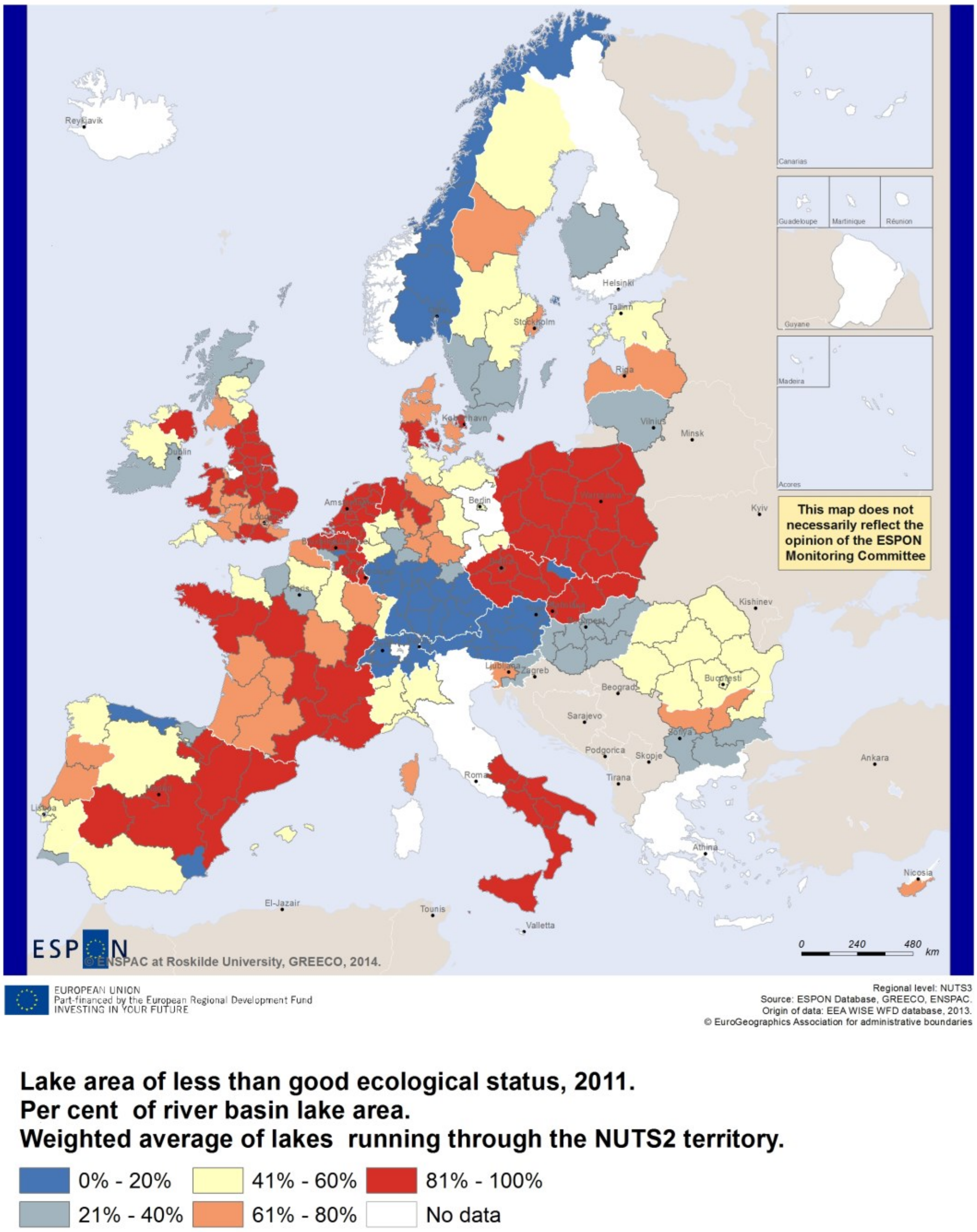
Map 13. Coastal water area of less than good ecological status by NUTS2 regions, 2011. Per cent.
Source: Author's calculations based on the EEA Waterbase (see Hansen 2013a).

The method enables assigning the coastal water pollution caused by emissions upstream in the river basin to all upstream regions. As shown on map 13 coastal water pollution is a problem for many regions situated several 100 kilometres from the coast.

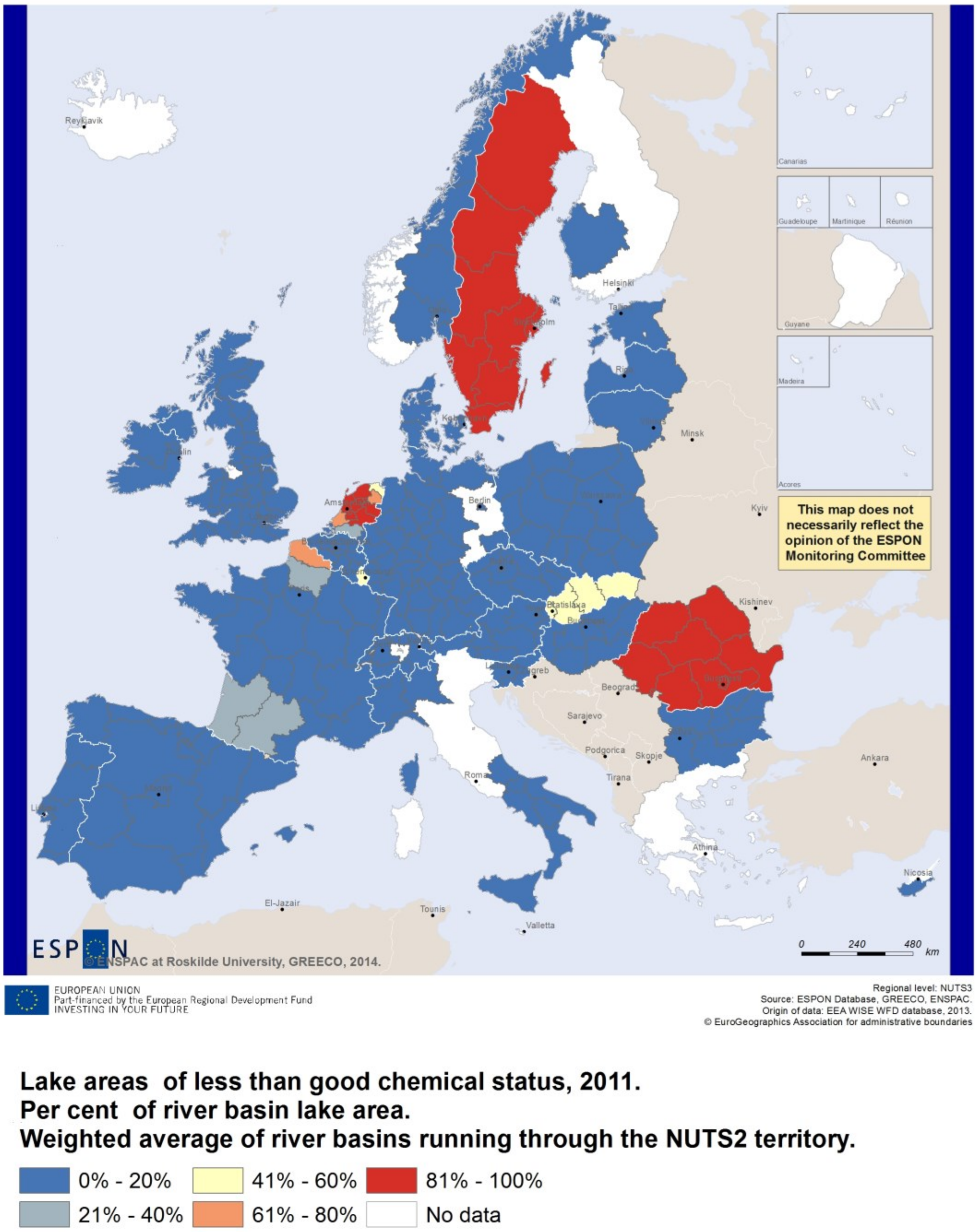


Map 14. Transitional water area of less than good chemical status by NUTS2 regions. Per cent.
Source: Author's calculations based on the EEA Waterbase (see Hansen 2013a).

The chemical status of transitional waters is also a concern for upstream regions as it appears from map 14.

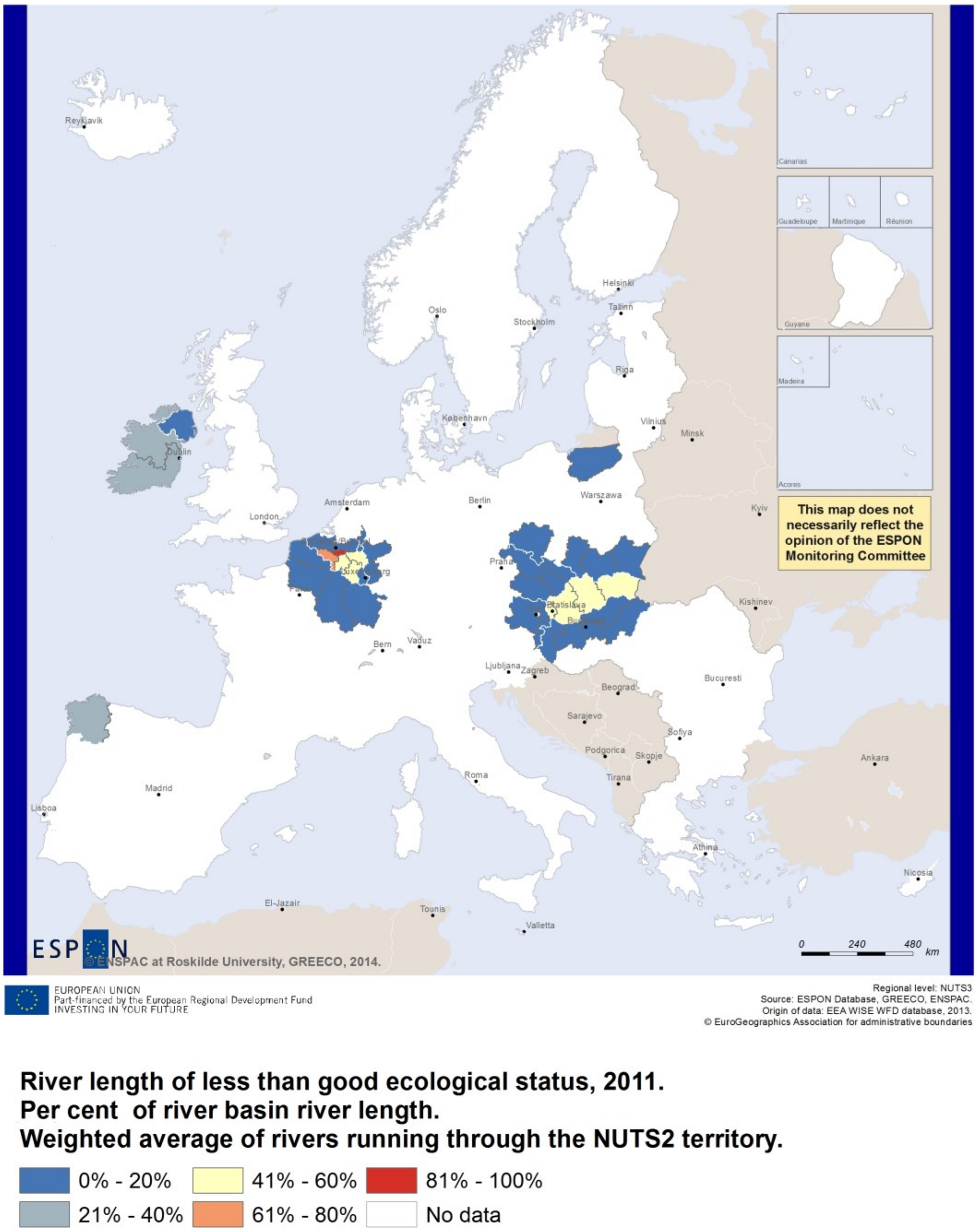


Map 15. Lake area of less than good ecological status by NUTS2 regions, 2011. Per cent.
Source: Author's calculations based on the EEA Waterbase (see Hansen 2013a).

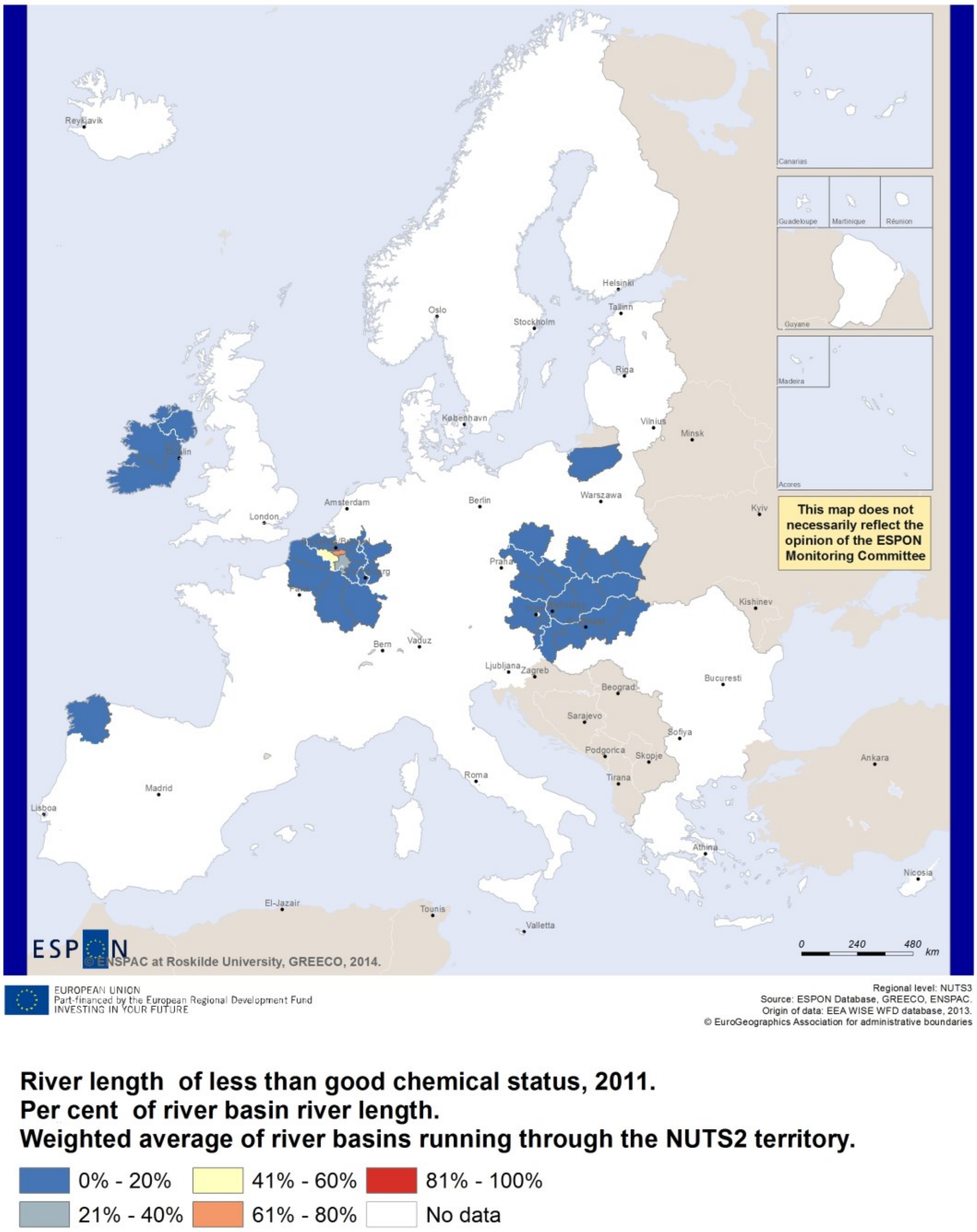


Map 16. Lake area of less than good chemical status by NUTS2 regions, 2011. Per cent.
Source: Author's calculations based on the EEA Waterbase (see Hansen 2013a).

Map 15 and map 16 shows that a less than good ecological status is more pervasive than a less than good chemical status.



Map 17. River length of less than good ecological status by NUTS2 regions, 2011. Per cent.
Source: Author's calculations based on the EEA Waterbase (see Hansen 2013a).



Map 18. River length of less than good chemical status by NUTS2 regions, 2011. Per cent.
Source: Author's calculations based on the EEA Waterbase (see Hansen 2013a).

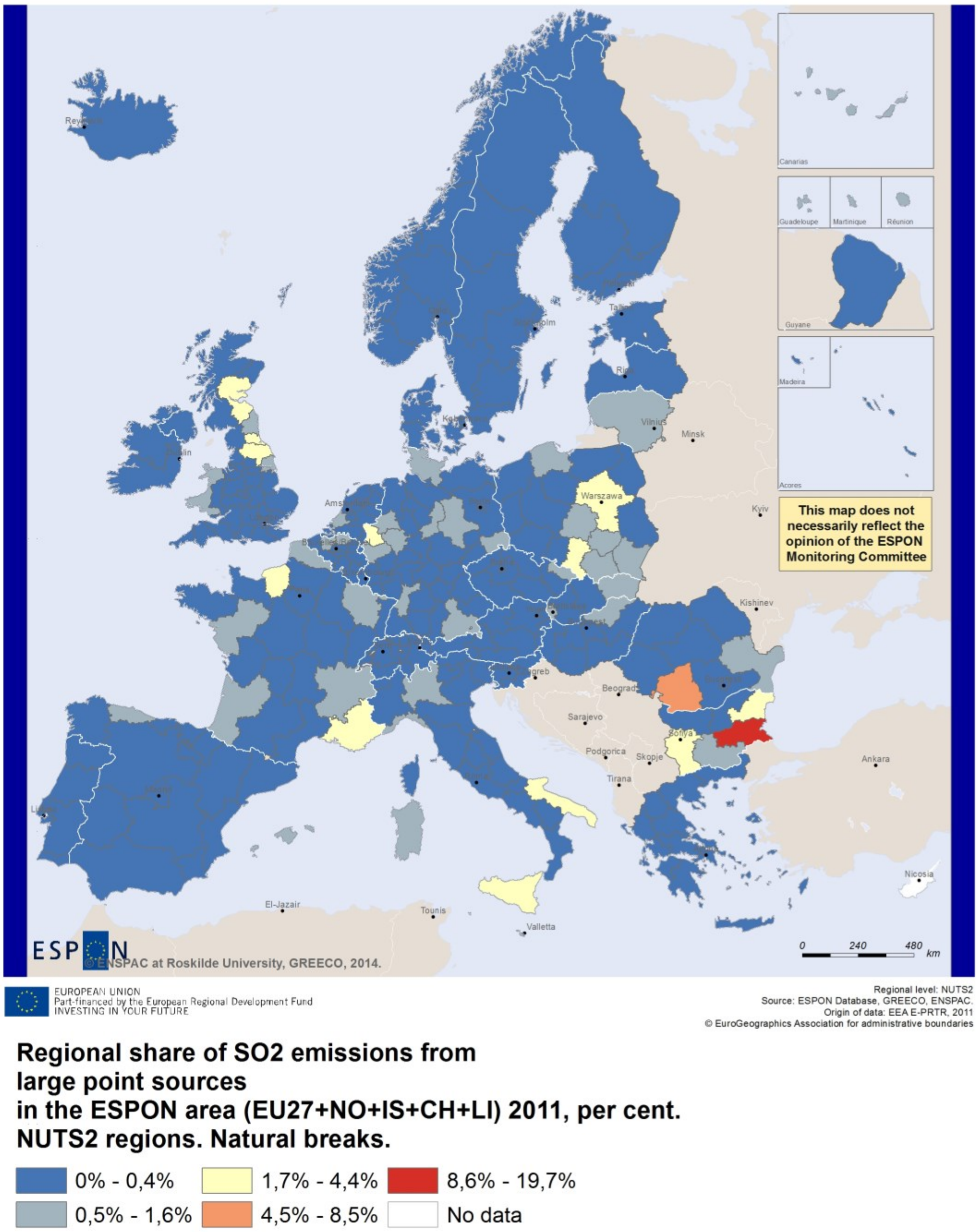
The data collected for rivers are not sufficient to calculate indicators for most regions as shown in map 18 and map 17. The few data that exists seem to confirm the finding for lakes that measured by area, the ecological status is more severe than the chemical. Measured by degree of environmental risk to humans, it may, of course, be different.

7.5. Emission to air of main tropospheric pollutants

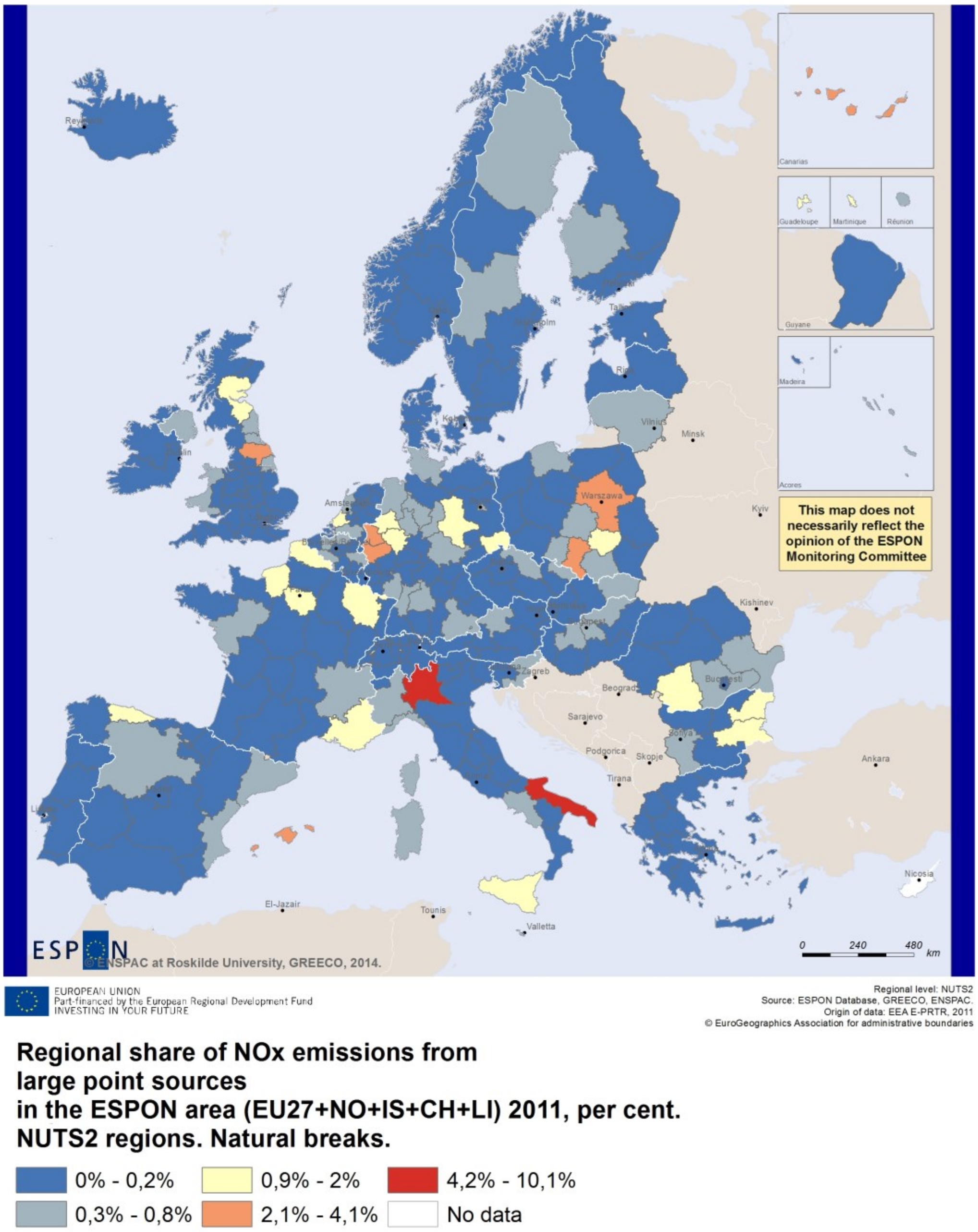
The unsustainable air pollution in many regions identified above is the result of a combination of a geographical concentration of emissions and a limited absorption dilution capacity of the local wind shed. Not all of the pollutants, however, are of local origin. The following section thus analyses the geographical concentration of emissions as the regional share of the European total emissions.

The emissions of SO_2 and NO_X have been dramatically reduced in Europe through the recent decades, but are still imposing severe environmental risks on populations in many regions of Europe. The pollutants are transboundary and contributions to the pollution problem come from all countries and even other continents. The hotspot regions with populations exposed to high levels of environmental risk from PM10 and ozone pollution are, however, also regions with strong local sources of emissions.

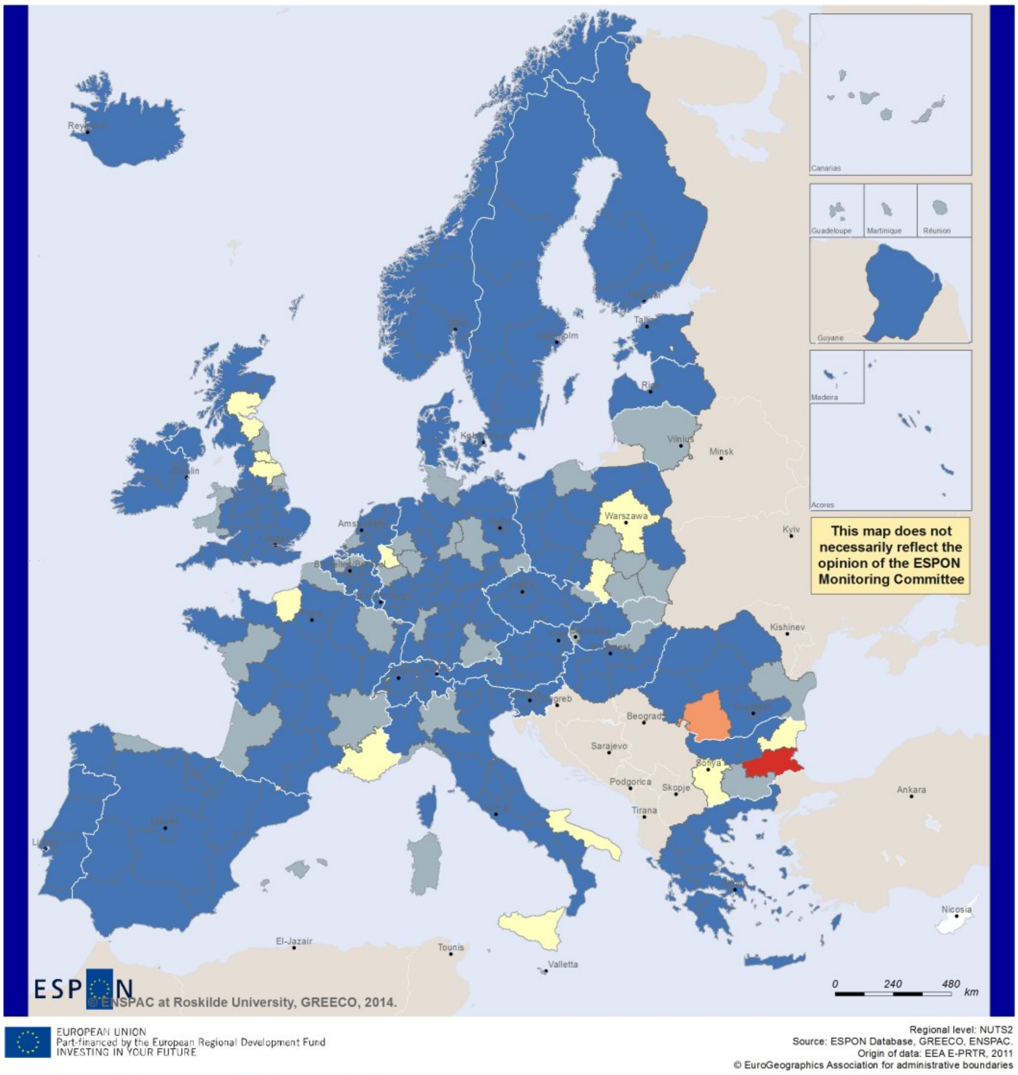
The emissions from which the particulate matter and ozone are formed are not evenly distributed among the European regions. They come from diffuse as well as from point sources. The emissions from large point sources are reported to the authorities and recorded in the E-PRTR database of the European Environmental Agency (EEA). Primary data on emissions from diffuse sources are not systematically collected.



Map 19. Regional shares of European point source emissions of sulphur dioxide (SO_2) in 2011. Per cent.
Source: Author's calculations based on the EEA E-PRTR database (European Environment Agency (EEA) 2013b).



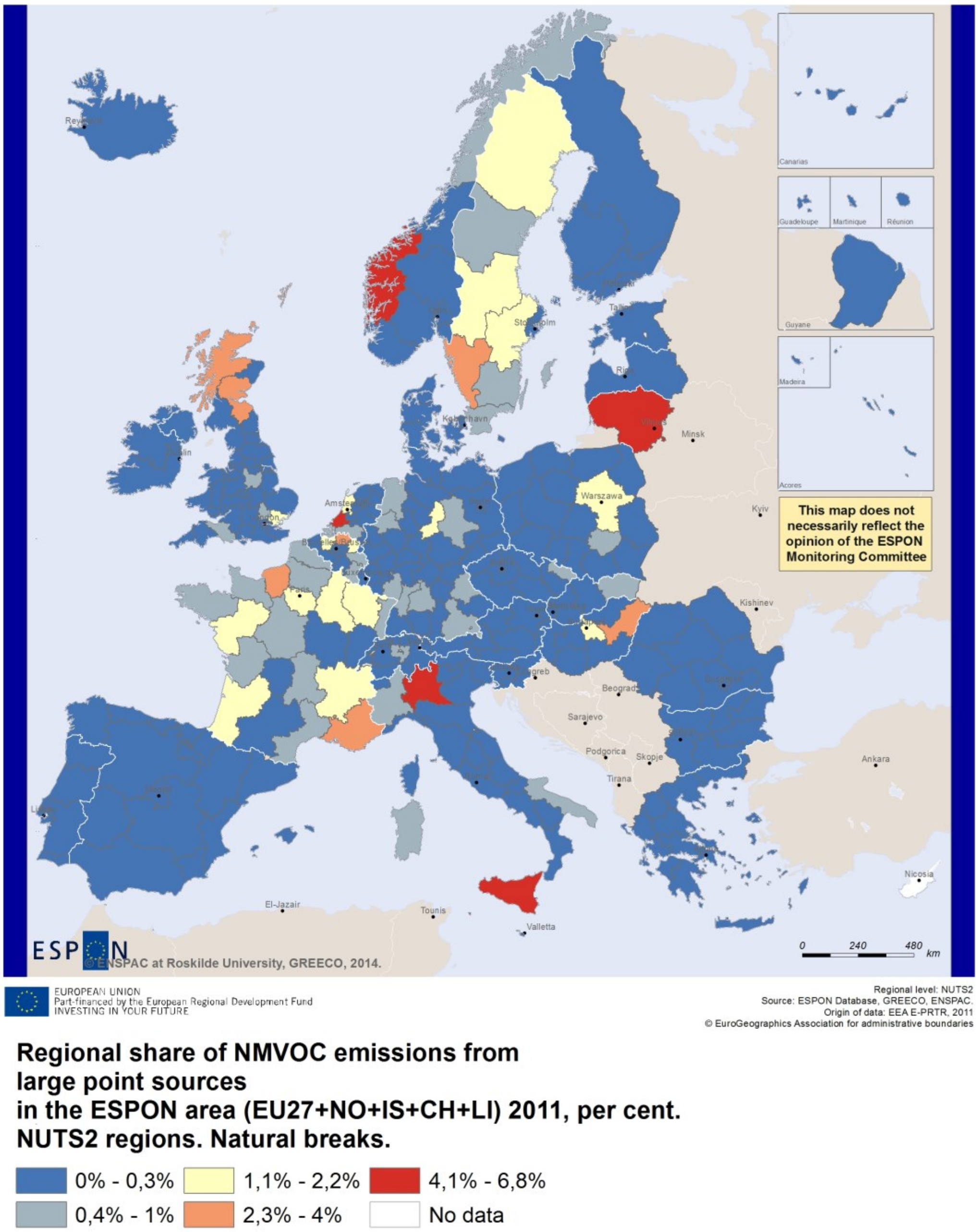
Map 20. Regional shares of European point source emissions of nitrogen oxides (NO_X) in 2011. Per cent.
Source: Author's calculations based on the EEA E-PRTR database (European Environment Agency (EEA) 2013b).



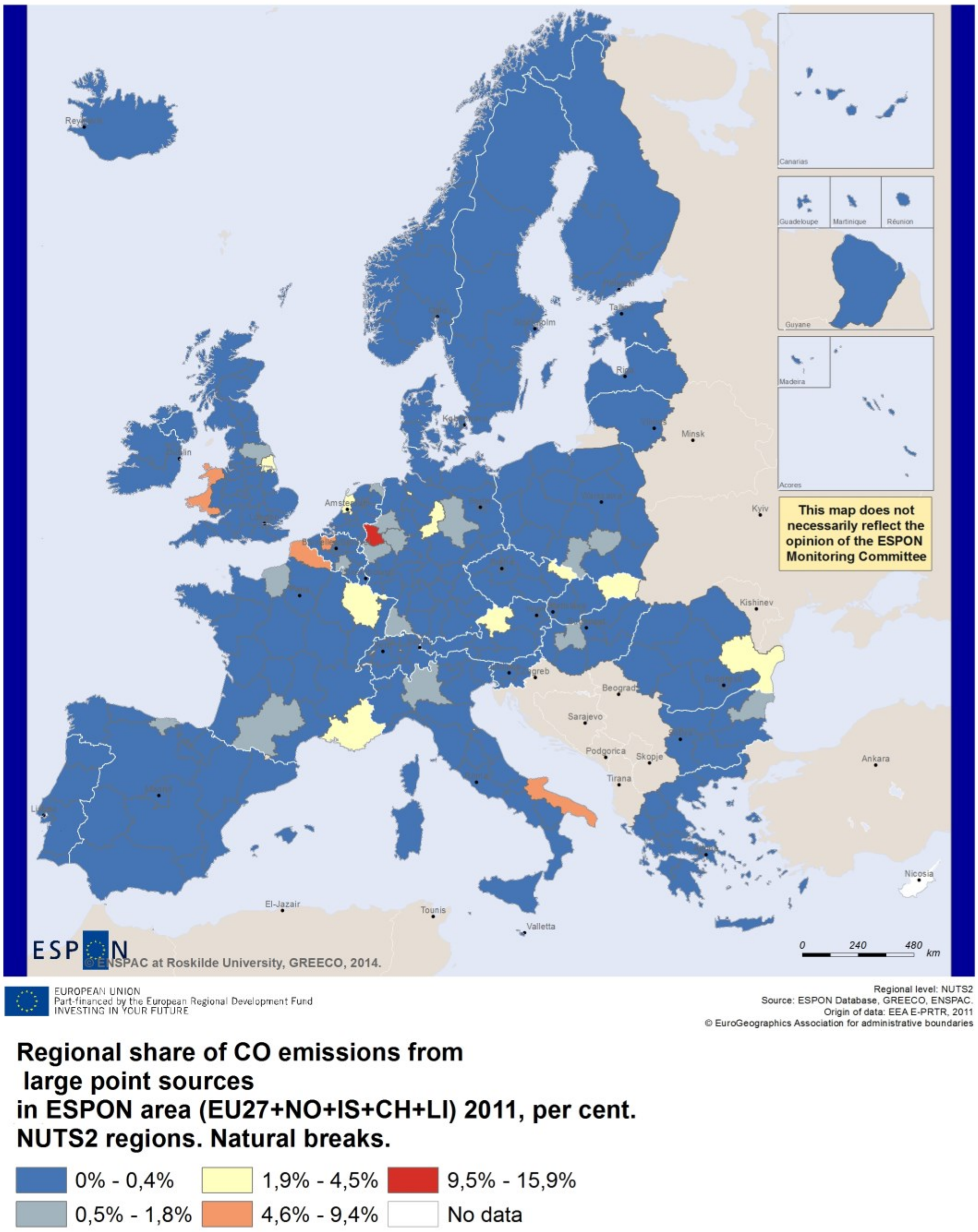
Regional share of SO2 emissions from large point sources in the ESPON area (EU27+NO+IS+CH+LI) 2011, per cent. NUTS2 regions. Natural breaks.

0% - 0,4% | 0,5% - 1,6% | 1,7% - 4,4% | 4,5% - 8,5% | 8,6% - 19,7% | No data

Map 19 and map 20 show that although the emissions of SO_2 and NO_X have been dramatically reduced in Europe through the recent decades, there are still regions with very large emissions of these pollutants according to the E-PRTR database. Lombardia and Puglia in Italy alone stands for 20% of the European point source NOX-emissions. Yugoiztochen in Bulgaria and Sud-Vest Oltenia in Romania delivers 28% of the European point source sulphur dioxide emissions. Another 15% comes from the three regions of Mazowieckie and Yugozapaden (BG) and Slaskie (PL).

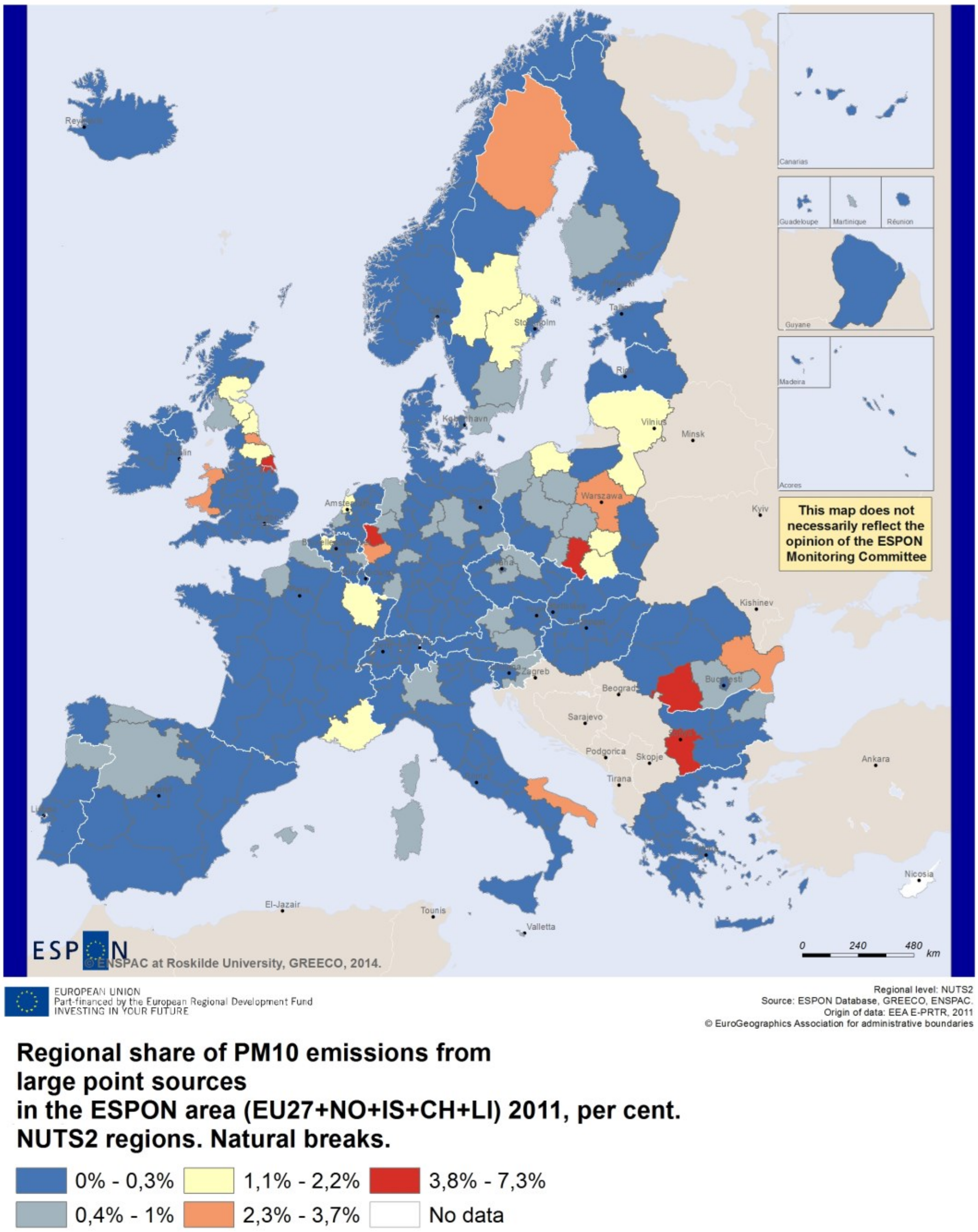


Map 21. Regional shares of European point source emissions of non-methane volatile organic compounds (NMVOC) in 2011. Per cent.
Source: Author's calculations based on the EEA E-PRTR database (European Environment Agency (EEA) 2013b).



Map 22. Regional shares of European point source emissions of carbon monoxide (CO) in 2011. Per cent.
Source: Author’s calculations based on the EEA E-PRTR database (European Environment Agency (EEA) 2013b).

Map 21 and map 25 show that the point source emissions of NMVOC and CO that are emitted by evaporation are distributed among regions slightly differently than the other pollutants, but also with very high rates of emission in few regions.



Map 23. Regional shares of European point source emissions of particulate matter with diameter less than 10μ (PM10) in 2011. Per cent.
Source: Author's calculations based on the EEA E-PRTR database (European Environment Agency (EEA) 2013b).

The emissions of PM10 from point sources are also highly concentrated with the 5 regions of Sud-Vest Oltenia (RO), Düsseldorf (DE), Yugozapaden (BG), East Yorkshire and Northern Lincolnshire (UK) and Slaskie (PL) providing 30% of the emissions.

The concentration of point source emissions in a few regions makes it easier to identify the sources and thus the solutions, but it makes it also more difficult to implement them if they involve downscaling of the polluting activities. Such plants often play a major role in the local or regional economy. In any case, however, it poses the challenges of transformation to a green economy totally different for regions with such emission sources compared to regions without.

7.6. Carbon budgets

7.7. The 20th century carbonisation-growth model

The concept of a "green economy" must be understood in a historical perspective. The green economy is a "low-carbon" economy, which is in sharp contrast to the increasingly "carbonised" economy of the 20th century.

The unprecedented economic growth in Europe through the 20th century - despite two world wars – was closely related to the access to "easy" or relatively low cost fossil fuels.

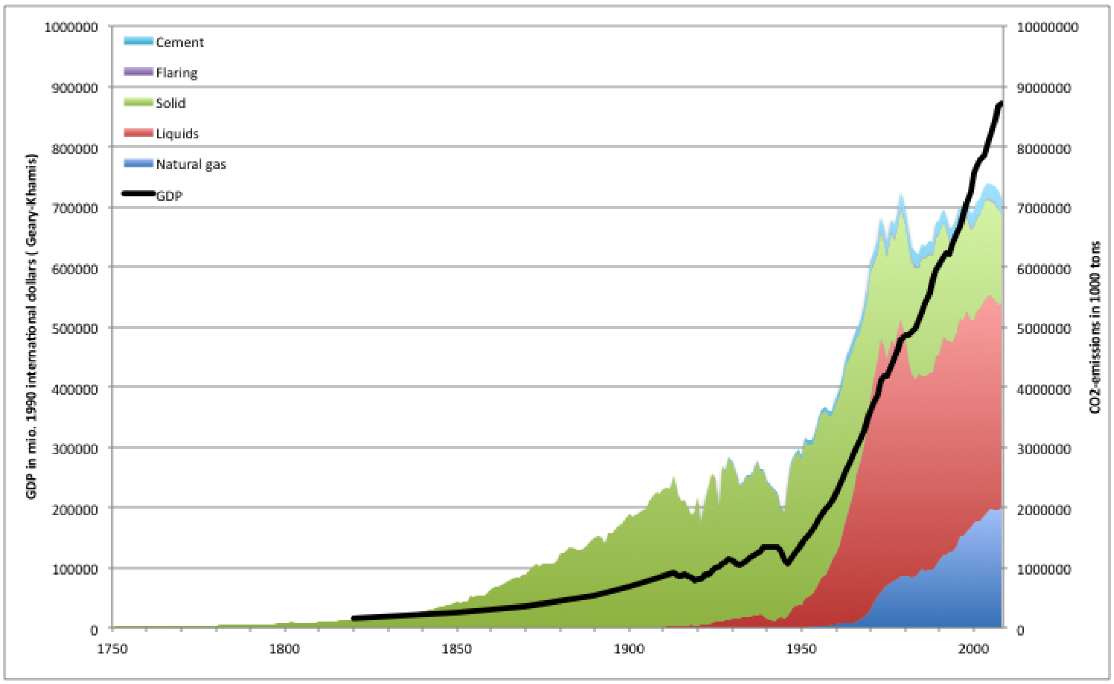


Figure 9. GDP and CO2 emissions (by source) of Western Europe. 1751-2008.
Authors calculations based on historical data (Andres, Boden, and Marland 2011; Maddison 2006).

Figure 9 shows the *carbonisation* of the European economy in particular through the first three quarters of the 20th century. The access to cheap fossil energy enabled the growth of not only value creation, but also heavy flows of other materials through the economy.

Energy access as a competitiveness factor contributed to the formation of the European map of industrial topography. In the pre-industrial economy, the size of the population and its production depended to a high degree on the regional carrying capacity in terms of human controlled bio-productivity in the territory. A key process of the industrialisation was that the primary movers converting biomass to horsepower were relieved by steam engine driven vehicles, pumps etc. instead (E.g., Rifkin 2011; Smil 1994).

The period following the WW2 period during which the oil economy was built up has been called the oil era or another industrial revolution were new prime mover technologies driven by oil and electricity were taken massively into use (Smil 1994).

GDP as well as CO_2-emissions tripled over three decades from the end of the 1940s. This was because the growth model was based on transforming the massive flows of materials and energy to useful goods. The fixed capital stock built up in Europe after WWII was designed to do so transport and process these flows driven by continuous flows of energy, notably oil.

Of course, many other factors – not least science, education and international specialisation – contributed to these historically exceptional growth rates. Economic growth is in the long run a matter of specialisation and cooperation, but the oil economy made it physically possible.

During the most recent three decades the emissions rose only modestly compared to the dramatic increase through the three decades after WW2. The economic growth has continued, which shows that economic value creation does not have to be as closely linked to fossil energy use as it was in the 50s to 70s. This has been found to follow from the shift from coal with a high content of carbon to energy to oil, natural gas, nuclear and hydro power and, eventually, electricity. These shifts to more convenient fuels also implied an overall *decarbonisation*, a trend of lower CO_2-emissions per energy unit consumed (Grübler and Nakićenović 1996). This unplanned and spontaneous decarbonisation was much to weak to curb the CO_2-emissions from fossil fuel combustion to sustainable levels, but it represents historic changes towards cleaner fuels and, eventually, electricity. These trends can be amplified.

Part of this weakening of the carbon link could, however, be explained by "carbon-outsourcing" as the manufacturing industry is in decline and its products are increasingly imported from the emerging economies. Recent analyses based on the CO_2-emissions "embodied" in the consumed goods irrespective of their origin show that the level of CO_2-emissions caused by the economic activity in the EU27 must be expected to be 20-25% higher than the CO_2-emissions emitted from the EU27 territories. The CO_2-emission trend from 1990 to 2010 is, however, even more delinked from economic growth when defined as emissions embodied in consumption (Peters, Davis, and Andrew 2012). Thus, the delinking observed for the EU as a whole does not depend on the omission of the international trade aspect.

The green economy must also be seen in such a historic perspective. Its physical basis must be as different from the physical basis of the fossil energy fuelled economy as the oil economy was from the steam economy and the steam economy from the preindustrial "muscle and sail economy". Otherwise, it will link increasing fossil energy use to economic growth.

This carbonisation-growth model of the 20th century is not sustainable and replicating it in the emerging and developing economies in the 21st century is not an option. It is unsustainable in many respects. First, it transfers carbon from the hydrocarbon reserves in the lithosphere through the economy to the atmosphere, where it has a greenhouse effect. Second, fossil fuel combustion emits air pollutants with severe effects on human and ecosystem health. Third, the fossil fuel resources are non-renewable and global economic growth increases the competition for a dwindling resource of decreasing quality. Fourth, the remaining reserves are controlled by a small number of countries that it would be undesirable for European countries to depend on for their energy security.

The transformation to the green economy a *decarbonisation growth model* and the growth effects of that are different than those of the 20th century model, whereas some properties of it has been developed in the last decades of the century.

7.8. Allocating the European carbon budget

Each of these four factors could justify a more or less restrictive carbon budget, but the greenhouse effect sets the effective constraint. In the following, the sustainable "carbon budget" refers to the greenhouse gasses that can be emitted without causing global warming beyond 2°C.

According to the IPCC the global GHG emissions must be reduced by 50% from 1990 to 2050 in order to curb global warming to 2°C. The panel recommends that the developed economies reduce emissions with 80-95% of the 1990 carbon emissions within this timeframe. The EU has adopted this long-term target for decarbonisation. The end point is the general objective of the EU: "reducing greenhouse gas emissions by 80-95% by 2050 compared to 1990, in the context of necessary reductions according to the Intergovernmental Panel on Climate Change by developed countries as a group" (European Commission 2011a).

The IPCC assesses in its Fifth Assessment Report the remaining global budget (2012-2100) to be 140-210 GTC with a mean value of 170 GtC. It corresponds to a greenhouse gas emission budget of 991 $GtCO_2$. Keeping this budget should by more than 60% probability curb global irradiation to 2.6 W/m^2 by 2100 corresponding to a global warming of 2°C (Intergovernmental Panel on Cliamte Change (IPCC) 2013).

An alternative approach is to determine the "carbon budget" from the limited bio-productivity of land. The "ecological footprint" approach (Wackernagel and Rees 1996) converts the carbon emissions to the forest area that would be needed for sequestering the CO_2 emissions in forest biomass. For the questions addressed in this study, however, it is preferred to use the direct accounts of emissions and the IPCC results about the carbon budget rather than conversions of the emission figures to hectares.

Based on the IPCC assessments the carbon budget of Europe can be translated to a greenhouse gas emission path leading to emission levels of 5-20% of the 1990 level in 2050. This is the sustainable GHG emission path of Europe and it is shown in figure 10.

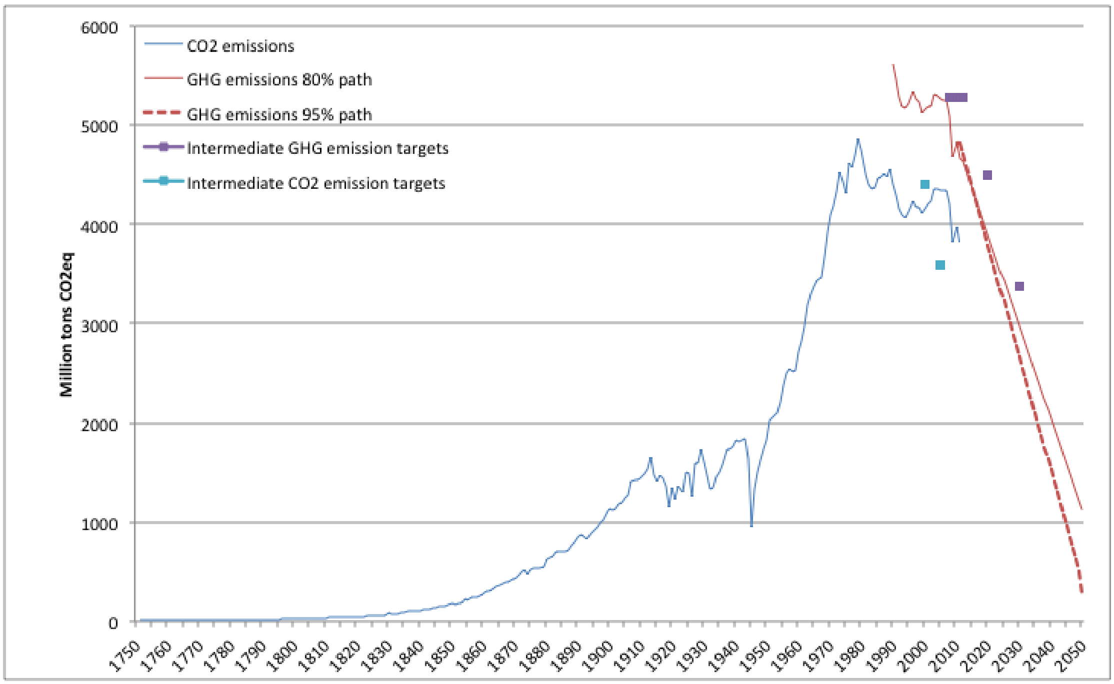


Figure 10. CO_2 emissions 1750-1989, GHG and CO_2 emissions 1990-2011 and sustainable GHG emission paths 2010-2050 for EU27+NO+IS+CH+LI. Million tons (Tg) CO_2 equivalents.

Note: 1990-11 figures are the officially reported emission inventories. 2010-2050 emission reduction paths are linear reductions towards the 5-20% of 1990-levels. The emissions include emission removals by land-use change and international bunkers attributed to the country of refuelling.

Authors calculations based on various sources (Andres, Boden, and Marland 2011; European Environment Agency (EEA) 2012).

Figure 10 shows the historic CO_2-emissions 1750-2010, the reported greenhouse gas emissions 1990-2010 and the paths for *sustainable emissions* from 2010 to 2050.

As milestones towards this end, the EU has adopted the target of reducing emissions by 20% of the 1990 emissions in 2020 (European Commission 2010d). The EU Commission has proposed a 40% emission reduction target for 2030 (European Commission 2013p). The minimum GHG emission reduction consistent with the EU goal of delimiting global warming to 2°C is according to the IPCC 80% and this is the basis for the EU decarbonisation roadmap (European Commission 2011a). These decisions sum up to what can be characterised as a "20-40-80 carbon budget".

Table 4 shows the annual changes in GHG emissions from EU27 in the sub-periods 1990-2011 and the future changes consistent with the 20-40-80 GHG emission reduction budget (or an 80-60-20 GHG emission budget).

Table 4. EU27 greenhouse gas emission budget. Reported annual changes in subperiods 1990-11 and planned emissions in subperiods 2011-50.

1990-00	2000-08	2008-11	2011-20	2020-30	2030-50
-1.0%	-0.3%	-2.8%	-0.2%	-2.8%	-5.3%

Assumptions on reduction targets: 2020: 20%, 2030: 40%, 2050: 80% of 1990 emissions.
Source: (European Commission 2011a; European Commission 2010d; European Commission 2013p; European Environment Agency (EEA) 2013c)

The EU 2020 target of 20% rather than the 30% emission reduction that would have been more in line with the long term budget, implies that a smaller budget is available for the 2020-50 period. The moderate reduction rates in 2000-08 and in 2011-20 imply more dramatic rates of reduction in the 2020-2050 period. The emission reductions are postponed to the future. The higher reduction rates in 2030-50 are also due to the reductions being imposed on a still smaller budget.

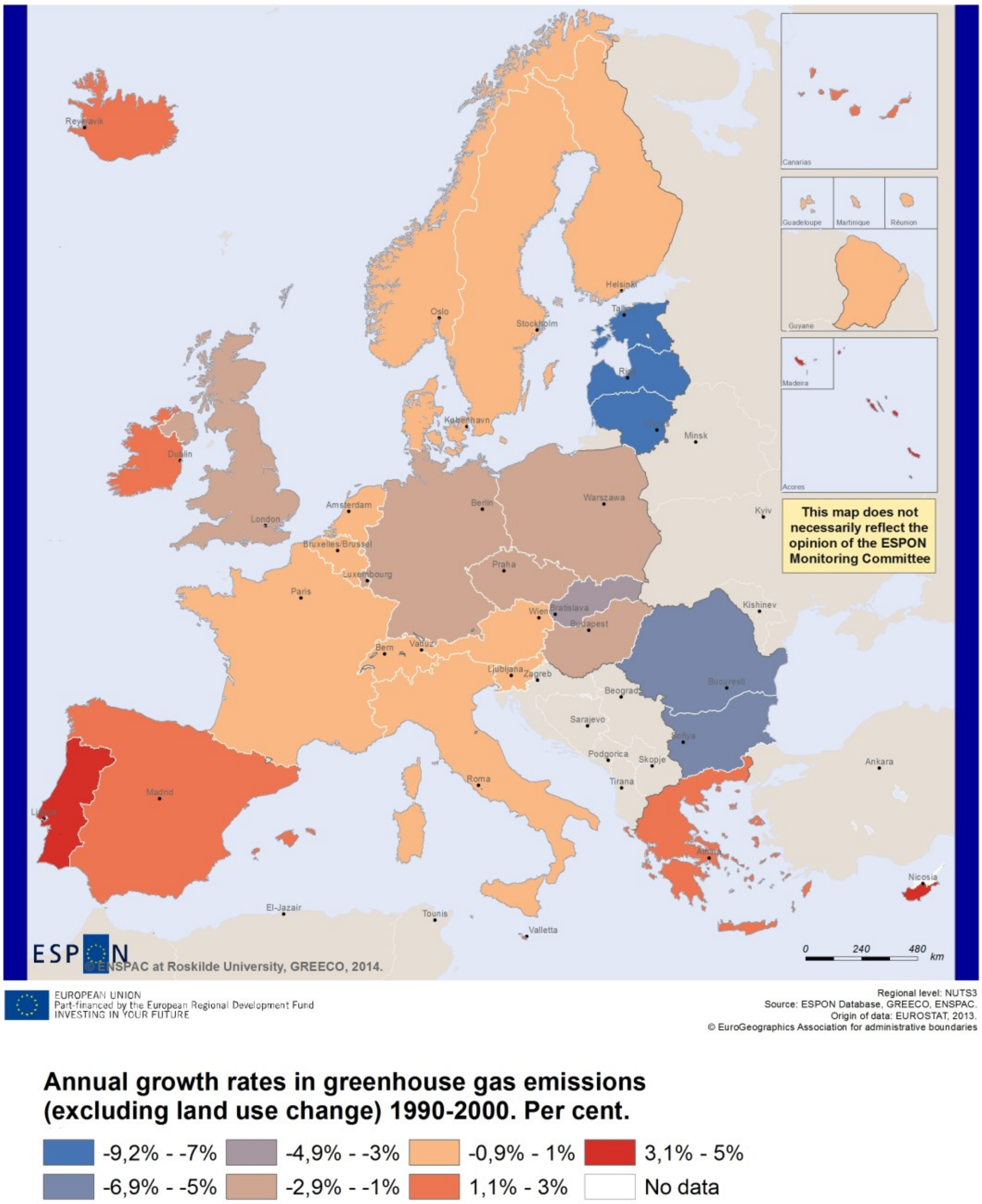
7.9. Historic changes in CO_2-emissions by regions

The average annual rate of reduction of greenhouse gas emissions in 1990-2000 and 2000-2008 is known for the EU as a whole and for the individual member-states. Primary data on fuel combustion are, however, not collected and processed in a harmonised way across Europe and we do not know the overall emissions at the regional level.

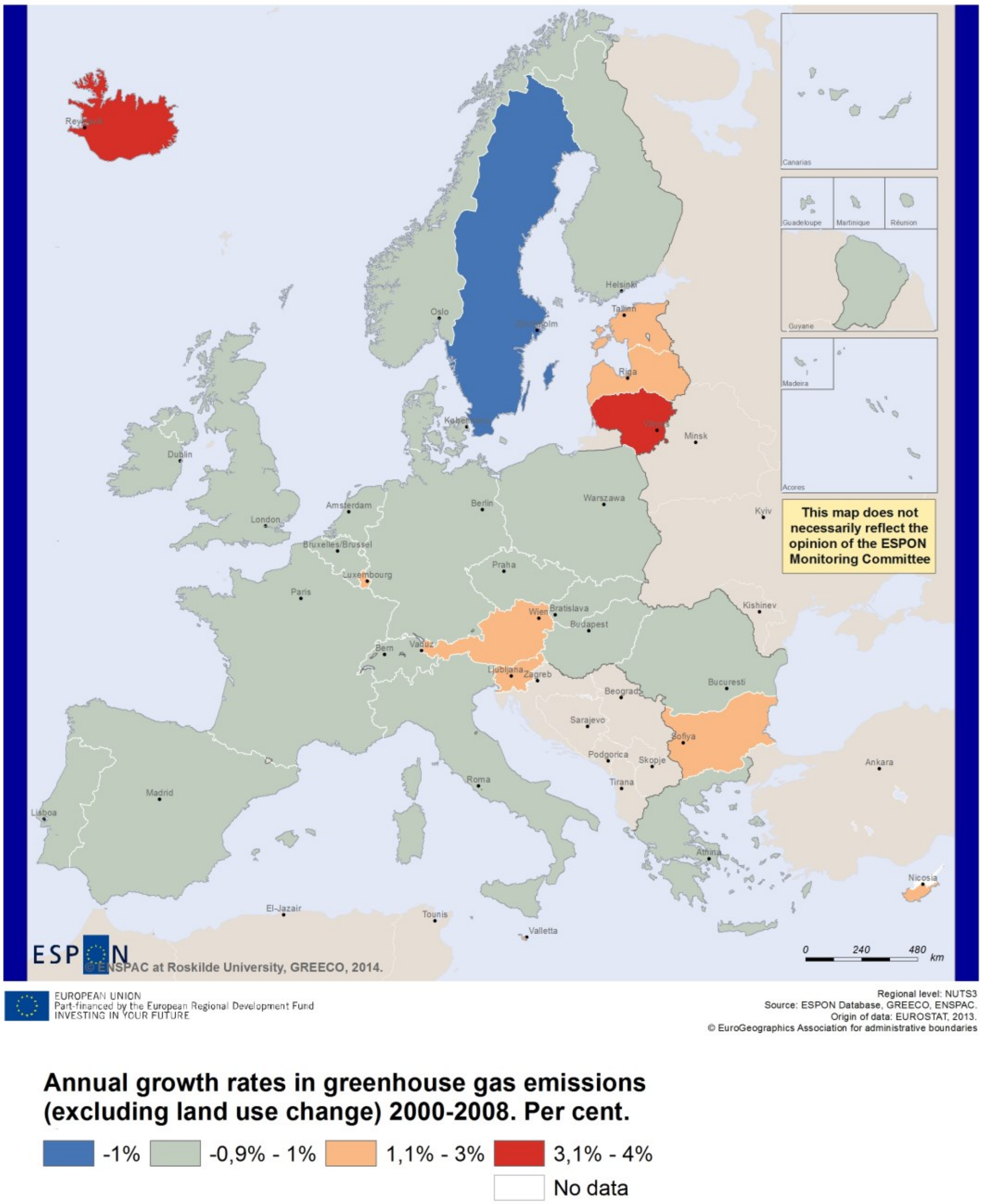
Instead, we have used the "gridded" emission data from the EDGAR database to predict the regional CO_2-emissions from the national emission data just like future developments are "predicted" from experience gathered in the past. The gridded emissions in the EDGAR database are estimated by distributing the national emission figures according to known spatial distributions of production, population and other economic variables that are known to be associated with the spatial distribution of energy combustion.

Map 24 and map 25 show the compound annual growth rates of expected GHG emissions in European countries in the 1990s and in the 2000s until 2008.

In the 1990s, the emissions declined dramatically in the countries of the former eastern block following the collapse of the fossil fuel intensive industry of these economies. At the same time, a rapid economic growth in some economies such as Spain and Portugal led to high rates of emission growth.



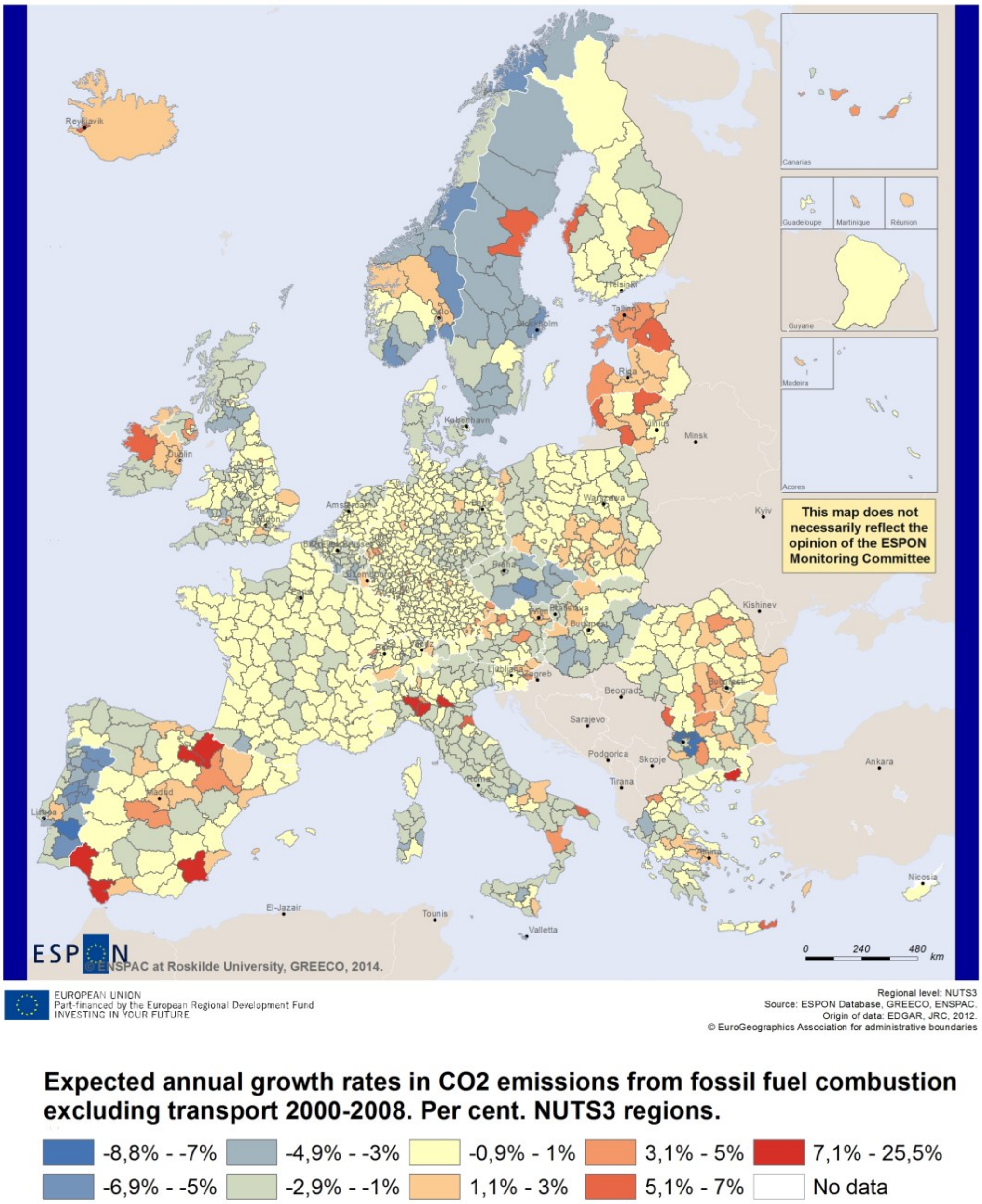
Map 24. Greenhouse gas emission growth in European countries. Reported change 1990-2000. Per cent per year.
Source: EUROSTAT (European Commission 2013f).



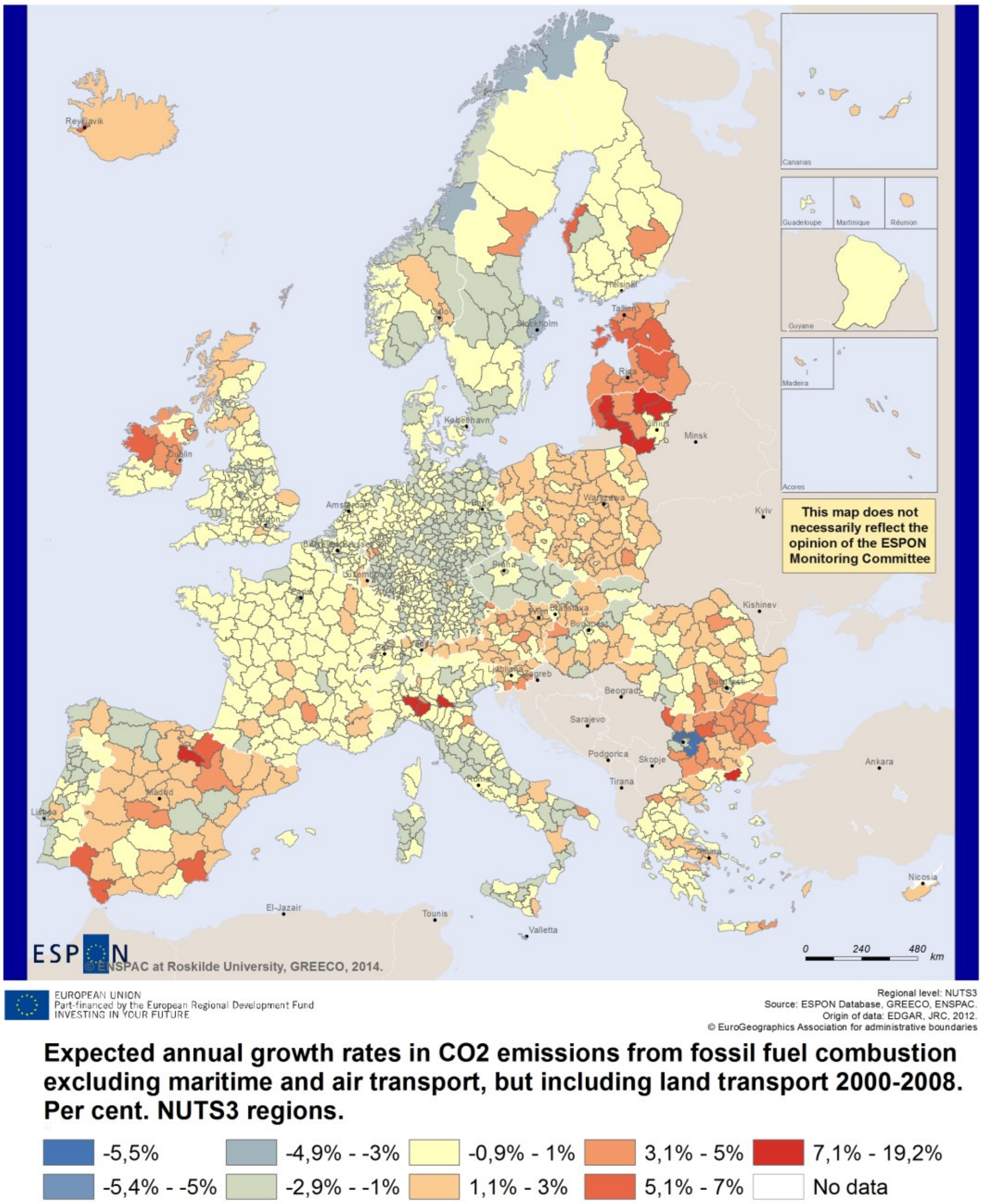
Map 25. Greenhouse gas emission growth in European countries. Reported change 2000-2008. Percent per year.
Source: EUROSTAT (European Commission 2013f).

Map 25 also shows that despite high growth rates across Europe until 2008, the annual change of GHG emissions remained within the interval between +1% and -1% per year in most countries.

The spatial predictions from the EDGAR database are regionalised to the NUTS3 level. Based on these estimates the predicted change in the 1990s and the 2000s are shown in map 26.



Map 26. Expected regional pattern in annual change in CO_2-emissions from fossil fuel combustion excluding transport. 2000-08. Per cent.
Sources: Author's calculations based on the EDGAR database (JRC 2012).



Map 27. Expected regional pattern in annual change in CO_2-emissions from fossil fuel combustion excluding maritime and air transport, but including ground transport. 2000-08. Per cent.
Sources: Author's calculations based on the EDGAR database (JRC 2012).

Map 26 and map 27 show how the emission growth rates of map 24 and map 25 could be expected to unfold by NUTS3 regions. The EDGAR-project gridding of national emission figures were based on regional economic statistics and transport route and road network statistics. The gridded data have been regionalised to the above NUTS3 patterns.

In the 1990s, GHG emissions were reduced in Germany and the United Kingdom and what became the new member-states. In Spain, Portugal, Greece, Ireland, Iceland, Cyprus and Malta they were increasing, whereas in the rest of the countries the rate of change were between 1% and -1% cf map 25. In 2000-08 the changes were less significant in either direction.

As shown in map 26, however, different regions within the same country must be expected to differ by changes in emissions. It is because some regions are growth regions and some are in regions in decline. In some regions, energy intensive plants are retired whereas in other regions they are established. Reducing emissions is preferable, but it is not equally preferable whether the reduction happens in a growth region or in a region in decline. Solutions to this problem are suggested in section 12.2 below.

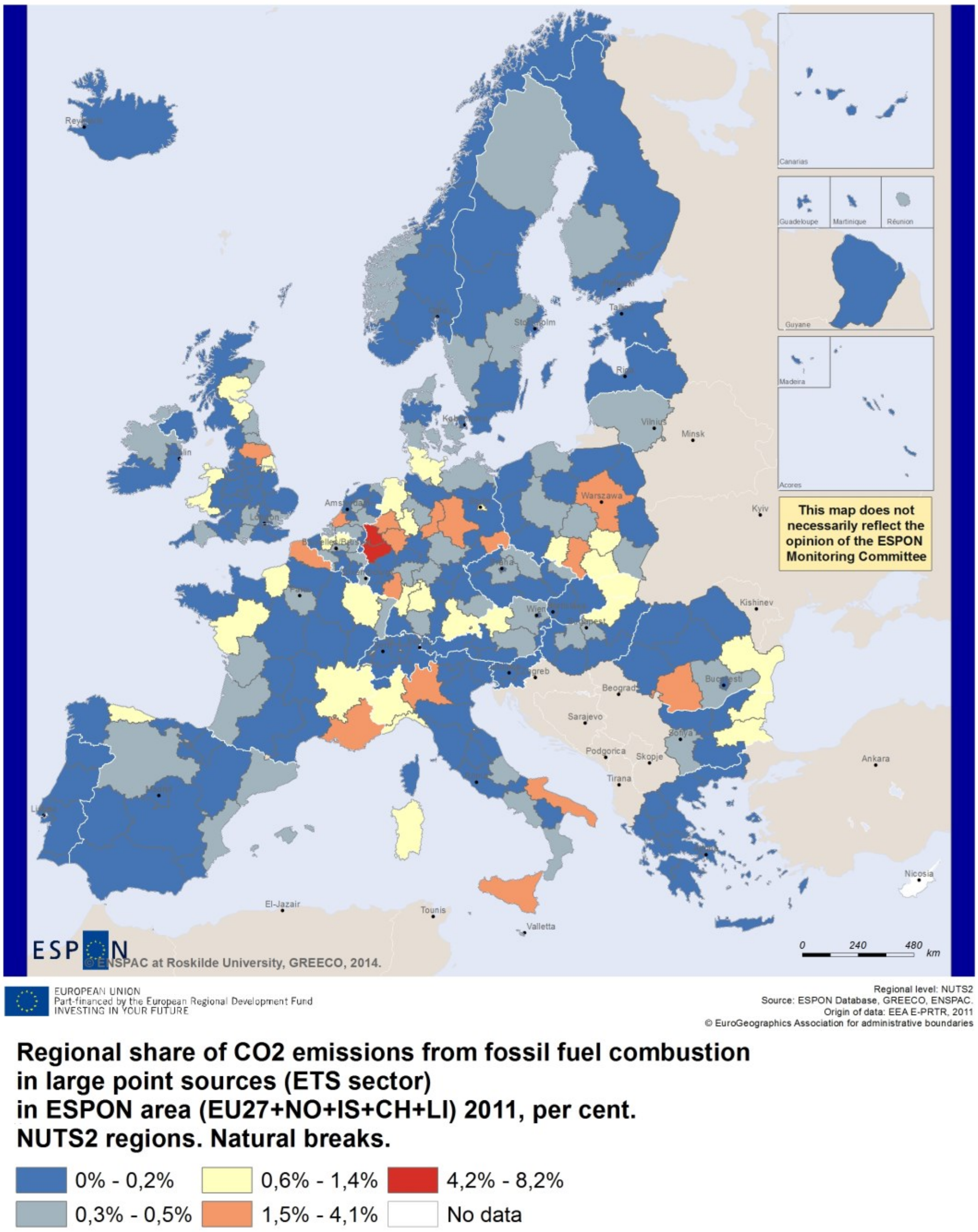
It is important to note that the regional emission figures are not observed emissions or based on observed fossil energy combustion but just the emissions one would *expect* to find *if* these data were collected. Consequently, the data are of no use for monitoring, performance measuring or even target setting. A region can only reduce these emission data relative to those at the national level by inducing its citizens and firms to migrate to other regions.

7.10. Regionalized ETS CO_2-emissions

The E-PRTR database includes reported CO_2-emissions for large point sources since 2005 (incomplete compared to national reporting) whereas the smaller emitters in industry, agriculture, services, transport and housing are predicted cf. above.

The large point source emissions of CO_2 are regulated by the EU emission trading system (ETS). In principle, it includes all plants with a fossil fuel boiler with a capacity of more than 20MW in. The emissions are reported to the E-PRTR database of the European Environmental Agency (EEA).

Based on these data, it is possible to study the regional distribution of these large point source emissions.



Map 28. Share of ETS CO_2-emissions by NUTS2 region, 2011. Per cent.
Source: Author's calculations based on the EEA E-PRTR database (European Environment Agency (EEA) 2013b).

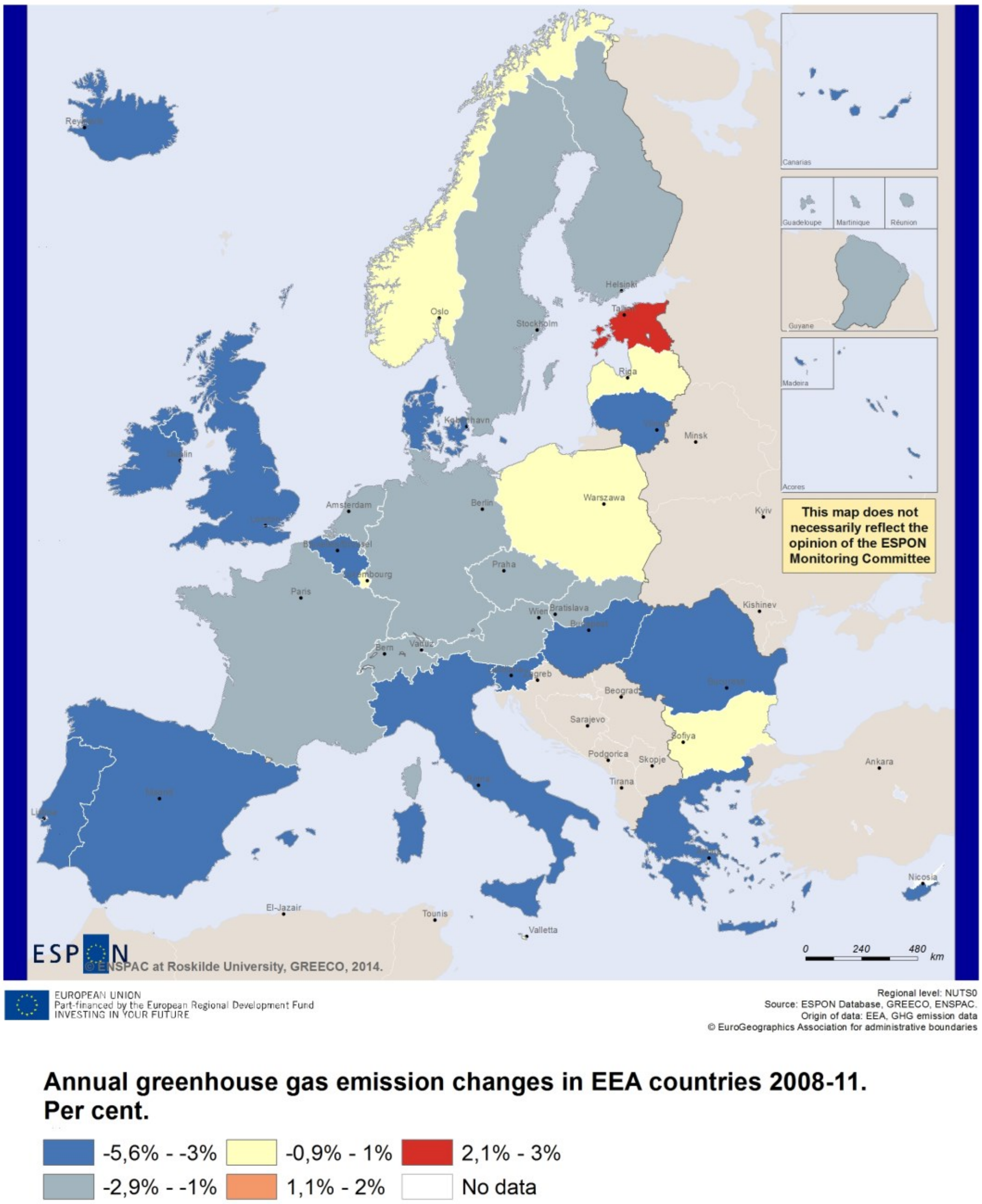
The emissions of CO_2 from the large point sources regulated by the ETS are not evenly distributed across the European map. Some regions have the potentials of becoming global leaders of the transformation of large point source econosphere whereas other regions only have diffuse sources. 18.5% of the reported point source emissions in 2011 came from the three regions, Düsseldorf (DE), Cologne (DE) and Puglia (IT) (the darkest blue on map 28). Another 16.6% were emitted from the 7 regions Münster and Arnsberg (DE), Slaskie and Mazowieckie (PL), Zuid-Holland (NL), Lombardia (IT) and North Yorkshire (UK) (the slightly lighter shade of blue on map 28). Another 13.6% were reported from the 8 regions of Sicily (IT), Dresden, Braunschweig, Rheinhessen-Pfalz and Sachsen-Anhalt (DE), Nord - Pas-de-Calais and Provence-Alpes-Côte d'Azur (FR) and Sud-Vest Oltenia (RO) (the still lighter shade of blue on map 28).

Almost half of the point source emissions from the ETS area in 2011 came from fossil fuel combustion in these 18 regions. The local governments of the 18 regions do not control the solutions to the problem of transformation. They are mainly controlled by the EU and national governments. The challenge of transformation to a green economy, however, is markedly different to these regions than to regions with no point sources.

7.11. Regionalised non-ETS carbon budgets

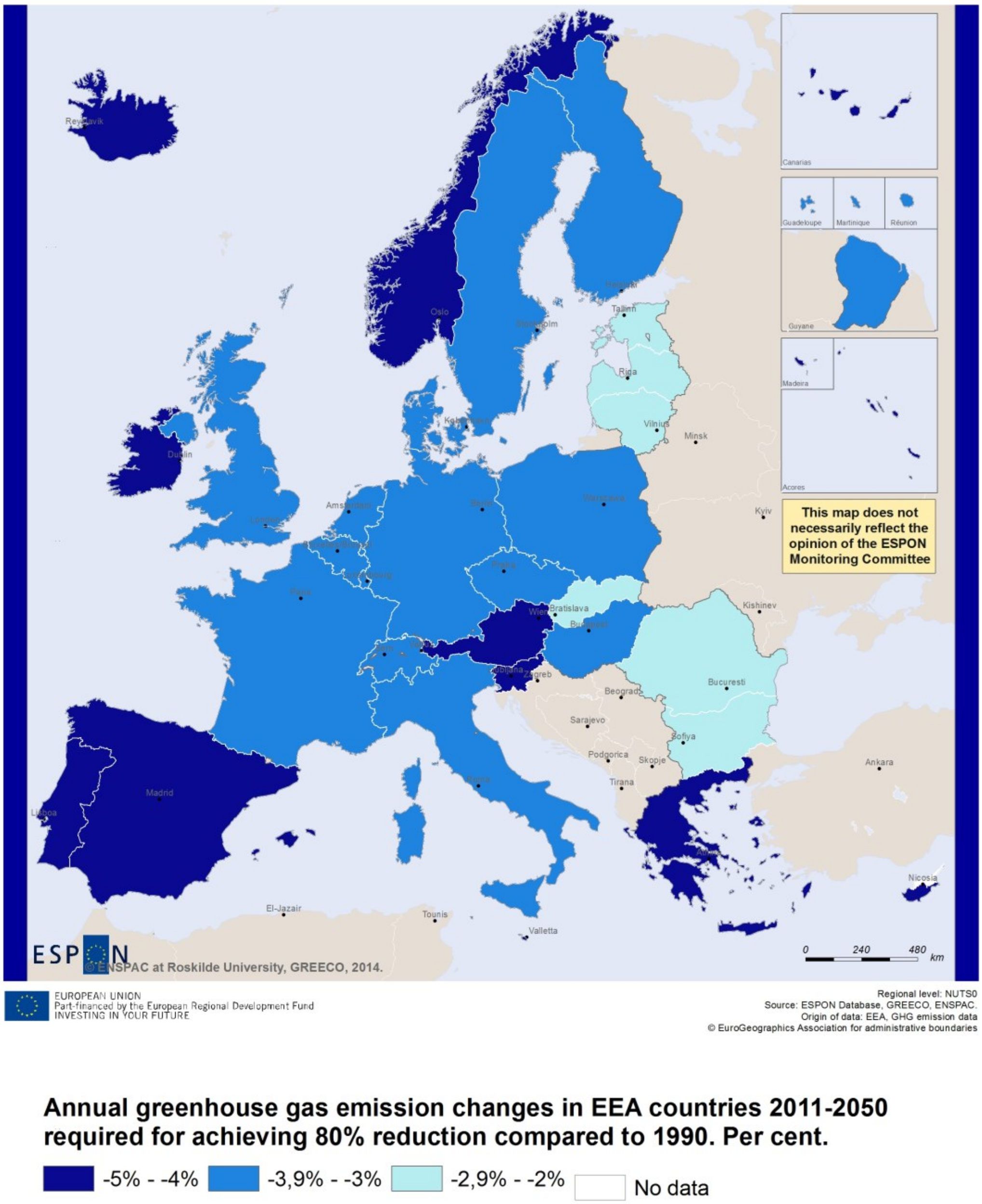
The expected CO_2-emissions above are of no use as baselines or monitoring indicators, as they do not reflect regional changes in CO_2-emissions that deviate from the national. Nevertheless, according to the EU effort sharing agreement the rate of emission reduction for a member-state depends on the income level of the member-state. This principle can be transferred to the regions when regional CO_2-statistics are established.

Map 30 shows the changes in greenhouse gas emissions required through 2011-2050 to arrive at 20% of the 1990-level in European countries to be compared with the emission changes through the 2008-2011 period (Map 29).



Map 29. Annual changes in greenhouse gas emissions from European countries 2008-2011. Per cent per year.
Source: Author's calculations based on GREECO datasets (Hansen 2013b).

As shown in map 29, the years of a dramatic drop in GDP in 2008-09 followed by a temporary recovery 2009-11 contributed to a substantial reduction in GHG emissions in most of the European countries.



Map 30. Required annual growth in greenhouse gas emissions from European countries 2011-50 for achieving 80% reduction compared to 1990. Per cent per year.
Source: Author's calculations based on GREECO datasets (Hansen 2013b).

The carbon budgets are politically recognised when governments commit themselves to achieve targets either unilaterally with credible long term institutions such as a climate act or in international agreements.

The early targets for CO_2-emissions following the Toronto agreement in 1988 was to return to 1990 levels in year 2000 and reduce emissions to 80% of the 1988 emissions by 2005. The first target was achieved in Europe, but the 2005 emissions were far higher than the target. These targets, however, were not legally binding.

The Kyoto targets for 2008-2012 include all greenhouse gasses and offsets and are legally binding. The targets do not include international bunkers.

As a party to the convention and the protocol, the EU15 committed to reduce GHG emissions by 8% of the 1990 emission level. The EU decided to fulfil the commitment jointly, but differentiated between member states according to "expectations for economic growth, the energy mix and the industrial structure" (European Commission 2002a). It was assumed that expectations for economic growth is inversely related to GDP per capita as the economies with low GDP per capita are expected to catch up with the economies with high GDP per capita.

This EU approach to burden sharing lies in the continuation of the principles adopted in the UNFCCC of common but differentiated responsibility. According to this approach, countries with stronger economic and technological capacities should commit to larger emission reductions than countries with smaller economic and technological capacities.

The EU adopted unilateral targets of 20% emission reduction in 2020 and the Commission has proposed 40% reduction in 2030, all relative to 1990. Figure 10 shows that the 20% and 40% targets are above the linear emission reduction path starting in 2010. This is because the emission level in 2010-11 was lower than corresponding to a linear emission reduction path from 1990.

The 20% emission reduction target for 2020 is, however, not the preferred climate policy for the EU. Staying within the sustainable GHG emission budget calls for an emission reduction target of 30% of the 1990 emissions in 2020. However, if the rest of the world does not engage equivalently in climate policy, there is a risk that European industries lose competitiveness. Thus, as long as it is a unilateral commitment, the EU target is only a 20% reduction by 2020 (European Commission 2010d).

For the EU (+ Norway) as a whole, the carbon budget is divided between the ETS sector and the non-ETS sector. The ETS sector includes large fossil energy consumers defined as a starting point as plants with a boiler of 20MW effect or more. International aviation is also about to be integrated in the ETS-sector. The non-ETS sector includes residential and transport use of fossil energy as well as productive use outside the ETS sector and emissions of other greenhouse gasses.

The carbon budget for the ETS sector is laid down in the ETS directive (European Commission 2009e). The non-ETS emission budget is allocated to each member state in the effort sharing decision (European Commission 2013o) continuing the Kyoto burden sharing principles of joint fulfilment of the common target through differentiated targets for the individual member-states. The common ETS and the non-ETS emissions allocated to each member-state in each of the years 2013-20 are shown in figure 11.

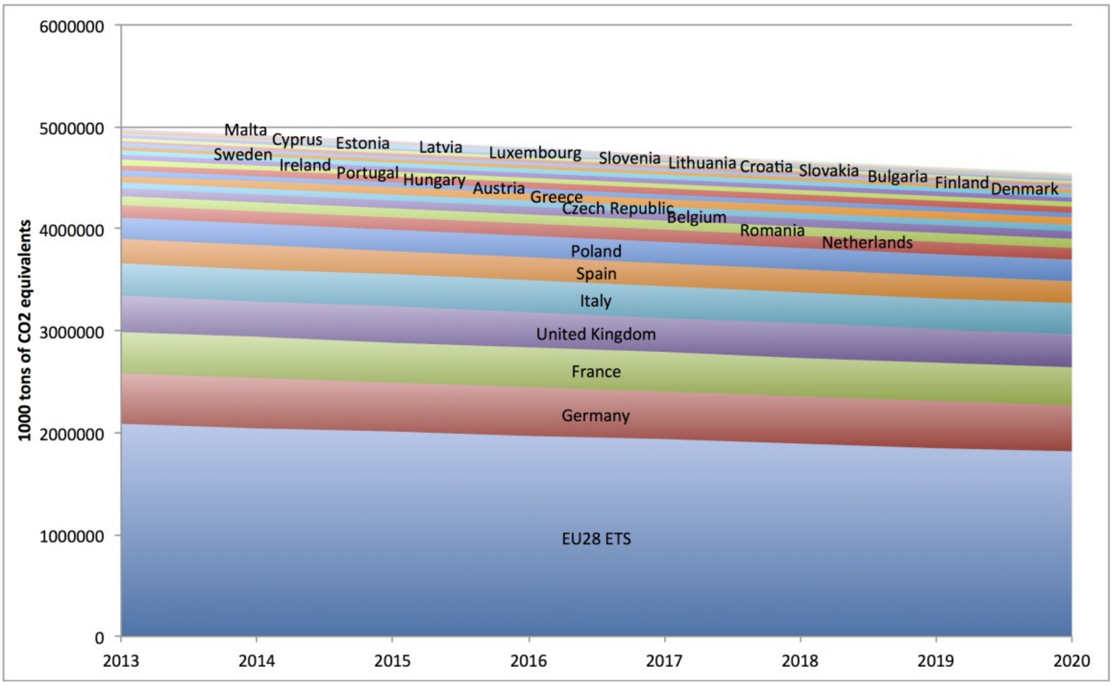


Figure 11. The EU GHG emission budget 2013-20 (Excl. international bunkring, offset credits and saved allowances). 1000 t.
Sources: Author's calculations based on the ETS directive (European Commission 2009e), EU Commission (European Commission 2013g) and effort sharing decision (European Commission 2013o).

The non-ETS emission budget for each member-state is adjusted considering their prospective economic growth. As in the case of Kyoto burden sharing it is generally expected that the future economic growth in the period depends on the per capita GDP at the outset. A country with a lower GDP per capita is expected to grow faster than a country with a higher GDP because it can take advantage of the technical and organisational solutions that have already successfully been implemented in the country with a higher GDP. This "catching up" hypothesis is supplemented with a distributional aspect, leaving a higher share of the EU effort with the economically stronger member-states.

The budgeted change in emission budgets is related to income levels as shown figure 12 below.

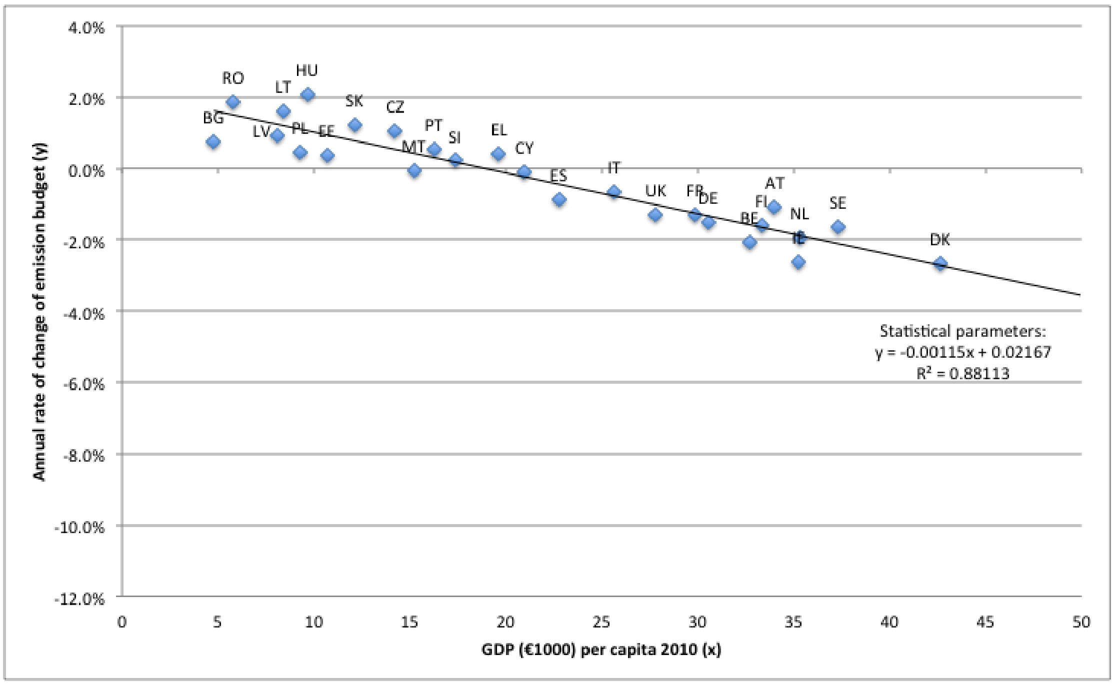


Figure 12. Dependency of reduction rate of annual non-ETS emission budgets on income level*.
Source: EU Commission (European Commission 2013o) and EUROSTAT (European Commission 2013h).
** Luxembourg is considered an outlier and excluded from the analysis due to its high income level.*

The income-adjusted emission reduction efforts shown in figure 12 actually allows for increased non-ETS emission in all member states with a lower per capita GDP in 2010 than Cyprus, that is, the other new member states, Portugal and Greece. This is only compatible with a lower EU-wide budget if the emission reduction efforts of the other member-states are correspondingly stronger. Moreover, the carbon budget used in 2010-20 cannot be used again later on. A higher carbon budget in 2010-20 implies a smaller budget in 2020-50.

It should be noted that member-states might unilaterally adopt tighter emission budgets for the 2010s. The emission reduction target of the Danish government, for instance, is 40% in 2020 heading for a 100% decarbonisation in 2050 (Danish Energy Authority (Energistyrelsen) 2013).

There are important economic potentials in completing more of the decarbonisation process in the present decade rather than postponing it to later decades. Despite temporary fluctuations the relative prices of fossil fuels are be expected to be increasing in the long-run until the global demand for fossil fuels declines.

Thus, advancing the decarbonisation allows the economy to mitigate the otherwise foreseen fossil fuel drag on the economy cf. figure 38 and figure 39.

The costs of decarbonisation are also higher, the higher the pace of transformation. A more even pace of transformation will be better for cost competitiveness later on. There are costs, but also first mover advantages in terms of future export potentials of developing productive capacity in the future technologies before others.

The cascade of crises and recessions since 2008 has left large productive potentials in Europe unused. Therefore, economies may gain from advancing future investments for decarbonisation to the present. These economic potentials must be balanced against the prospective decline in the cost of the renewable energy and energy saving technologies, but at an international level this cost decline only materialises as a result of cumulative use of the technologies. Some economies have more to gain than others from new renewable technologies. Denmark, for instance, with its rich wind resources and outstanding wind technology expertise has much to gain from wind energy technology and thus has an incentive to invest in wind technology development although all countries eventually will benefit from it.

7.12. Regional emission budgets

Regional economies may also achieve economic gains from advancing the decarbonisation targets relative to the EU 20-40-80 targets. The Covenant of Mayors is an EU initiative uniting municipalities and cities with ambitions of being on the more ambitious side of the EU targets (Covenant of Mayors 2013). It now includes more than 5000 signatories. The city of Copenhagen, for instance, have decided to become the first carbon neutral capital by 2025 (Copenhagen Municipality (Københavns Kommune) 2013).

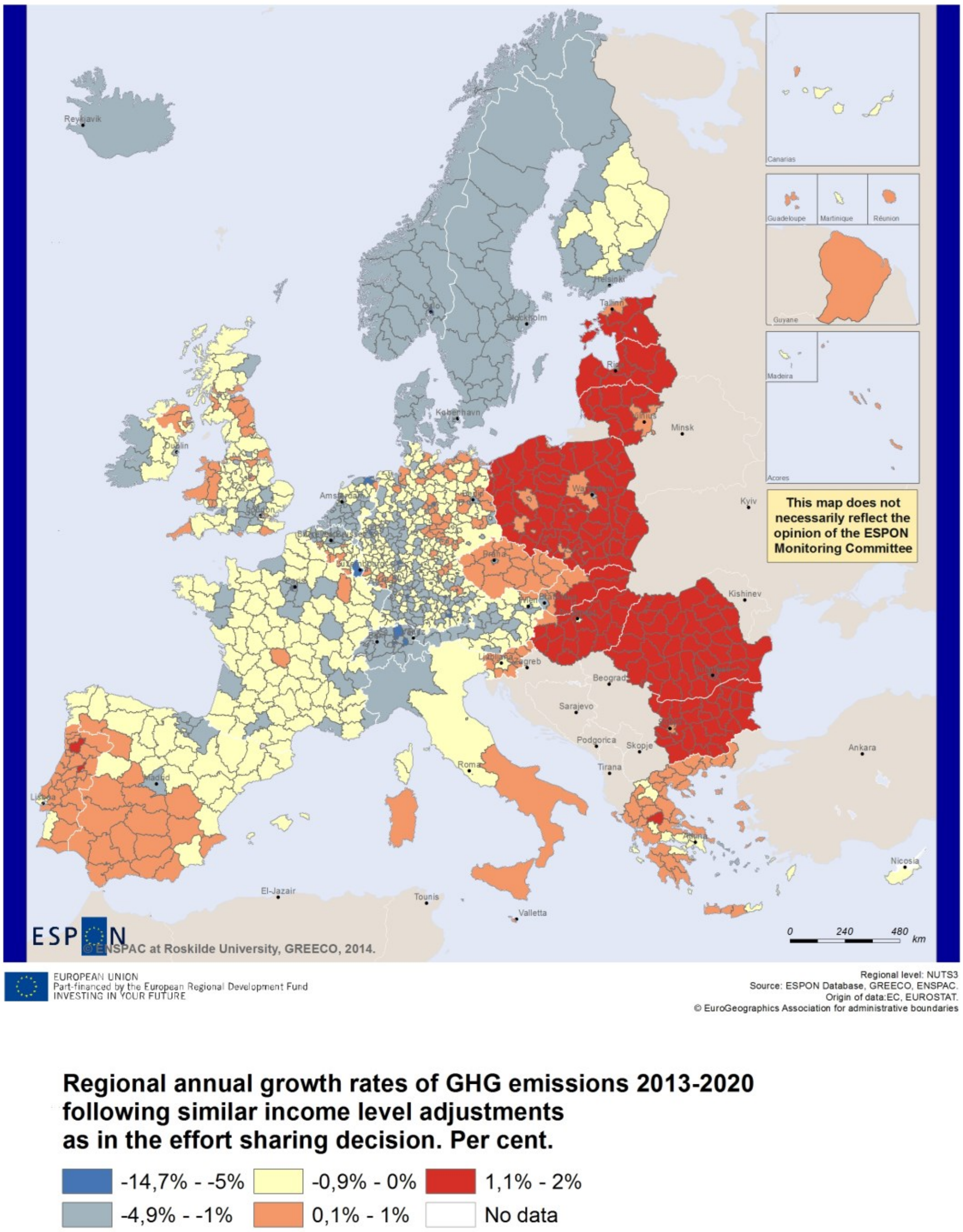
The member-state budgets are not allocated further to NUTS2 or NUTS3 regions. This would also be difficult as the regions play different roles in the division of labour inside the country and in the EU. Blast furnaces and paper mills are, for instance, not located in the City of London and the head quarters of large banks are not located in rural areas. The energy requirement associated with the industrial structure of the region should be recognised in a regional budget allocation.

Nevertheless, it could be useful to have benchmark-figures reflecting the rate of non-ETS emission rate reduction typical for economies with the income level of the region.

Many regions have potentials for cost efficient emission reductions far beyond the national targets. Many regions and cities have joined the Covenant of Mayors. Despite a national target allowing an increase in non-ETS sector emissions in new member states, the signatories have committed themselves to 20-40% emission reduction from the non-ETS sector in their regional territories (Covenant of Mayors 2013). The potentials identified concern, in particular, the energy consumption for heating and cooling of buildings. Following the same approach, the regional indicative targets should be adjusted for regional potentials for cost-effective emission reductions.

This is, however, easier to do for a region in economic and population decline than for a growth region. Thus, the regional emission-budget should be adjusted according to population growth.

The conclusion is, that a useful regional benchmark figure for non-ETS emissions would be the income-adjusted rate of emission change (cf. figure 12) plus the rate of population change. The regional potentials for advancing the transformation of, e.g., the building stock should also be considered when the regional authorities define their budgets. Map 31 below shows the income-adjusted rate of emission change by NUTS3 regions following the statistical pattern of figure 12.



Map 31. Benchmark rates of change for budgets for non-ETS GHG-emissions from NUTS3 regions 2013-20. Regionally differentiated by GDP per capita following the effort sharing principle of differentiation. Per cent per year.
Source: Author's calculations based on EU burden sharing agreement (European Commission 2008a).

The regional income-adjusted benchmark rates follow the same pattern as that of figure 12. In addition, the emission budgets of high-income regions in countries with more average income levels would be reduced at a faster pace following these income-adjustments.

The whole idea of regional emission budgets or targets, however, requires that energy statistics is collected with a regional coverage that enables statistics at least by NUTS2 regions, but preferably at as high a spatial resolution as possible.

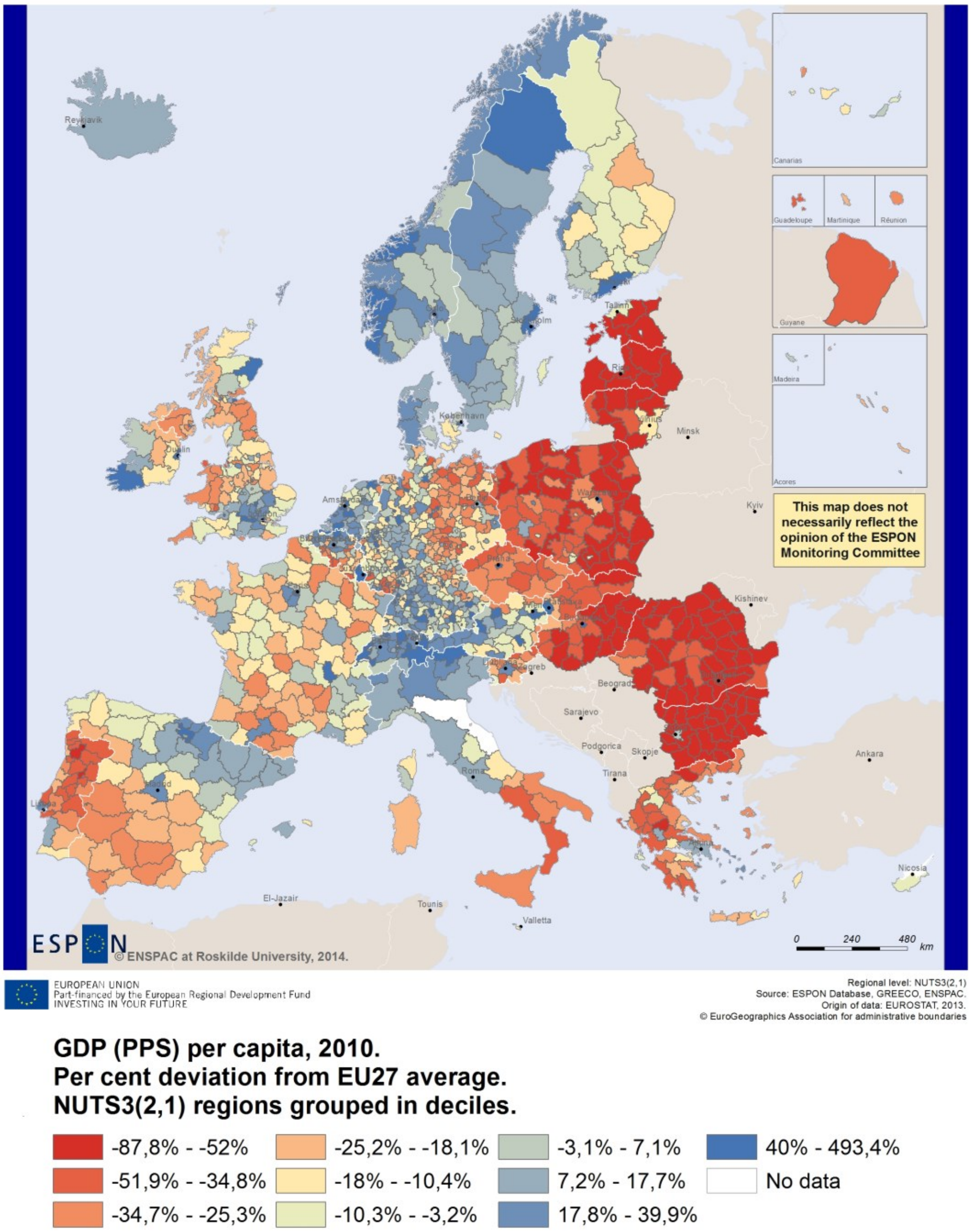
At the present, data on the use of fossil fuels at a level of detail enabling regional statistics are only collected in some countries. The predictions shown in map 25 and map 26 are in the nature of the case not useful as indicators of the actual emissions.

The variation in emissions between countries and regions can be attributed to the economic activity producing it, the final energy consumption required to generate the economic activity, the gross inland consumption required to generate the final energy consumption and the fossil fuel consumption share of the gross inland consumption. Regional data on energy consumption are available in some countries. They do not necessarily follow the same statistical definitions, but it has been possible construct the partly regional and partly national level statistics on final energy use. The fossil fuel consumption share equals one minus the non-fossil energy share. Non-fossil energy is includes nuclear and renewable energy. The regional datasets generated through the GREECO project on final energy consumption and renewable energy potentials are described below.

8. Economic balances and budgets

8.1. Productive potential

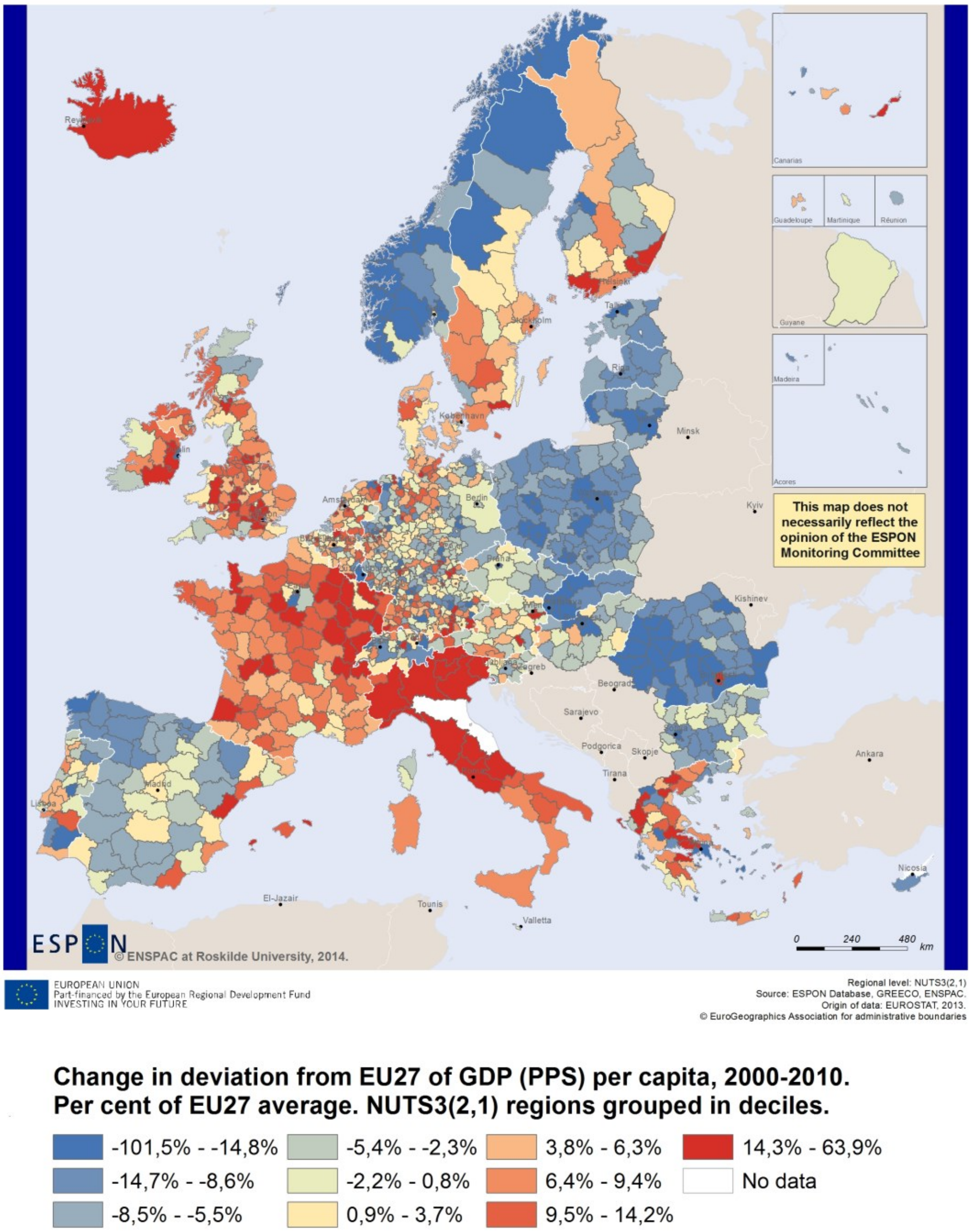
Economic growth can be seen as the unfolding of the productive potential of a region. Economies with a more developed productive potential have in practice demonstrated solutions and technologies that are still only possibilities in other economies. Due to the public good character of technology and the positive external effects of using it, the solutions can spread to the other economies. This is called the "catch-up potential" of the other economies and they are expected to have a higher economic growth.



Map 32. Income disparities in Europe, 2010. Per cent deviation from EU27 average of GDP (in PPS) per capita.

The position of the European regions relative to the EU27 average of GDP per capita is shown in map 32. The map shows the dispersion of income levels in 2010. The sharpest contrast in average income level is still between the EU15 and the new member states (NMS10). Income levels in almost all regions of the new member states were still in 2010 far below EU average. Note that the changes in income levels in the period 2008-10 were turbulent with a very wide range of income drops in 2008-09 and an equally wide range of income increases in 2009-10. Therefore, the position of individual regions in the pattern of income disparities in 2010 can be *transient*. The Polish NUTS3-region of Legnicko-Glogowski, for instance, observed a GDP increase of 30% from 2009 to 2010, which led to an income level of 13% above the EU average.

Map 33, however, shows that this pattern with large catch-up potentials remains after period of considerable catching-up from 2000 to 2010. Convergence in economic performance is a very long-term process.



Map 33. Change in deviation from EU27 of GDP (in PPS) per capita, 2000-2010. Per cent of EU27 average.

The continuing specialisation of individuals and production units of an economy leads to economic growth and this is also expected for the high-income economies of Europe. The growth rate, however, is expected to be more modest than the growth rates of the low-income economies that additionally realise their catch-up potential. They realise additionally growth from a high rate of investment in a capital stock closer to the EU average.

8.2. The constant capital stock approach

A standard interpretation of the intergenerational ethics of sustainable is that total wealth or capital stock of the economy should not decline. That would be to pass on less to the future years than was inherited from earlier years.

The total wealth or capital stock of an economy can be split in the human, the man-made and the natural capital. The man-made capital comprises the fixed capital stock plus the foreign wealth owned by the inhabitants of the country. The change in the man-made capital thus equals the savings of the economy. The savings must cover at least the consumption of fixed capital – depreciation or wear and tear – of the initial capital stock to keep it constant through the period.

The system of national accounts already allows for analysing this by distinguishing between gross and net income and production. The difference is the fixed capital consumption. The extraction of non-renewable resources resembles the fixed capital consumption and the natural capital consumption of the current generation should is a similar drag on the total capital stock.

The investments in human capital are difficult to estimate. They include the foregone income of students, pupils and apprentices due to their educational engagement and their public and private expenditures invested in teaching and in study facilities.

In conventional national accounting, the wealth of an economy is the value of the fixed capital and stocks plus the net financial wealth of its inhabitants. This is, however, a rather narrow definition of material wealth. The productive capacity of the economy also includes the human capital and the natural capital. Human capital enables the labour force and the firms to specialise and achieve high levels of productivity. Natural capital allows the production of raw materials and energy while harvesting a resource rent depending on the cost advantage of producing these goods at the territory of the economy.

The theoretical literature of sustainable extraction of non-renewable resources goes back to the time of the Great Debate (Hartwick 1977; Solow 1974). It has subsequently been enriched with contributions driving it more towards operational indicators. The operational sustainability criterion suggested against this background is the "non-declining total capital stock" principle. If the sum of the man-made, natural and human capital stocks decreases, the development is not sustainable. If one of them is reduced, it can be substituted by increases in one of the others.

The ethical principle behind this criterion is that the future generations are entitled to a stock of capital – generalised productive capacity. They may inherit more, but are not entitled to more than the same stock of capital as the present generation enjoys – at least for developed economies (Solow 1992; Solow 1974).

Due to this fundamental assumption of substitutability between the different types of capital, the sustainability criterion can be defined in financial terms. Economic development is financially sustainable if the total capital stock (the sum of man-made, human and natural capital) does not decline.

Adjusting the savings rate for this consumption of and investment in the various forms of capital gives a direct measure of whether the economy over-consumes in an inter-generational perspective. It leads to the *adjusted net savings rate* as an indicator of general over-consumption in the economy. Net-savings represent the difference between the consumable income and the actual consumption. Negative net-savings indicate over-consumption.

There are several levels of net-savings rate adjustment. The first level adjusts for the reduction of natural resource stocks (extraction minus natural regeneration). A second level additionally adjusts for the overconsumption of sinks such as unsustainable CO_2-emissions and PM10-emissions. The third level adjusts for the investment in education and a fourth level for other investment human (and even social) capital.

The international system of national accounts includes harmonised methods of accounting for changes in stocks and values of these natural resources. It is, however, much more difficult to arrive at reliable monetary estimates of the over-consumption of sinks. The results of the studies on these costs vary by orders of magnitude (See, e.g., Kuik, Brander, and Tol 2009). Internationally comparable datasets have recently become available for third level adjustments.

First level adjusted net savings rate of the EEA countries with data included in the World Bank database on adjusted net savings is shown in figure 13.

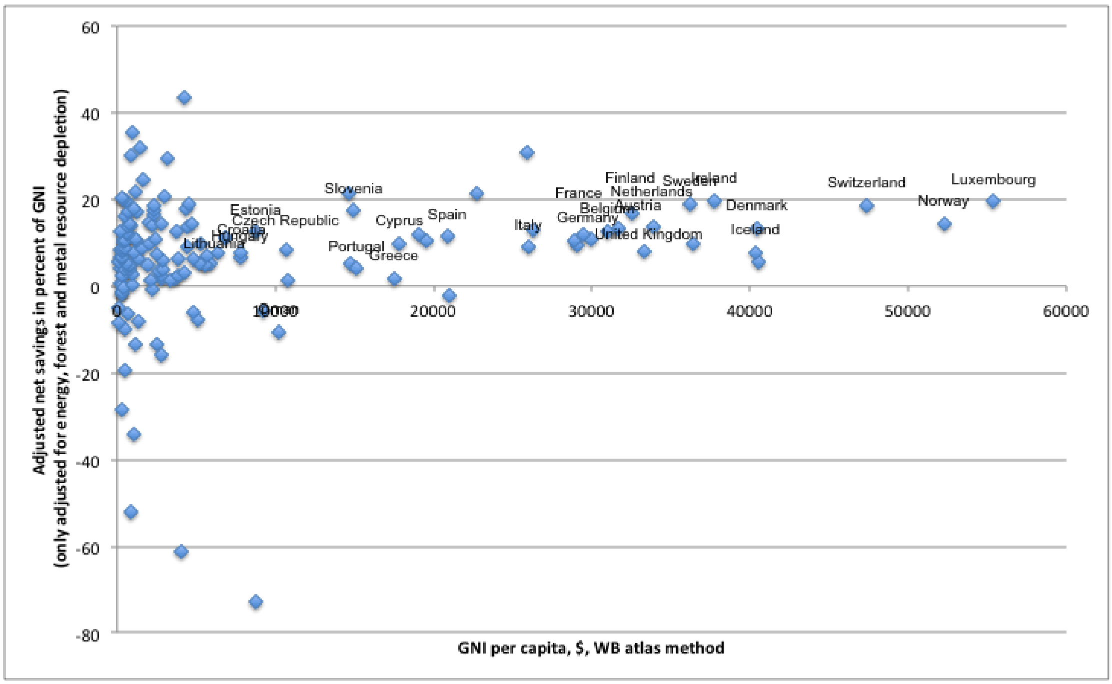


Figure 13. Adjusted net savings for 150 economies, adjusted for energy, metals and forest resource consumption, average of 2000-08. Per cent of GNI.
Source: Authors calculations based on the World Bank adjusted net savings database (The World Bank 2011).

Figure 13 shows the average adjusted net savings rate over the period 2000-08 where the net savings rate only has been adjusted for over-consumption of the resource budget so that fewer resources are left to posterity. For transparency, only the European economies are labelled by their name in the diagram.

The figure shows that the EEA countries generally had a positive adjusted net savings rate in the 2000-08 period. Greece 1.7%, Bulgaria 2.4% and Portugal 4.1%. The rest of the economies had comfortable net savings rates in the 10-20% band.

In second level adjusted net savings rate indicators, the overconsumption of sinks and space is expressed in monetary units. The World Bank, for instance, includes a cost per emitted ton of CO_2 and PM10 (The World Bank 2011). Others would claim that human lives and health, biodiversity and climate stability belongs to value categories that are unique and incommensurable. These are not substitutable by financial or man-made capital. They are "critical capital". Against this backdrop the literature distinguishes between "strong" and "weak" sustainability criteria, where weak sustainability ignores critical capital (see, e.g.,P. Ekins et al. 2003; Neumayer 2010).

It is important to note that the net-savings rate is a measure of financial capacity, which cannot measure ecological balances and compliance with sink and space budgets. These are matters for natural science.

The idea of strong sustainability implies a multidimensional framework such as the idea of "four capitals" including man-made, human, natural and social capital – the latter including financial capital as well (Paul Ekins, Dresner, and Dahlström 2008).

This perspective on sustainability lends from the framework of portfolio management where stocks of various types of assets can be exchanged and passed on from one year to another. The ecological assets do not fit well into such a paradigm. The carbon budget, for instance, cannot be halved from year to another and replaced by another asset. It takes time to replace the fossil fuel design of the econosphere with a sustainable design - at least a generation or two. In that perspective, what is passed on to future generations are not stocks of natural and man-made assets, but an economy that can work without the unsustainable flows of fossil fuel that the present economy is dependent of. With a given budget, however, the costs of one unit of pollution imposed on the rest of society (the "external costs") are the costs of other firms or households for reducing their pollution by one unit to keep the overall budget.

A positive net savings rate indicates how much an economy *could* spend additionally for purposes that do not add to future productive capacity, that is, investments that do not increase future GNI. It could be consumption or investing in other assets than those resulting in financial returns and marketable goods. For instance investments in ecosystem restoration, clean air and organic food that do not provide more economic value, but do improve quality of life.

Thus, Figure 13 shows that most European countries in the 2000-08 period have a comfortable financial potential for such investments. From a financial perspective, it is not a question whether it is possible to ensure economic sustainability and ecological sustainability at the same time. Most European economies could spend 10-20% of their national income on such investments without reducing the level of consumption in the future. Investments with a higher return in the form of environmental qualities, but a slightly lower return in the form of GNI could still underpin future consumption growth at a slightly lower rate.

Neither does the adjusted net savings indicator carry any information about what the saved income is invested in. This is unfortunate because investment in more of the unsustainable system of boilers and engines designed to use large amounts of fossil fuels will not bring the economy closer to a green economy, but investment in efficient systems of renewable energy, heat pumps and electro-motors will. Moreover, even high levels of investment can be in assets of dubious viability such as it was experienced in economies with a real estate bubble up to the financial crisis.

There is little doubt that many of the investments in the real capital stock as well in financial assets during the bubble 2005-09 were made in assets that would never deliver the expected returns. On the contrary, there was no demand for many of the services delivered by the real capital stock, whereas many of the financial assets turned out to be "toxic". Wealth added with such investments will be reassessed and unable to carry the future productivity implicitly assumed in the sustainability criterion of non-negative net adjusted savings.

When the UNEP refers to the 00s as an era of misallocation of capital (UNEP 2011) it also includes the necessary investments in green transformations that were not undertaken in the period. Thus, even when restricting the interpretation of the adjusted net savings rate in figure 13 to the economic dimension, it is important to recognize these delimitations of its field of validity.

The consensus on the intergenerational balance in economic development has given rise to a debate of what future generations really are entitled to. The political definitions of a green economy reviewed above point to their right of development and it could be a more operational approach than the paradigm of future generations being entitled a constant sum of various man-made and natural asset stocks. Then a the progress towards a green economy can be monitored by collecting data on the rate of installed fossil fuel boilers and engines vs. renewable electricity generators, heat pumps and electro-motors, the rate of replacing chemically harmful substances with harmless, replacing throughput solutions with circular supply chain management etc. The problem today is that data on these processes are not collected systematically and harmonised in the EU.

8.3. Fiscal sustainability

Fiscal sustainability is a central objective for the Economic and Monetary Union and not least after the fiscal crisis. The fiscal crisis revealed unsustainable financial budgets in the public sector as well as in the private sector.

The EU Commission developed in the 00s a criterion for fiscal sustainability, that is, avoiding over-consumption of government budgets. It was the gap between the primary balance of government budgets and the balance required for debt stabilisation in the long term. The criterion was expressed in per cent of GDP and can thus be interpreted as the additional taxes or reduced expenditures in per cent of GDP that theoretically would be required for stabilising debt. It was developed in two versions, S1 and S2, assuming government debt at 60% and 0% of GDP in 2050, respectively (European Commission 2006).

The analysis for 2006 showed that according to the S2 indicator, the EU economy as a whole was on a very unsustainable path with an S2-underfunding of public expenditures of 3.2% of GDP. The taxes collected in some member-states were up to 10.5% of GDP less than needed for financing public expenditure in the long run. Only Denmark, Finland and Sweden, Malta, Poland and Estonia had sustainable public budgets in 2006 according to the S2 criterion. Underfunding of the budget implies lower taxes in the year of under-funding, but higher taxes later on when the debt generated is paid back. S1 and S2 are measures of postponed taxes in per cent of GDP (European Commission 2006).

The underfunding of public budgets in the years around 2006 was also unsustainable in a short-term perspective. European governments pursue stabilisation policies and let automatic stabilizers work during recessions to reduce the decline in employment and GDP. This policy necessarily generates budget deficits that must be matched by budget surpluses in years with high growth. In large parts of the Euro-area, the government budgets were in deficit during the boom years adding to overheating of the economy. The resulting debt added to the motivation of governments to reduce deficits in the years with a weak economy and thus inducing a second recession in 2012-13.

The Treaty on Stability, Coordination and Governance (TSCG) lay down sustainability criteria for government budget balances at the national level in the "Fiscal Compact". Whereas budget consolidation is required for the long-term viability of any economic activity, the timeframe within which the consolidation must take place, is can vary.

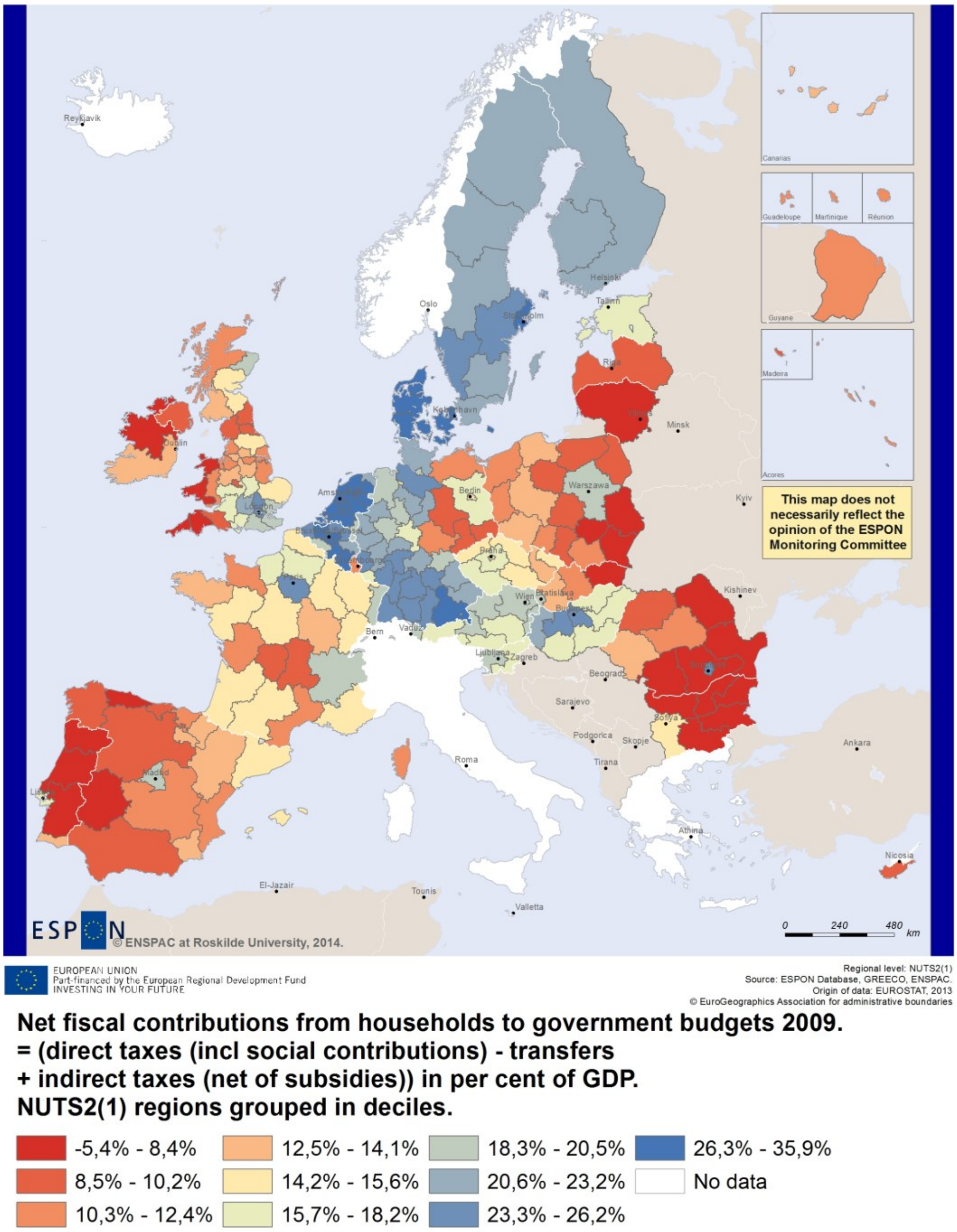
The consolidation strategy of the EU countries has negative impacts in terms of weakening aggregate demand further and positive impacts on restoring confidence of investors. Reviewing the economic models on which the policies were based, the IMF found in 2012 that they severely underestimated the negative impacts of the consolidation strategy with the tight timeframes (International Monetary Fund (IMF) 2012). The timeframe for consolidation was adjusted in 2013.

If Europe wants to return to a stabilisation policy - that is, dampening rather than amplifying booms and recessions -, a sustainability criterion would require governments to run budget surpluses in "good years" when growth is high and unemployment is low. That leaves room for budget deficits in recessions, when aggregate demand needs to be kept from spiralling down. Many European economies have done the opposite, resulting in high levels of consumption, investment and employment in the bubble-years that could not endure and very low levels of consumption, investment and employment during a prolonged recession.

The government budgets at the regional level are not aimed at stabilising macroeconomic fluctuations. This function is typically reserved for central government budgets. The local government budgets in regions and communities allocate funds between alternative services and transfers to the citizens of the region. Investment in human resources, infrastructures and living environments are important functions of these budgets.

The mobilisation of public funds and their investment in human capital, infrastructures and healthy living environments has been an important growth engine for the European economies in the 20th century. It has increased the rate of participation of women in the labour force and thus to a higher rate of employment. It has also expanded the productivity of the labour force.

These potentials are far from exhausted in all regions, but the mobilisation of funds is a necessary condition for realising such potentials. Map 34 shows the net fiscal contribution from the regional economies at the NUTS2 level to financing such investments. This indicator is similar to the "modified tax burden" (OECD 2000), but it does not include corporate and capital taxation.



Map 34. Net fiscal contribution rate, 2009. Households net contributions to government budgets. Per cent of GDP.

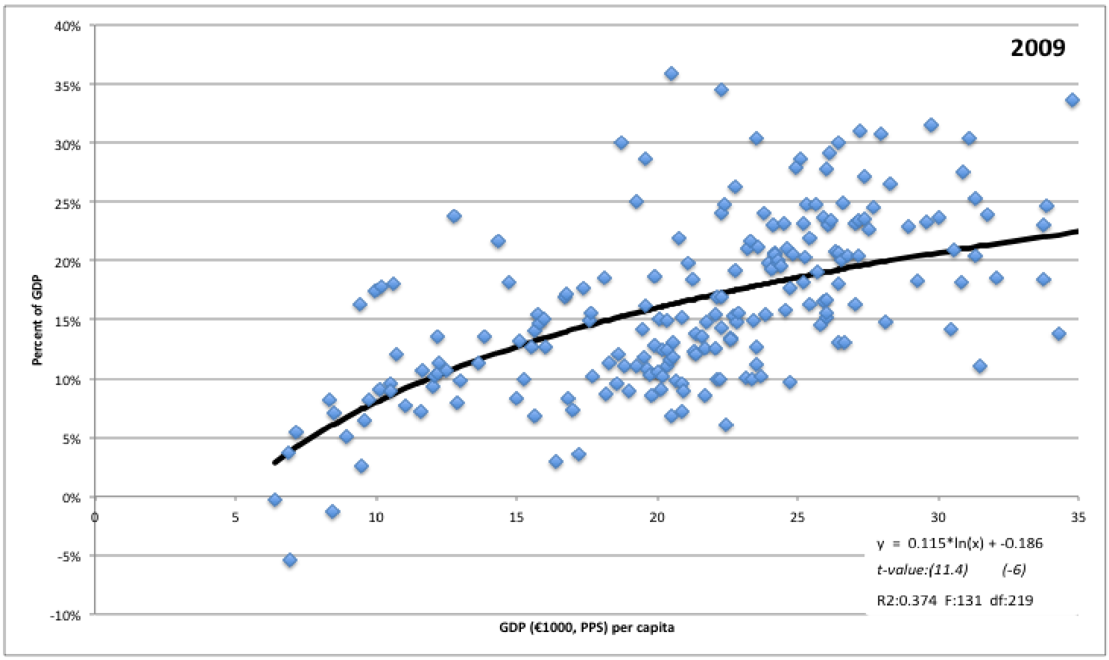


Figure 14. Income-level and net-contribution rate, 2009. Per cent of GDP and €1000 (PPS)/person. Net fiscal contribution (taxes net of transfers) from households to public budgets. Per cent of regional GDP. 2009.
Source: Author's calculations (Hansen 2013b).

Figure 14 shows the ratio of the net fiscal contribution of an economy to GDP as a measure of the aggregate income generated in the regions. The pattern shows that regions with higher levels of income not only generate proportionally higher levels of public funds. On average, the doubling of income level is accompanied by almost a doubling of the net fiscal contribution rate.

Whereas some regions have benefitted from the dynamics of investments in productive capacity of the region, higher GDP and still larger funds for investment, other regions are stuck in low-income traps unable to mobilise funds for investment. Some regions even receive more transfer incomes from the other regions than they pay in taxes. Thus, they receive financial support from other regions - not only in the same country, but also from other EU countries. This support may contribute to put those regions on a development path benefitting from the investment-GDP-public funds dynamics.

It is difficult to define an operational criterion for the net-financial contribution that is financially sustainable. The stabilisation criteria discussed above for central government budgets are not directly transferable to local government budgets. There is not one rate of net fiscal contribution that is recommendable for all regions, not even all regions in a country.

The regional specialisation leads to differences in income levels. Metropolitan regions specialise in corporate headquarter functions, government institutions etc. all which need highly specialised and well paid labour and services. Other regions specialise in industries that intensively use low-skilled labour. Some regions "specialise" in being a good area for retired citizens, nature and tourism ensuing relatively low levels of primary income. Thus, the surpluses that can contribute to public finances must be expected to differ between regions.

The link between localisation and specialisation patterns and income levels means that the redistribution between households in different income groups will also have an interregional dimension. As shown in figure 14 some regions were even net receivers of public funds from other regions. A permanently negative net fiscal contribution, however, can hardly be classified as "sustainable" and permanent transfers from public budgets of other EU countries may be politically un-sustainable in the long run.

The higher rate of social contributions sustainability of regional budgets with low regional fiscal contribution rates have exhausted their own potentials for mobilising public funds may still have inadequate funds to get on the

It should further be noted that the regions differ with respect to commuting. Regions adjacent to metropolitan centres often serve as commuting hinterland to these. Thus, they have more out-commuters than in-commuters and these out-commuters often have higher incomes. Thus, the tax in such regions will tend to be higher in proportion to GVA and GDP than in proportion to the incomes of the residents. This is because GVA and GDP reflect incomes generated in the firms of the region, whereas the taxable income is the income earned by households and firms residing in the region. Regions with a high inward net commuting will inversely tend to have some of their high GDP or GVA taxed in neighbouring regions. In figure 14 this property causes a wider spread of the data.

9. Social balances and budgets

9.1. The meaning of "social"

The concept of "social" is a broad concept used with several meanings. It refers to society as a whole (cf. the above "social progress"), the redistribution of consumption opportunities and (social services and safety net) and the institutional frameworks in which we organise our collective actions such as democratic elections, citizen participation etc. In the international community, poverty eradication is the most important meaning of progress in the social dimension.

In the EU, "inclusion" is the key principle related to progress in the social dimension. Poverty eradication is the primary content of "inclusion", but in many EU countries with well functioning welfare-states, poverty has been reduced to a minimum and inclusion policies address a broader range of marginalisation mechanisms.

9.2. Social inclusion and government finance

The Brundtland Commission and the subsequent declarations and treaties from the international summits continuously stress the social dimension of sustainable development and the green economy. The heavy emphasis on the balance between present and future generations would be ethically inconsistent if not accompanied by similar concerns for people in the present generations.

The European experience from the second half of the 20th century is that the institutions making up the European welfare states have been effective instruments for achieving poverty eradication and social inclusion. Regions and sectors where citizens are exposed to poverty and social exclusion can catch up with regions where poverty and social exclusion are reduced to minor problem by learning from the European experience.

A high rate of employment and a high rate of social investments are key means to this end.

The indicators chosen for monitoring social balances in the EU sustainable indicators set and the Europe 2020 strategy contains Population at risk of poverty or exclusion (i.e., People living in households with very low work intensity, People at risk of poverty after social transfers or Severely materially deprived people). The Europe 2020 target is to reduce poverty by aiming to lift at least 20 million people out of the risk of poverty or exclusion.

The performance of the EU in becoming more inclusive by reaching its poverty reduction targets is not good. For the EU27, the number of people exposed to poverty and social exclusion have increased from 2009 to 2012: people living in households with very low work intensity, people at risk of poverty after social transfers and people severely materially deprived. The employment rate has declined instead of raised in the same period. There is no reason to believe that the performance should have improved in 2013 with its economic recession.

Achieving the poverty and employment targets is important for generating financial resources for investment in any economic development towards a green economy. The relation between the net fiscal contribution and poverty risk of NUTS2 regions appear from figure 15.

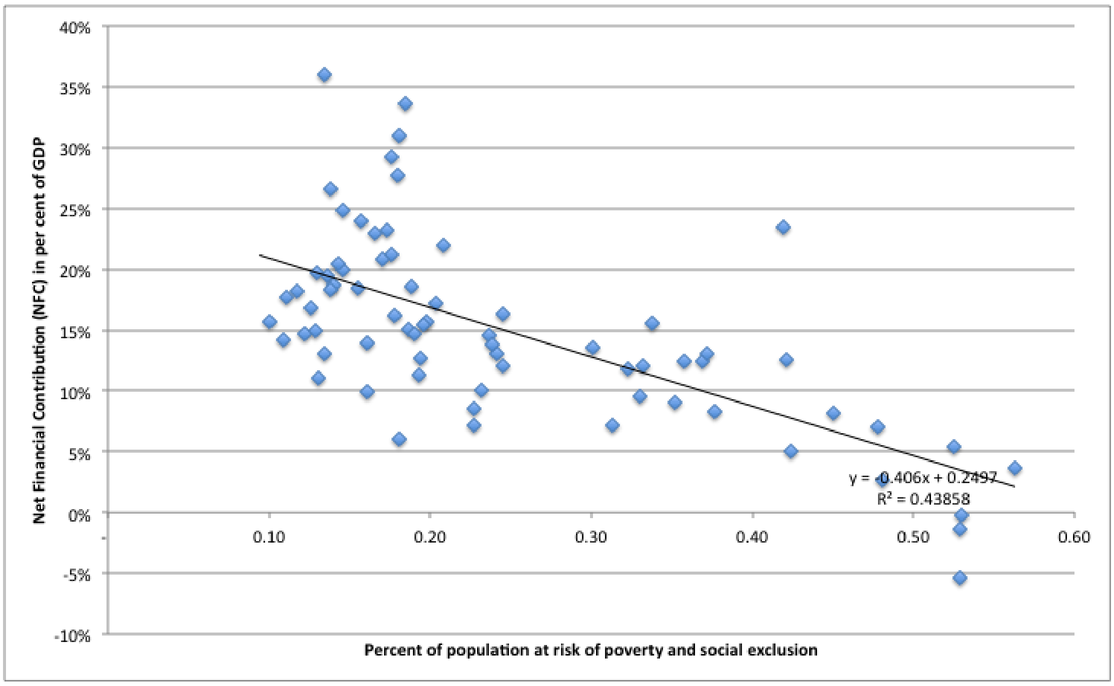
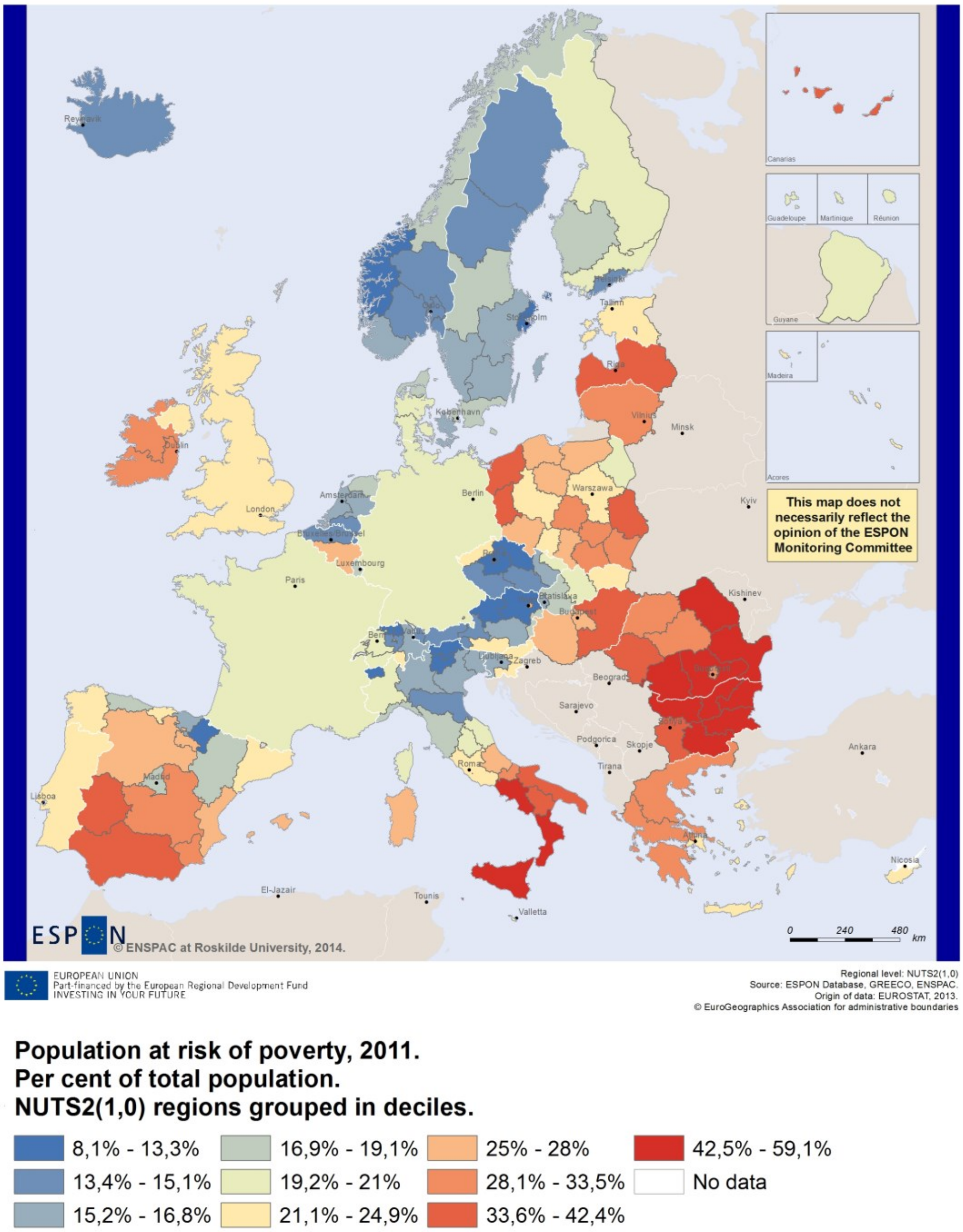


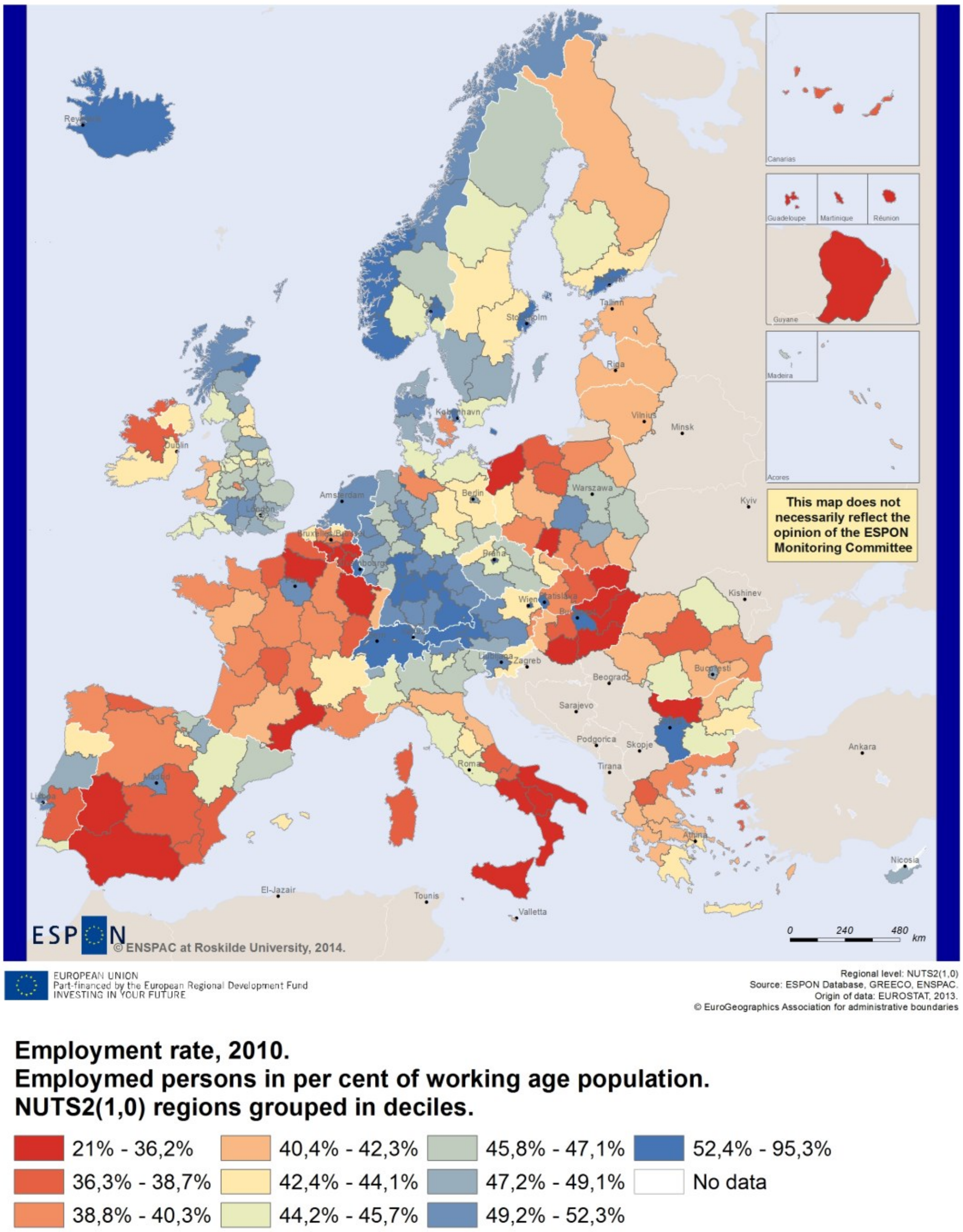
Figure 15. Dependence of the net financial contribution rate on the per cent of population at risk of poverty or other social exclusion in NUTS2 regions, 2009.
Source: Author's calculations based on the GREECO datasets (Hansen 2013a).

Achieving the EU target of bringing 20 million EU citizens out of the risk of poverty and social exclusion holds the potential of transforming entire regions from being net receivers of fiscal contributions from other regions to become net contributors or from being modest to become average net contributors. However, the poverty prone regions are also the regions that have most difficulties in mobilising the public funds required for breaking the vicious circle of poverty.



Map 35. People at risk of poverty and social exclusion 2011.
Sources: (Hansen 2013a).

The at-risk-of-poverty rate coincides to a wide extent with the rate of employment (inverse), but far from perfectly.



Map 36. Employment rate, 2010. Employed persons in per cent of working age population.
Source: Eurostat.

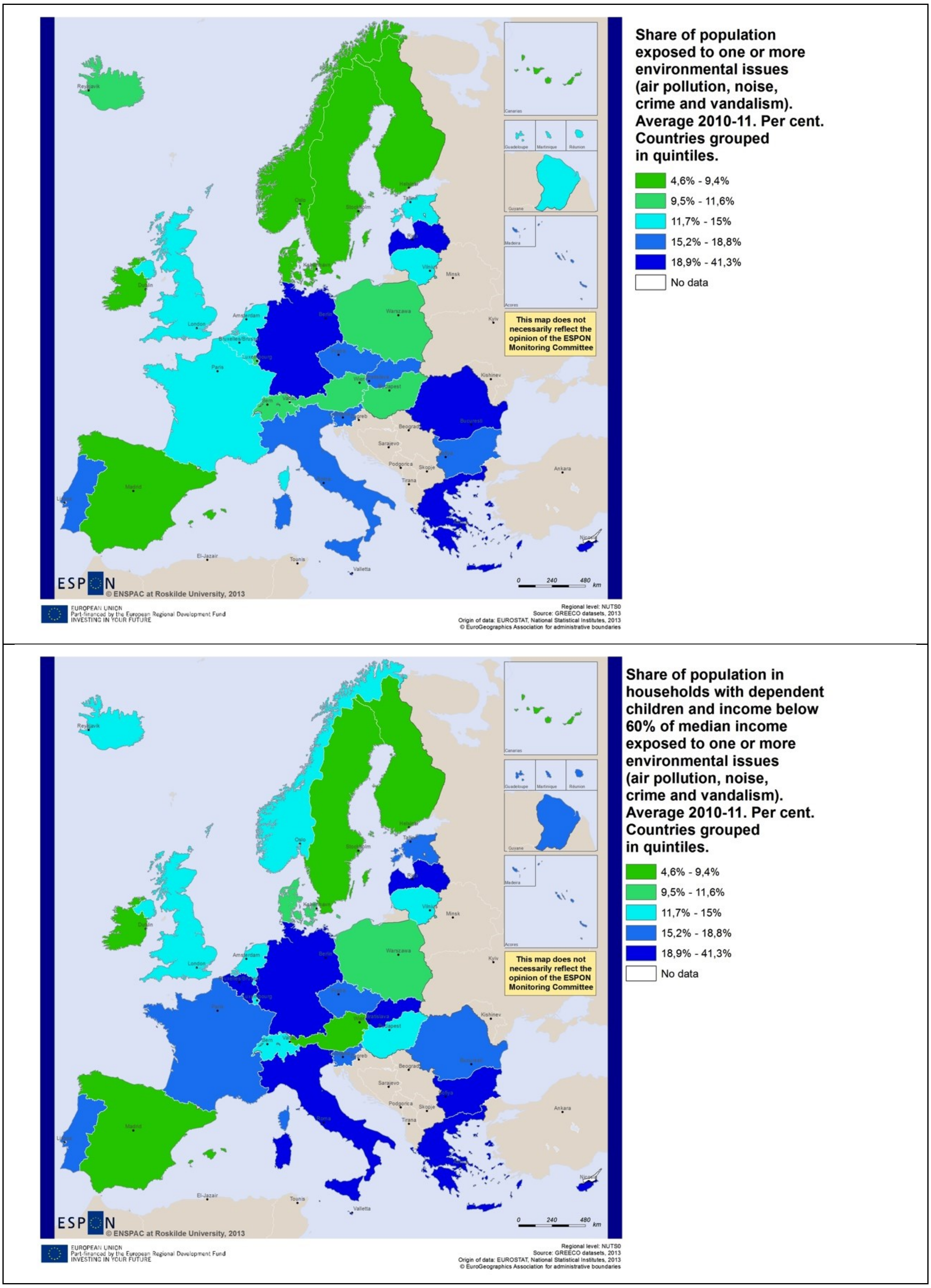
Map 36 displays how much the employment rate differs between regions. Together with the productivity of the employed and the age structure of the population is explains the differences in GDP per capita.

The transformation of the European building stock to a near-zero-energy standard has potentials for progress in all three dimensions. It is labour intensive with local demand. It saves expenditures for imported fuels. It reduces air pollution from fuel combustion. It raises the comfort of dwellings.

The employment effect may further contribute to a lower risk of poverty and a higher income and net fiscal contribution rate.

In urban agglomerations and their hinterland, the residential segmentation by income groups often follows ecological assets. Households that can afford residences in areas with green surroundings, low levels of air pollution and good water and waste infrastructure tend to prefer to settle in such areas rather than in areas with the opposite characteristics.

Thus, in many regions the social segmentation is reflected in spatial segregation. Including all segments of society in the social progress also means improving access to nature for areas with poor nature access, reducing exposure to air pollution in areas with high exposure and improving coverage of adequate water, wastewater and waste infrastructure in areas with deficient infrastructures.



Map 37. Share of population exposed to environmental issues (air pollution, noise, crime and vandalism), average 2010-11. Per cent. All households (upper map) and households with children and income below 60% of median income (lower map).

Source: Author's calculations based on Eurostat data.

The patterns of map 37 show that the European populations are exposed to environmental issues to different degrees. The same map based on data for households with children with incomes below 60% of the median income (at risk of poverty) shows that a higher fraction in most countries of this part of the population is exposed to environmental issues.

The differences, however, are not large at the national level of aggregation. The environmental issues primarily occur in and around urban agglomerations whereas in many countries a relatively large part of the rural population is at risk of poverty measured by their income level.

The environmental burden of disease in six European countries was estimated to account for 3% of the total burden of disease in Finland and 6.5% in Italy. The environmental burden of disease was calculated in discounted age-weighted DALYs per 1000 people with 3.9 in Finland and 7.2 in Italy (population figures weighted according to exposure) (Hänninen and Knol 2011).

Transformation policies themselves may also be related to redistribution mechanisms. It is important to reflect the external costs of fossil energy in the prices to enable investments in household and firms in energy efficiency and renewable energy. This is done by, e.g., energy taxes. Energy taxes move the tax burden from the energy saver to the energy user. In this way, the energy user is indirectly helping the energy saver financing the energy saving investments.

Since energy saving and energy using is largely independent of income, there is some minimum level of energy tax that everybody must pay irrespective of income. Thus, to the extent the income tax is replaced by energy taxes, unintended effects on redistribution can occur.

The energy bill makes up a larger share of the budget in low-income households than in high-income households. This pattern is pervasive in almost all European countries.

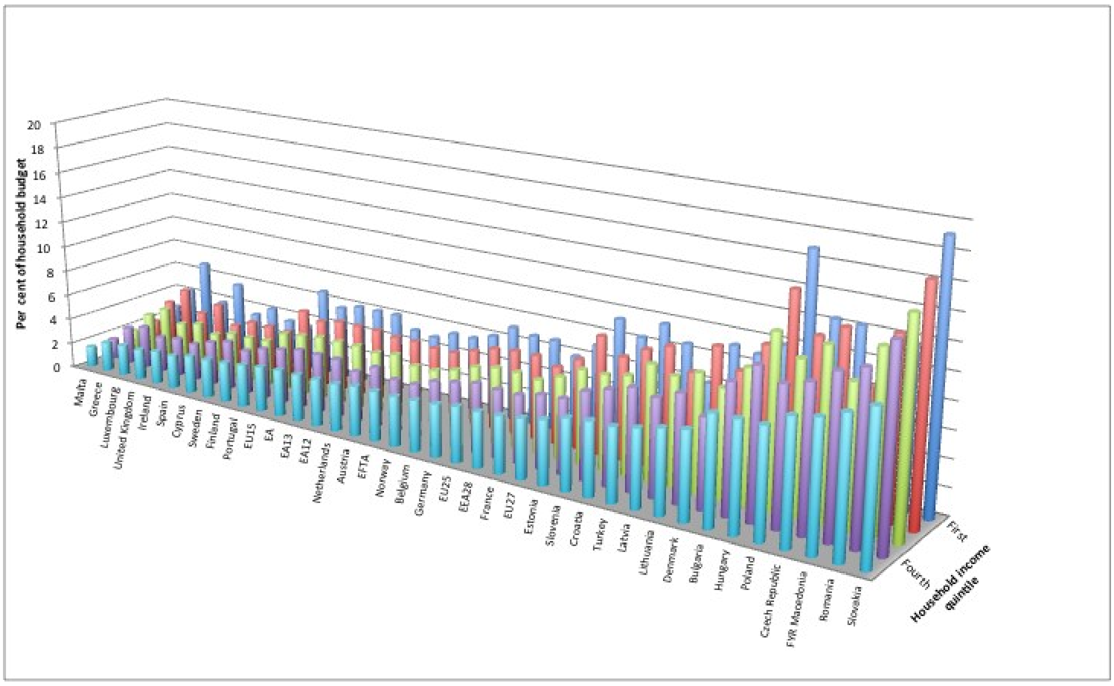


Figure 16. Share of energy expenditure in total consumption budget of households by quintile (first to fifth) in European countries, 2005. Per cent.

Source: Author's calculations based on EUROSTAT household budget survey 2005 (European Commission 2013i).

Figure 16 shows the share of fuels, heat and electricity in the budgets of European households by country and income quintile. In almost all countries these expenditures make-up a higher share of the consumption budget the lower the income quintile. Realising the economically attractive energy saving potentials in Europe could thus be expected to be particularly favourable to lower income groups.

The replacement of fossil (and in some countries nuclear) energy by renewable energy involves the additional costs of learning. The ability to master the efficient production and use of immature renewable technologies has improved dramatically over the recent decades and is expected to continue to improve over the next two decades. Thus, the additional cost of investing in wind and PV-technologies in the past are investments in the enhanced productivity of the technologies in the future. This applies to the investment in energy generating plants, infrastructure and electricity storage solutions as well. These costs, however, are typically financed via electricity, heat and natural gas tariffs and via energy taxes paid irrespective of income. Moreover, these costs may be born disproportionally by households to protect industrial activities from loss of competitiveness.

Energy is an essential good – i.e., we cannot live decent lives without a minimum of energy services – and the energy consumption of households is thus in the short-term not very elastic to changes in incomes and energy prices. Energy consumption to a high extent is build-in in the physical structure of the residential building and the equipment installed in it. Thus, final energy use changes relatively slowly in response to price changes.

Additionally, low-income households in the EU are more frequently tenants (as opposed to owners) than higher income groups. For tenants, the ability to respond to increasing energy prices by investing in insulation and more efficient heating systems is limited. For low-income households it is also typically more difficult to achieve adequate and low cost finance for such investments. Thus, higher energy prices tend to result in a higher share of energy expenditure in the household consumption budget of low-income households than of high-income households.

Thus, the energy delinking process may entail changes in the final distribution of consumption opportunities (real disposable household income). This type of unintended changes in the distribution of disposable *real* income involves a risk of jeopardising the *political* sustainability of the transformation process. In the recent years raising electricity and gas prices have given rise to political response with varying political consequences from Bulgaria to the UK.

The notion of energy poverty combined with imperative of eradicating poverty implies that some sort of right or norm regarding energy consumption must be defined for EU citizens. From a green economy perspective, it is essential to distinguish between consumption of energy and consumption of energy *services*. EU citizens may be entitled to a floor area of some size with a healthy temperature all year round, but not to a specific amount of energy consumption. The energy service measured in heated square metres is essential, but energy consumption due to the high heat loss from buildings is neither morally not economically well-founded.

Similarly, the distributional impact of green taxes cannot be assessed in isolation from the total redistributive effect of public budgets. In Denmark, for instance, household electricity consumption costs around c28/kWh due to electricity taxes. This is far above the electricity price of other EU-countries, but as the electricity tax gradually has been raised, it has been accompanied by higher income transfers and by compensating tax measures maintaining the social balance. Higher income transfers to pensioners, unemployed, students and citizens with sickness benefits. The tax and related measures include, for instance, raising the personal tax allowance, "children family checks", "senior citizen checks" and recently a "green check" compensating citizens at low-income levels for energy taxes. Other safety nets of the Scandinavian welfare system catch citizens that despite these measures should be on the route to poverty due to energy prices, if any. This example shows that it is perfectly possible to have high energy prices without energy poverty if the rest of the government tax and income transfer systems are designed to offset the unintended distributional impacts of the higher taxes or tariffs.

The available indicators of social inclusion combine the measures of low disposable income, inability to pay the monthly bills and exclusion from the labour market. These indicators will in the long-term capture adverse impacts of higher energy prices in the form of the poverty symptom of not being able to pay the monthly bills. In the short term, however, it could be useful for local as well as national government to monitor the immediate impact on household budgets of changes in energy prices whether induced by international prices, infrastructure investment financing or government taxes.

The patterns also underline the importance of introducing redistributive mechanisms when energy taxes on household energy consumption are raised. Fortunately, the revenue of such taxes also offers the means for neutralising unintended distribution effects. Otherwise, the durability and impact of such taxes is questionable.

Ensuring the social balance by providing subsidies to the heat loss the buildings in which low-income households reside would be unsustainable in the economic and the ecological dimensions. Subsidising commodities for distributional purposes is leads to over-consumption of the subsidised commodities and economic theory is thus clear on the recommendation that redistribution should use other taxation and income transfers for re-distributional purposes. Subsidising low-income heat loss at the same time as high-income heat loss is taxed is not financially sustainable. Enabling households to continue energy consumption for the heat loss is not ecologically sustainable. Subsidising the refurbishing or replacement of older buildings by near-zero-energy buildings can unite progress in all three dimensions.

Whereas taxes and income transfers are typically the responsibility of national government in Europe, renewal of the building stock is much more a task that lies with local government (from NUTS2 to the municipality level). The national government, however, must provide the necessary institutional framework, e.g., on the citizens' right to energy services and the instruments to ensure that the necessary investments take place. It is important also for local government to see these investments in supply chain perspective as for instance the oil-well-to-heated-floor-space chain requires other end-use investments than the wind-to-heated-floor-space chain.

A statistical framework that could enable benchmark-analysis of the state and progress of the building sector in the regions would be useful for the regional and local policies for catching up with the European standard. Identification and quantification of energy poverty and of floor space by heat loss and heating system would be easier. It would facilitate the comparison to "peer-regions", setting quantitative targets and monitoring the progress towards them.
Second, statistics on the exposure of the population in various areas to environmental risk such as air pollution, inadequate drinking water and sewage, noise, chemical pollution and other pollution issues would be useful.

The statistics referred to above is the exposure *reported* by the income survey respondents. If local government and regional policy actors want to address the ecological-social dimension it would be useful to develop statistical indicator frameworks based on the known exposure of different areas to link it to area-specific socioeconomic/income statistics. Many of the necessary primary data are already collected cf. the analysis of air pollution in Europe below and some of the data could be produced in a top-down procedure.

10. Decarbonisation and delinking

10.1. Transforming the energy econosphere

The general result of the decarbonisation process is the delinking of fossil energy use from economic growth. The standard tools monitoring progress in this transformation of the economy are indices of emissions or energy intensity (ratios of emissions or energy consumption to GDP). However, these indicators do not provide any information about development since they only register the ratio of the flow to GDP.

In times of economic collapse such as has been observed in the 1990s for many of the new member states and after the financial crisis in other countries, it can happen that energy consumption drops faster than GDP. That would show as reduced energy intensity of the economy, but it is not what we understand by sustainable development or building a green economy.

Deindustrialisation without new economic activity to replace it can also cause the population and GDP in some regions to decline over a longer period. The energy intensity can decline too, but it will not reflect a green economic development.

Thus, there is a need for a measure that takes into account the general trend in economic development.

Another distinction is the size of the change in resource efficiency as it is measured by, e.g., the energy intensity. In particular, it is important to know whether the progress in energy intensity is sufficient to reduce energy consumption in the light of the upward pressure from economic growth.

We present below an indicator of delinking that also takes account of whether the delinking is sufficient as well as of the overall economic development. Such an indicator must distinguish between delinking and relinking, absolute and relative delinking, absolute and relative relinking as well as between a growing or a recessive economy.

The mathematical model framework for the delinking measure is described in the appendix to this report. The variables included in the delinking framework for analysing the overall appear from table 5.

In table 5, the decomposing the growth of per capita emissions into annual average growth rates of the following variables:

Table 5. Components of the model for analysing delinking.

Variable code	***Label***	***Growth rate code***
Z	*CO_2 emissions*	z
GIC	*Gross inland energy consumption*	gic
FEC	*Final energy consumption*	fec
L	*Employment*	l
N	*Population*	n
Z/GIC	*Emissions intensity*	z-gic
GIC/FEC	*Gross/final energy consumption*	gic-fec
FEC/L	*Final energy intensity of employment*	fec-l
L/N	*Employment rate*	l-n

The growth of per capita emissions can be decomposed into the four key factors described in the lower five rows of table 5.

(6) $Z/N= Z/GIC * GIC/FEC * FEC/L * L/N$

The model defines changes in CO_2-emissions per capita due to changes in

- the emissions per unit of primary energy consumed
- the use of primary energy per unit of final energy consumed
- the use of final energy per employed person and
- the employment ratio
-

The figure below shows the result of decomposition or shift-share analysis based on this model.

The contributions to per capita emissions growth from the four key factors in the European countries are shown in figure 17. The countries are arranged according to the growth in their per capita emissions.

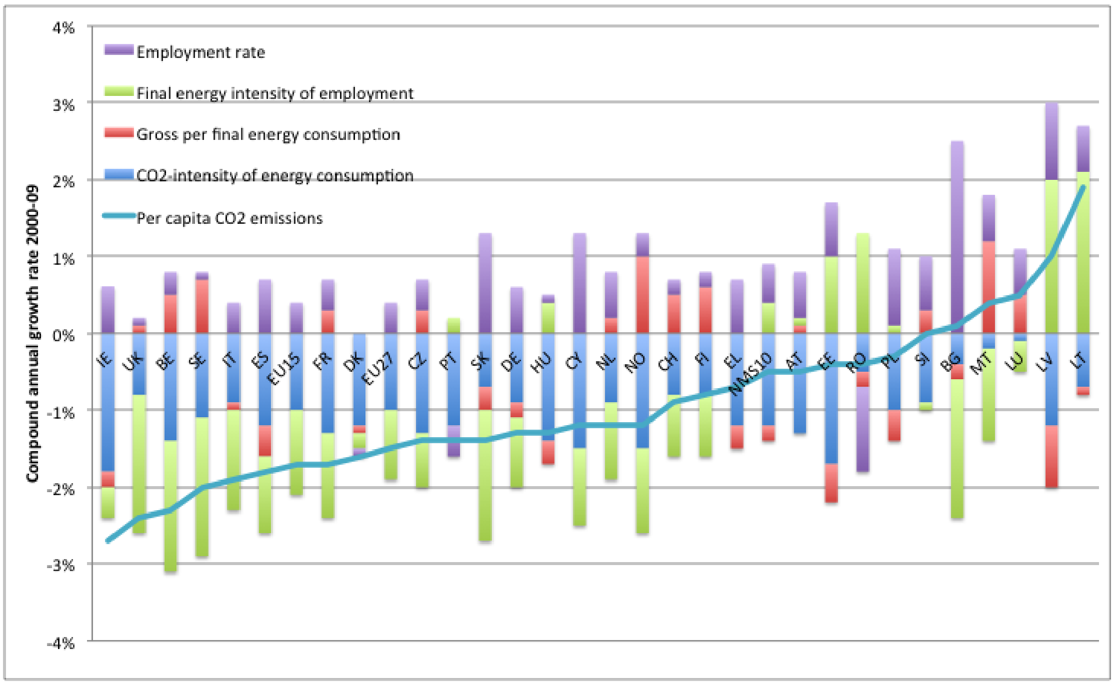


Figure 17. Factors affecting the growth of per capita CO_2 emissions 2000-09 in European countries.
Author's calculations based on Eurostat data.

The emission intensity of energy reflects the share of fossil fuels in gross energy consumption. The negative change in all countries reflects the combined effect of a growing share of non-fossil energy sources and less emission-intensive fossil fuels.

In most of the countries with decreasing emission rates, the energy intensity of employment has been a major factor behind the decreasing emission rate. All of the EU15 countries except Austria and Portugal share this characteristic whereas many of the new member-states have experiences an increase in final energy use per employed person (Hungary, Estonia, Romania, Poland, Latvia, Lithuania).

The employment rate[5] has increased in all countries except Portugal and Romania. This has pulled emissions in the opposite direction, that is, towards higher emission rates.

The gross per final energy consumption reflects the conversion and transport losses of the energy sector. It may, however, also be affected by the changes in the amount of energy that is imported or the fraction of final energy demand satisfied by on-site conversion. This factor is not systematically linked to the decline in the emission rate.

[5] This is the crude employment rate calculated as the employed persons in per cent of the total resident population (both national accounts concepts).

Countries with small emission reductions or even growing emissions include Slovenia, Bulgaria, Malta, Luxembourg, Latvia and Lithuania. The analysis does not reveal why these countries differ from the other countries as to the trend in emission rates. It is, however, consistent with the burden sharing agreement of how the Kyoto protocol commitments of the EU should be met by the individual member-states.

The conclusion is that both decarbonisation (emissions per unit of energy) and delinking (energy use per employed) have been more than sufficient in most EU countries to balance the upward pressure from economic growth (employment). This was even so in the most of the new member-states the economic growth of which was expected to increase CO_2-emissions.

Two methodological choices are of importance for the results. First, the period 2000-2010 is composed of a period before and one after the financial crisis in 2008 (or 2007-8). The trends could be quite different in the two sub-periods. Second, the growth rates are estimated as geometric compound rates rather than by log-linear regression. This choice could make start and end points influential.

11. Decarbonisation

11.1. Renewable energy potentials

The renewable energy directive sets the target of a 20% supply of renewable energy relative to final energy consumption (including transmission losses) (European Commission 2009b). The target has been allocated to member states as national overall targets for the share of energy from renewable sources in gross final consumption of energy in 2020. This also represents a set of commitments much like the above effort sharing decision.

The progress towards these targets achieved by 2011 appears from the figure below.

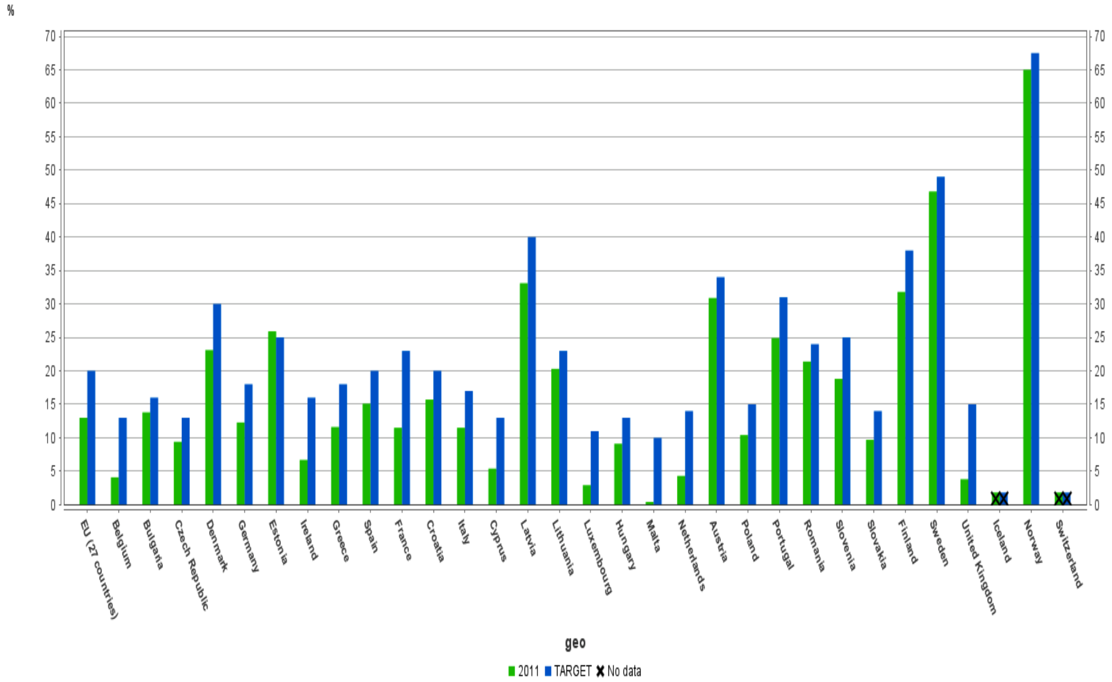


Figure 18. The share of renewable energy supply in gross final energy consumption by 2011. Per cent.
Source: EUROSTAT (European Commission 2013j).

The status of the renewable energy plan of the EU by 2011 is according to figure 18 is that 21 countries have attained more than half their targets while 7 countries still miss more than half of their targets. 1 country has even reached its target. The Commission expects the target to be more than achieved by 2020.

Obviously, many countries are able to proceed to higher targets than those originally committed to in the directive. Denmark, for instance, is expanding its renewable energy production to 36% rather than the EU-target of 30%. Such expansions will lower the need of CO_2-allowances in the future and enable a faster pace of lowering the cap of the ETS market.

The new target proposed by the Commission for 2030 is to generate 27% of the final energy consumption from renewables.

11.2. Regionalisation of renewable energy targets

The renewable energy targets for 2030 will be shared by the member-states based on voluntary commitments. They will be financed by the member-state arrangements according to state-aid regulation and supported by EU support mechanisms.

Each member-state will probably commit itself in proportion to its renewable energy potential. Thus, assessments of renewable energy potentials are very important to all member-states. The GIS based method for assessment of renewable energy potentials presented below can be useful in these assessments.

Installation of various renewable energy plants is very sensitive to the geographical context. Thus, the assessment method is designed to assess potentials at the NUTS2 level. Some member-states may find it expedient to further regionalise their commitments and in this process, such an assessment method may be useful.

11.3. Renewable energy potentials

11.3.1. Assessment methodology

The GREECO project has assessed the wind energy potentials of all the European regions. The scientific standard for assessment of renewable energy potentials makes use of a hierarchy of potentials. The physical potential refers to the energy in the environment that theoretically could be extracted. The technical potential is smaller because it is not practically feasible to extract that energy everywhere. Finally, the economic potentials are still smaller because not all practically feasible renewable energy installations are economically viable.

This structure is similar to the standard for assessment of fossil energy resources that distinguishes between deposits and ultimately recoverable reserves and a number of intermediate classifications. To be classified as a recoverable reserve, the cost of extraction must be lower than the price of the extracted material.

The renewable energy potentials available to Europe in this century include offshore and onshore wind energy, ocean energy, PV and concentrated solar energy, geothermal energy, ground and water energy and a variety of biomass based energy sources. In the GREECO project the economic potential of wind and PV energy has been estimated by region whereas the technical potential of biomass energy from agriculture and forestry has been estimated in the vol. 2.3

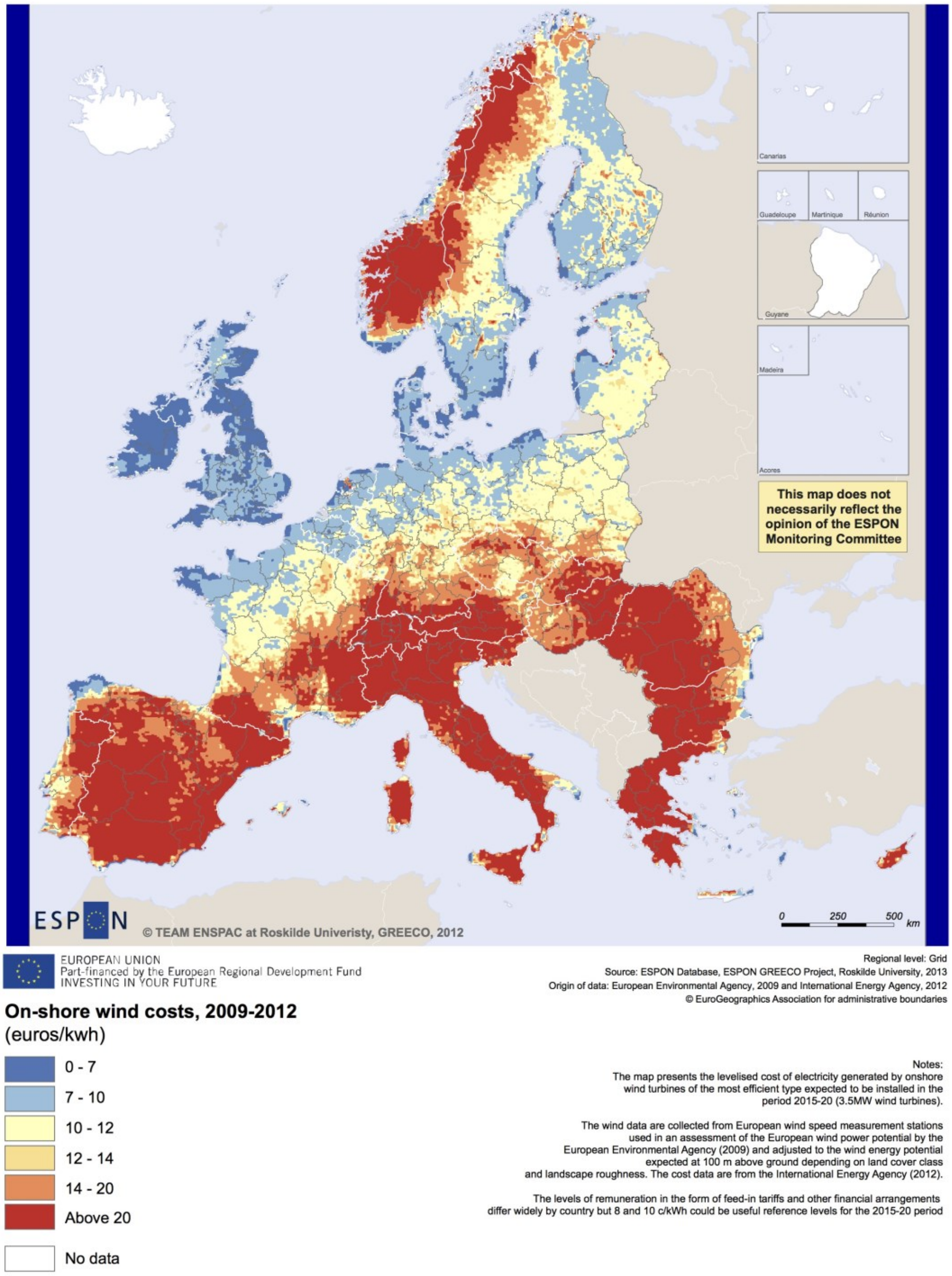
scientific report on Bioenergy Potentials. The wind energy potential from off-shore wind energy is probably in many northern European countries the most important renewable energy source in the future, but in this analysis the focus is on regional differences in renewable energy resource potentials.

In some cases, the primary energy commodity also may posses a social value beyond the market price. This can be the case if, for instance, it offers energy security and some degree of self-sufficiency and saves adverse environmental impacts of energy use. This is the case today for renewable energy technologies, but the of energy security has also endowed, for instance, coal with such a higher social value beyond the market price (European Commission 2010a).

A high social value is also rooted in the technological learning costs needed for making the renewable energy technologies competitive with the non-renewable alternatives. As the future low cost technology only depends on the investment in the technologies today, there is no do

The assessment of the economic potentials below are based on a social value of wind energy of 8 c/kWh and of PV energy of 10 c/kWh.

11.3.2. On-shore wind energy potentials

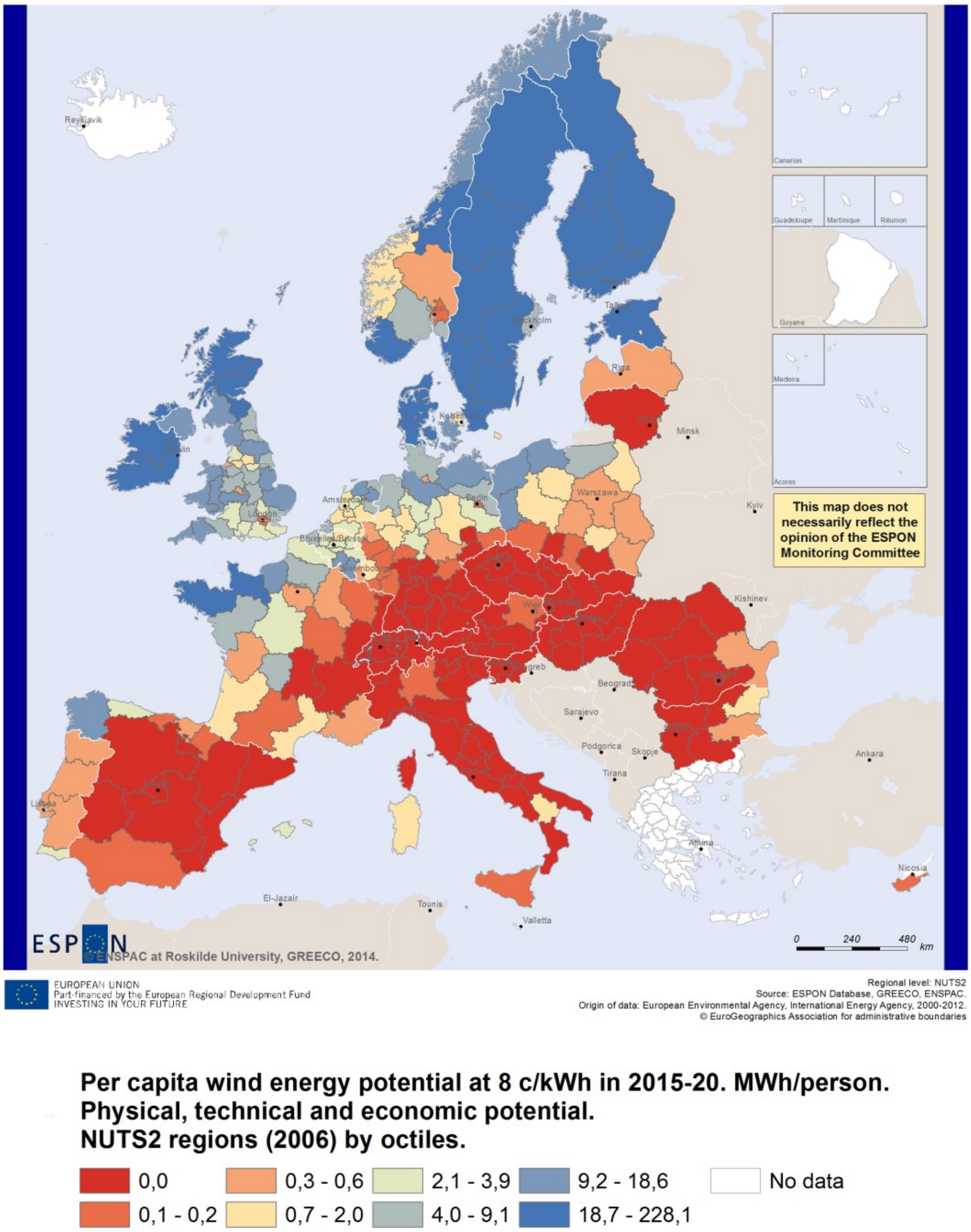


Map 38. On-shore wind costs, 2009-12.

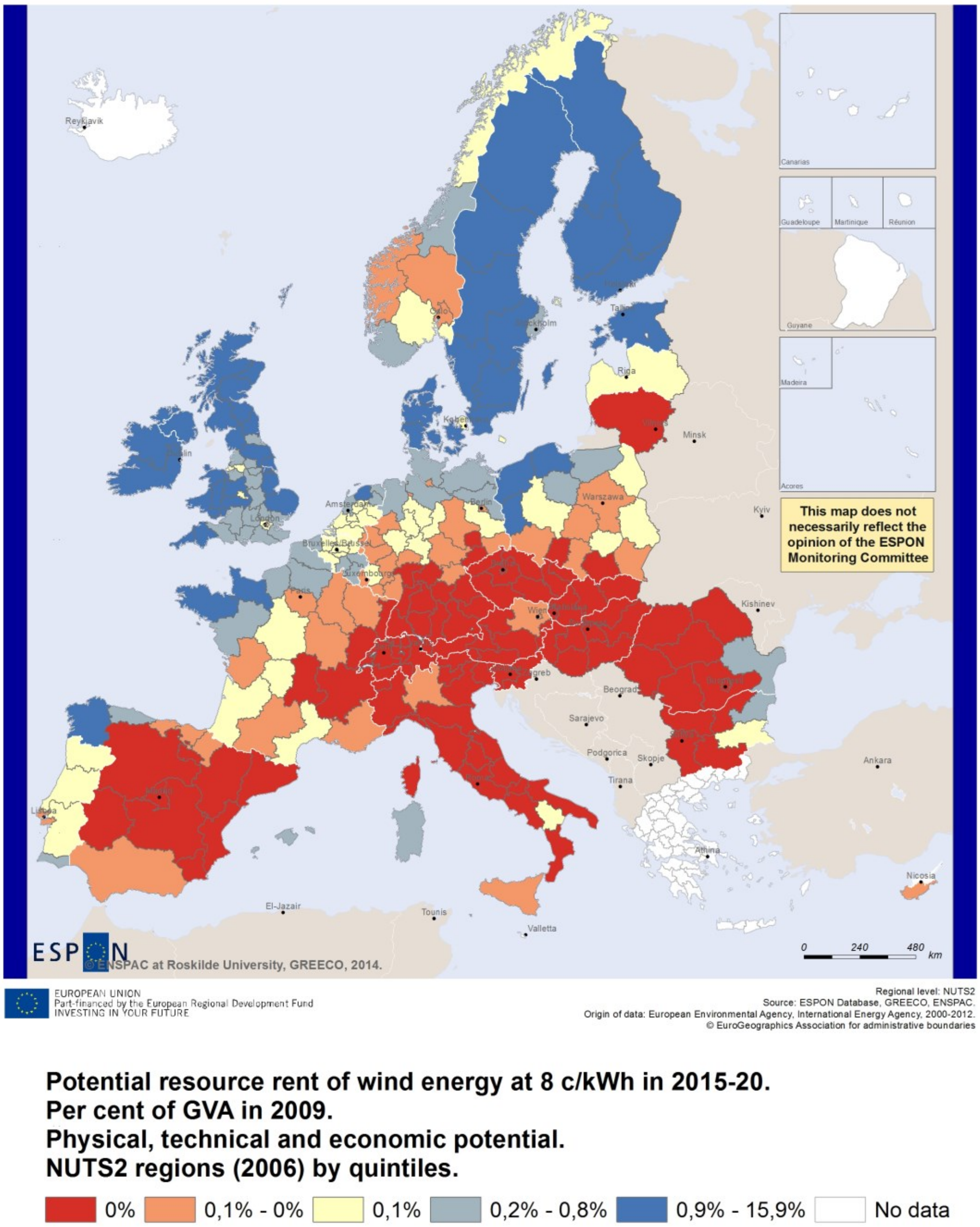
The physically and technically possible wind potentials are not necessarily useful as energy resources since the costs of generating electricity from them can be too high. Map 38 shows where wind potentials can become resources depending on the remuneration of wind energy that the society is willing to pay. This map shows that most of the onshore wind potential of Europe is located in a wind potential belt from Bretagne to Finland.

The wind potential that can actually be realized depends on land-use compatible with wind energy generation and the maximum density of wind turbines.

The assessments below are linear in the energy density. Thus, the wind energy potential assuming, e.g., 0.6 MWh/km^2 rather than 1.2 MWh/km^2 can be calculated as half the potential at 1.2 MWh/km^2.



Map 39. Economic wind energy potential per capita at a price of 8c/kWh and 1.2 MW/km2.
Source: Author's calculations based on GREECO datasets (Hansen 2013b).



Map 40. Potential wind resource rent in per cent of regional GVA (2009) at a price of 8c/kWh and 1.2 MW/km2.
Source: Author's calculations based on GREECO datasets (Hansen 2013b).

The potential wind resource rent shown in map 40 is the result of a meso-scale assessment, that is, all the pockets of good wind locations that can be revealed with micro-scale assessments are not included. In particular, potentials in mountainous areas probably underestimated. Wind energy potentials can on the other hand be overestimated because specific grid-connection and grid-enforcement costs are not included. They can be high in many regions, e.g., in remote areas like Northern Finland, Estonia and Scotland due to distance to grid etc. Finally, wind potentials can be considerable in higher altitudes but difficult to extract due to local circumstances. These and other uncertainties are subject to ongoing research aiming at encircling the costs of on-shore wind in different regions more narrowly.

Forest areas are included with the same density of 1.2 MW/km^2 as agricultural areas, but the possible future wind-energy density in forest areas is still subject to research. All potentials in areas designated for nature purposes are excluded.

The wind resource rent is defined as the social value of wind energy represented by an 8c/kWh feed-in price minus the expected levelised costs per kWh in 2015-20 multiplied by the amount of wind energy that can be generated competitively by wind farms at each location.

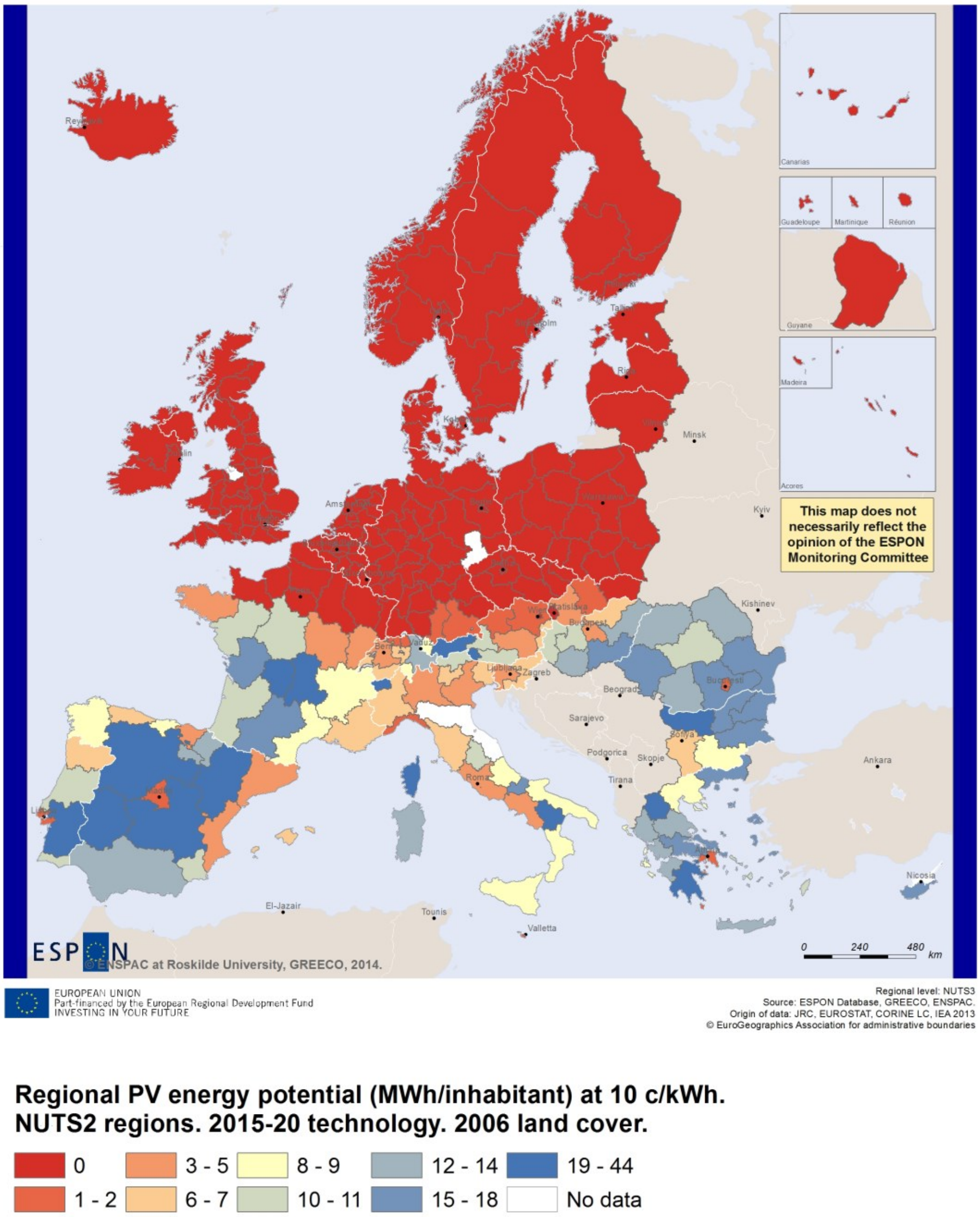
In any case, the map shows that there is a North-European wind-belt, where most of Europe's wind resources are located. It should be noted that the GREECO project also assessed the offshore wind energy potential. It is by far the most important renewable energy potential and it is mainly located in the North European wind belt too.

This has consequences for the regional patterns of the green economy. First, the resource rent of wind energy potentials can be a significant contribution to the income in many regions. Second, the geographical patterns of onshore and, in particular, offshore wind energy potentials will lead to new patterns in the trade of electricity. Wind power will be exported from the North European wind-belt to the rest of Europe. This will require reinforcement and expansion of the European transmission grid and energy storage capacity cf. map 65. The prospects of large scale concentrating solar or PV electricity generation capacity in the Mediterranean may lead to similar needs for transmission grid expansion and reinforcement.

The future reliance on renewable energy also forms the basis of synergies between energy producing regions and regions capable of electricity storage - primarily pumped storage in hydropower reservoirs - as well as smart grid/flexible demand solutions in all regions with access to the resource.

11.3.3. PV energy potentials

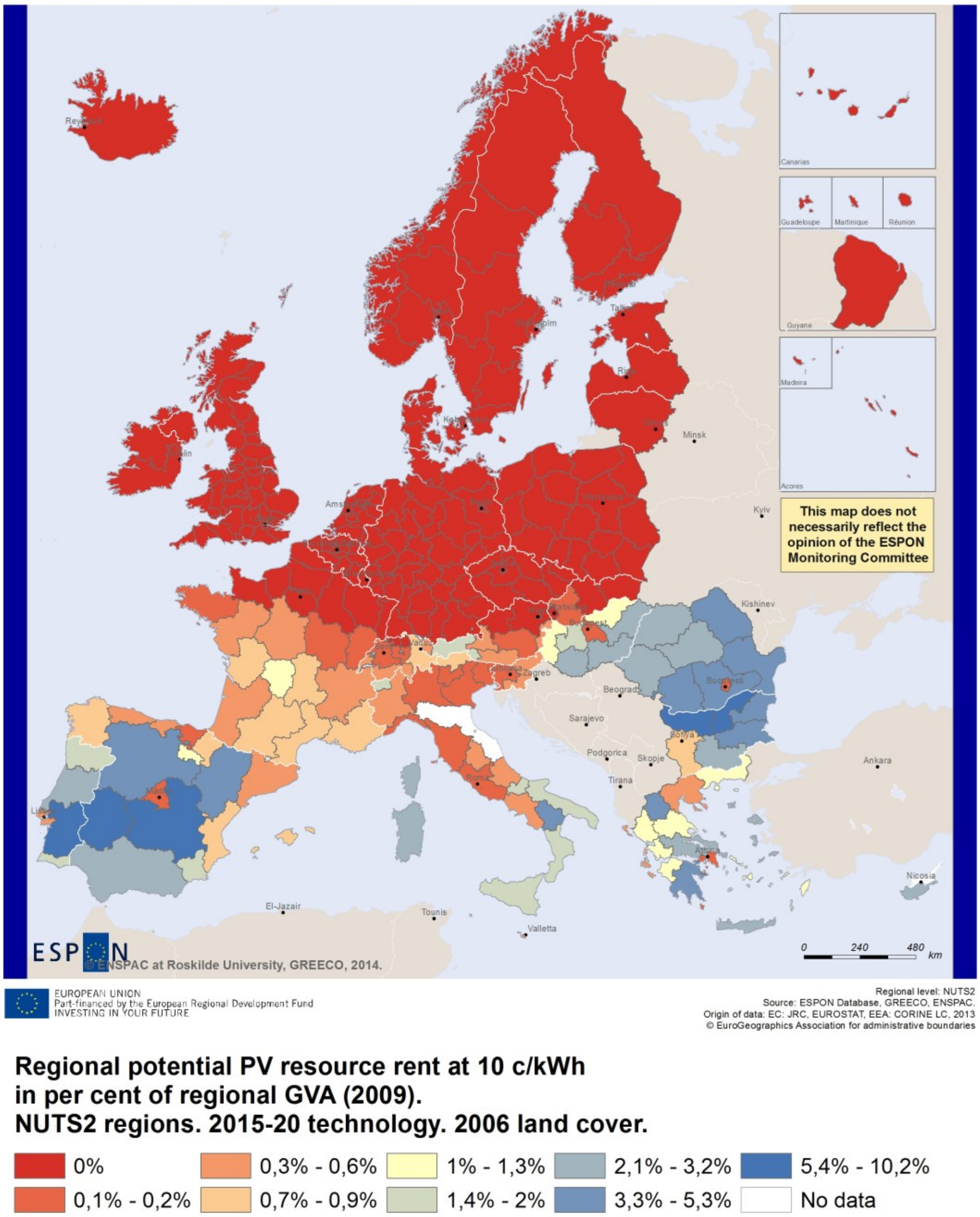
A similar assessment of the photovoltaic (PV) energy resource rent was made by the GREECO project with the following results.



Map 41. PV energy potential per capita (MWh/person) at 10 c/kWh.
Source: Author's calculations based on GREECO datasets (Hansen 2013b).

The PV energy potential is proportional with the solar irradiation and the area suitable for PV panel installation. Thus, it is no surprise that the richest PV potentials according to map 41 are found in the south.

The PV energy assessment includes the potential area of utility-scale as well as building integrated solar panel installations.



Map 42. Regional potential PV resource rent (% of GVA) at 10 c/kWh.
Source: Author's calculations based on GREECO datasets (Hansen 2013b).

The actual PV electricity generation has expanded considerably in the countries with 0% PV resource rent at 10 c/kWh. This is because the social value attached to PV electricity in the recent past has been much higher than 10 c/kWh reflected in high feed-in tariffs and direct and tax expenditures for that purpose.

11.4. Mediating conflicting interests in land use planning for renewable energy

Experience from the planning of onshore wind farms have shown that conflicting interests in land use planning may cause serious delays in the realisation of the wind energy potential. The same must be expected for utility size solar energy plants. Large technical installations in the landscape often have a negative effect on valuable landscape qualities and wind farms may additionally generate noise and shadow effects to the discomfort of neighbours.

Without additional institutional frameworks for reconciling such conflicting interests, there is an asymmetry of risk and reward built into the planning system. The central government obviously has an interest in achieving the commitment, but need consent from the local governments where the wind farms are to be located. The local government have no economic interest in the location of wind farms if residents outside the region own them. On the contrary, they may have negative effects on real estate prices, which could imply political "costs". In such a setting, many wind energy potentials are likely to remain undeveloped.

There are various ways to design an institutional framework for mediation of conflicting interests in wind farm planning. The Danish Renewable Energy Act provides such framework.

It offers a tariff premium for delivering onshore wind power to the grid supplemented with tax favours for owners of wind farms. Eventually, the premium contributes to the resource rent harvested by the owner of the wind farm. Part of the rent will be passed on to the landowner, who is liable to pay local taxes. To ensure that local residents are not only subjected to the discomforting side effects, but also get a stake in the resource rent, a series of arrangements have been introduced.

First, the wind project entrepreneur is obliged to offer at least 20% of the shares in the project to residents within a distance of 4.5 km from the wind turbine. Second, neighbours who experience a drop in the price of their property are entitled to compensation fixed by an independent appraisal committee. Third, the municipality is entitled to remuneration of around €12,000 per turbine to contribute to financing projects that can make the location more attractive.

Wind farms are often established by local *windmill-guilds*, but they have difficulties financing the pilot studies, establishing whether the project is feasible or not. These pilot studies are in the nature of the case very risky investments and a government wind energy security fund has been established for provides security for financing pilot studies, but the uncertainties relating to potential conflicts with landscape interests add to these risks.

An alternative arrangement to align local interests with development of the wind potential is to assign renewable energy obligations to each local government at regional or municipal level. They could be made tradable, which would make the total amount of wind power to be installed a matter for the central government but their specific location a matter for negotiations between local governments.

Local governments with little space for windmills considering the other interests in landscape values could compensate other local governments financially for taking on their obligations. Local governments with much space for wind farms could host wind farms that other originally was assigned to other local governments. The remuneration received could then be passed on to local residents who are affected by the technical installations.

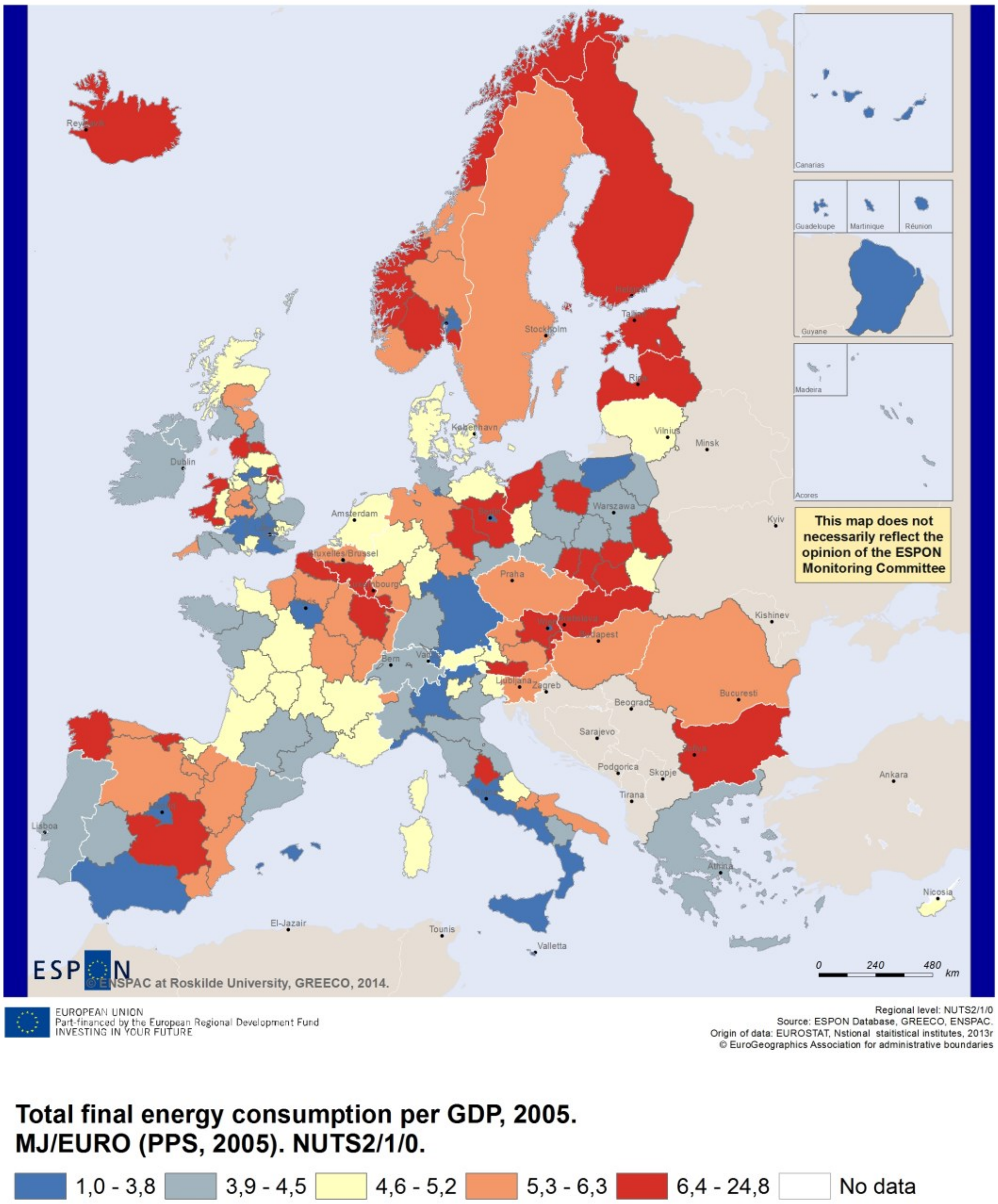
12. Energy dependency

12.1. Resource efficiency gaps and catch-up potentials

Energy use is closely linked to economic activities and any economic activity sets an energy chain into motion causing consumption of source and sink budgets along the chain. The final energy consumption is the energy used for specific economic purposes ignoring the energy consumed along the chain in conversion processes etc. Thus, the analysis of resource efficiency gap uses the final energy consumption related to general measures of economic activity (GDP in Purchasing Power Standards (PPS) per capita and population).

In the analysis below, the total final energy consumption by region is split into energy for production, residential and transport use. These data are not available at all territorial levels for all sectors and consequently, the maps below combine statics at more territorial levels.

Map 43 shows the ratio of total final energy use to the economic value created in the region.

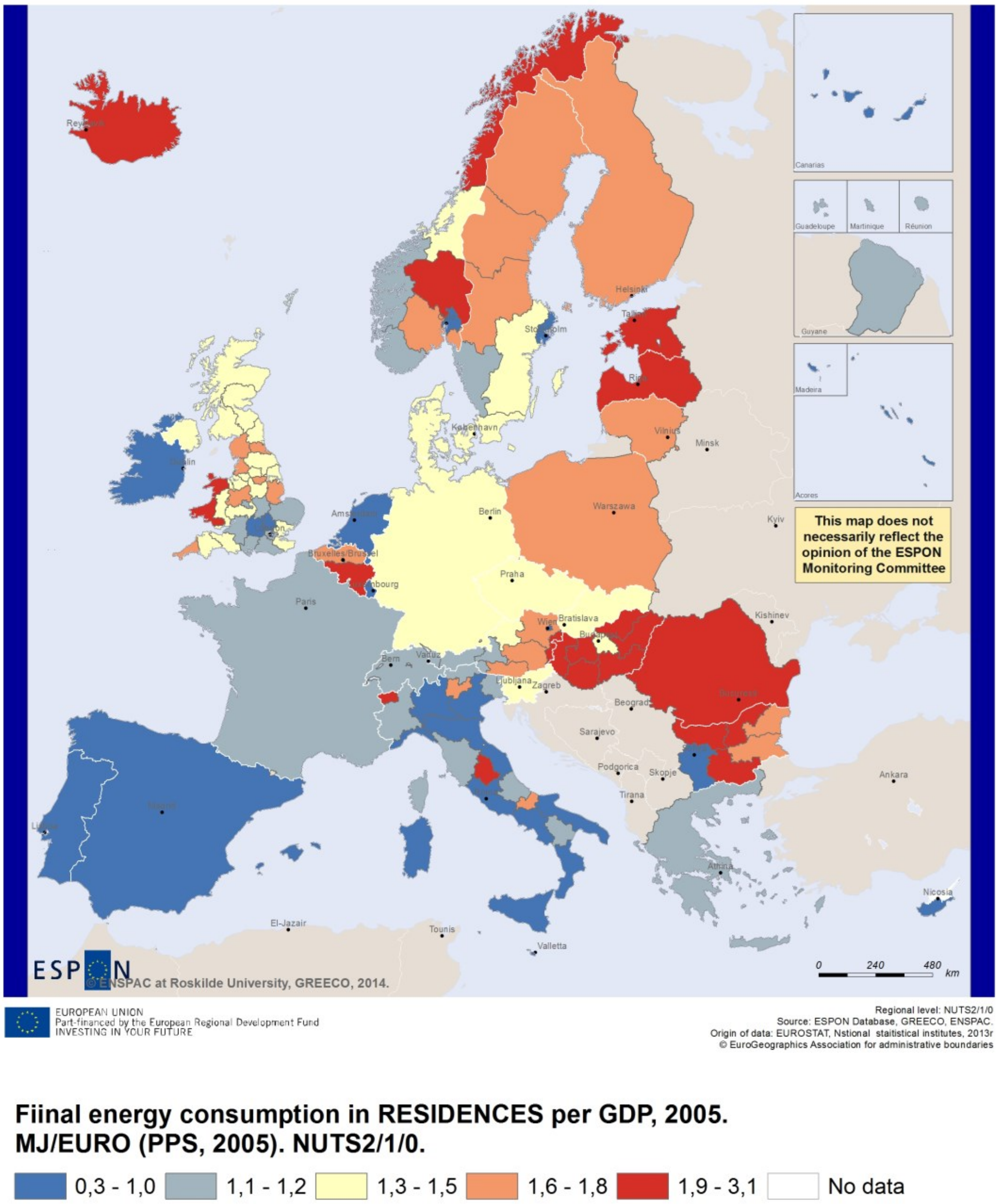


Map 43. Total final energy use per GDP (PPS), 2005. MJ/Euro (PPS, 2005).
Source: Author's calculations based on GREECO datasets (Hansen 2013a).

The interregional disparities of energy intensity shown in map 43 reveal considerable gaps between European regions as the energy used for producing and consuming the GDP of the region. Any region is, however, not necessarily comparable with any other region as they play different roles in the national and international specialisation. The City in London should not aim for the same energy intensity as a region in Finland or Norway with industries specialised in energy intensive paper or aluminium industries. The need for energy for building heating also differs across Europe by climate conditions. Thus, the operational measures of resource-efficiency useable for target setting and monitoring of progress needs more detailed accounts of energy use and a careful selection of other regions with whom to compare.

This is also the case for other measures of resource efficiency. Different regions face different challenges and the regional policies aiming at transforming the regional econosphere to the natural budgets without giving up producing the economic services it delivers need to define their own benchmarks for a region specific set of indicators.

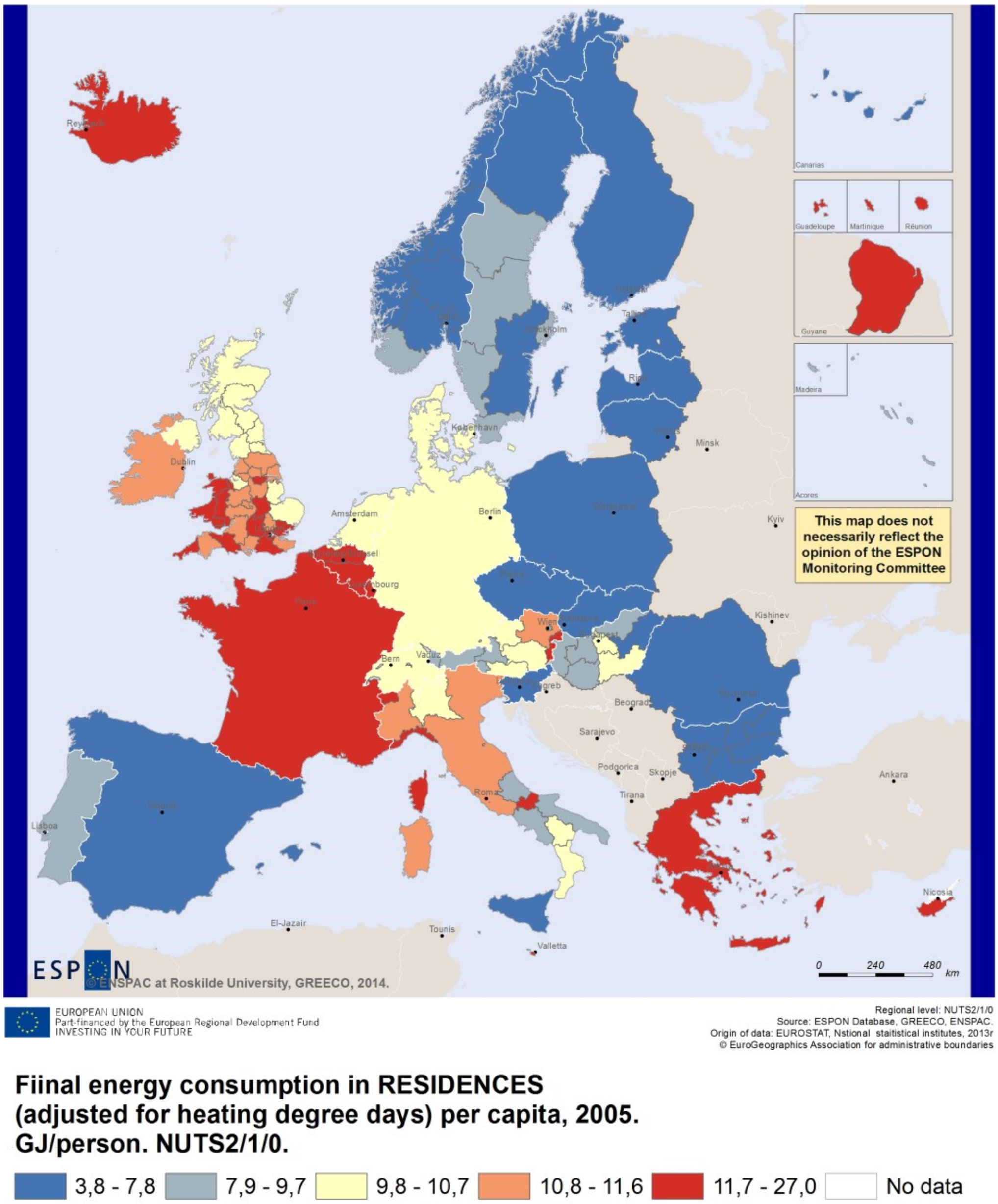
The final use of energy for residential purposes in the European regions appears from map 44.



Map 44. Residential energy use per GDP, 2005. MJ/€ (PPS,2005).
Source: Author's calculations based on GREECO datasets (Hansen 2013b).

The high residential energy consumption in the North and to some extent in the east of Europe could be heavily influenced by differences in the climate.

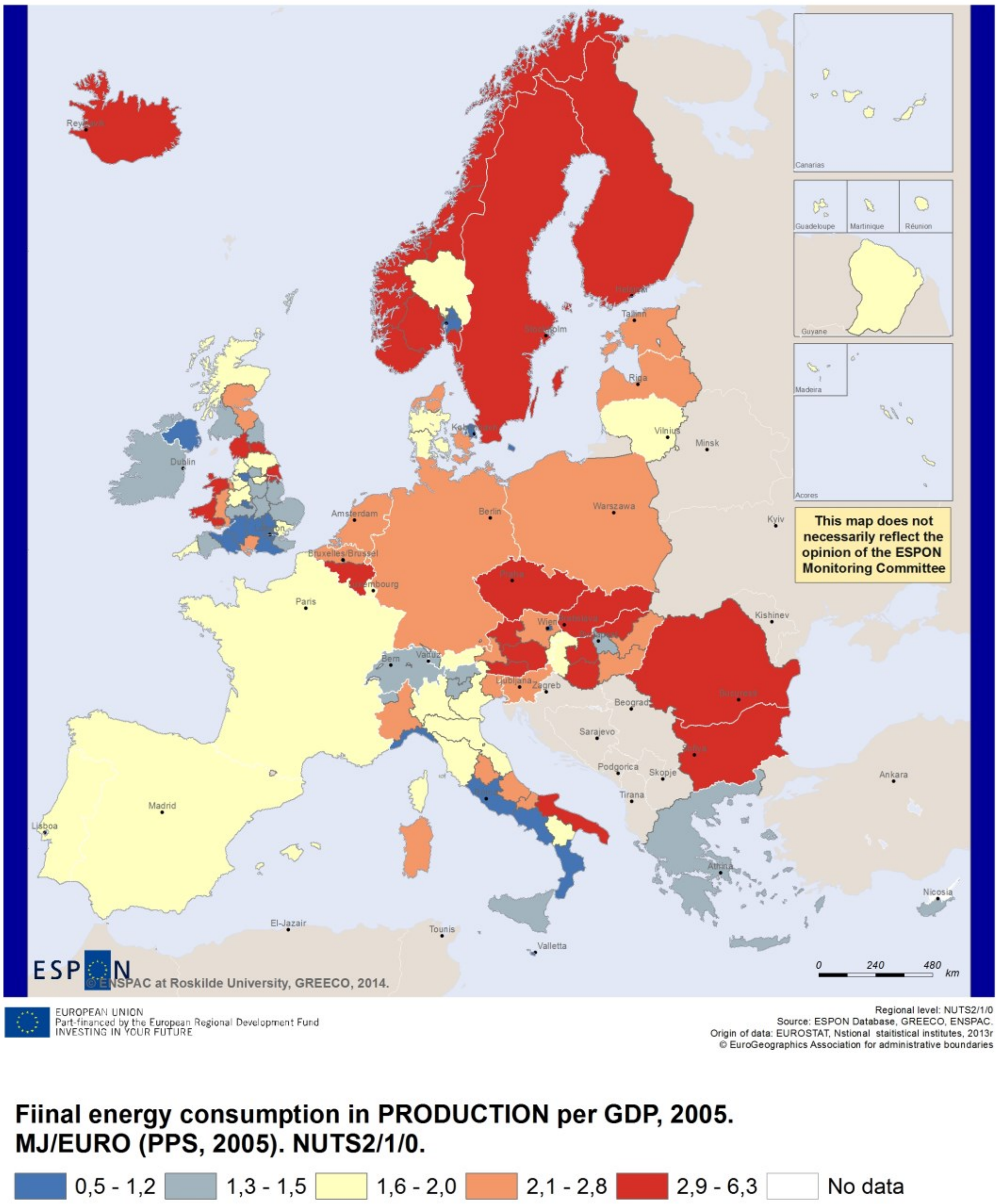
Moreover, the energy use for residential purposes per capita is as interesting as the residential energy use per GDP. Map 45 shows the regional variation in per capita energy consumption for residential purposes adjusted for variations heating degree-days.



Map 45. Residential energy use per capita adjusted for heating degree days, 2005. (GJ/person).
Source: Author's calculations based on GREECO datasets (Hansen 2013b).

The variation from South to North in the upper map becomes markedly smaller when adjusted for heating degree-days in map 45. The heating degree-day adjustment should, however, be interpreted with caution as more sophisticated methods of adjustment could reveal different patterns.

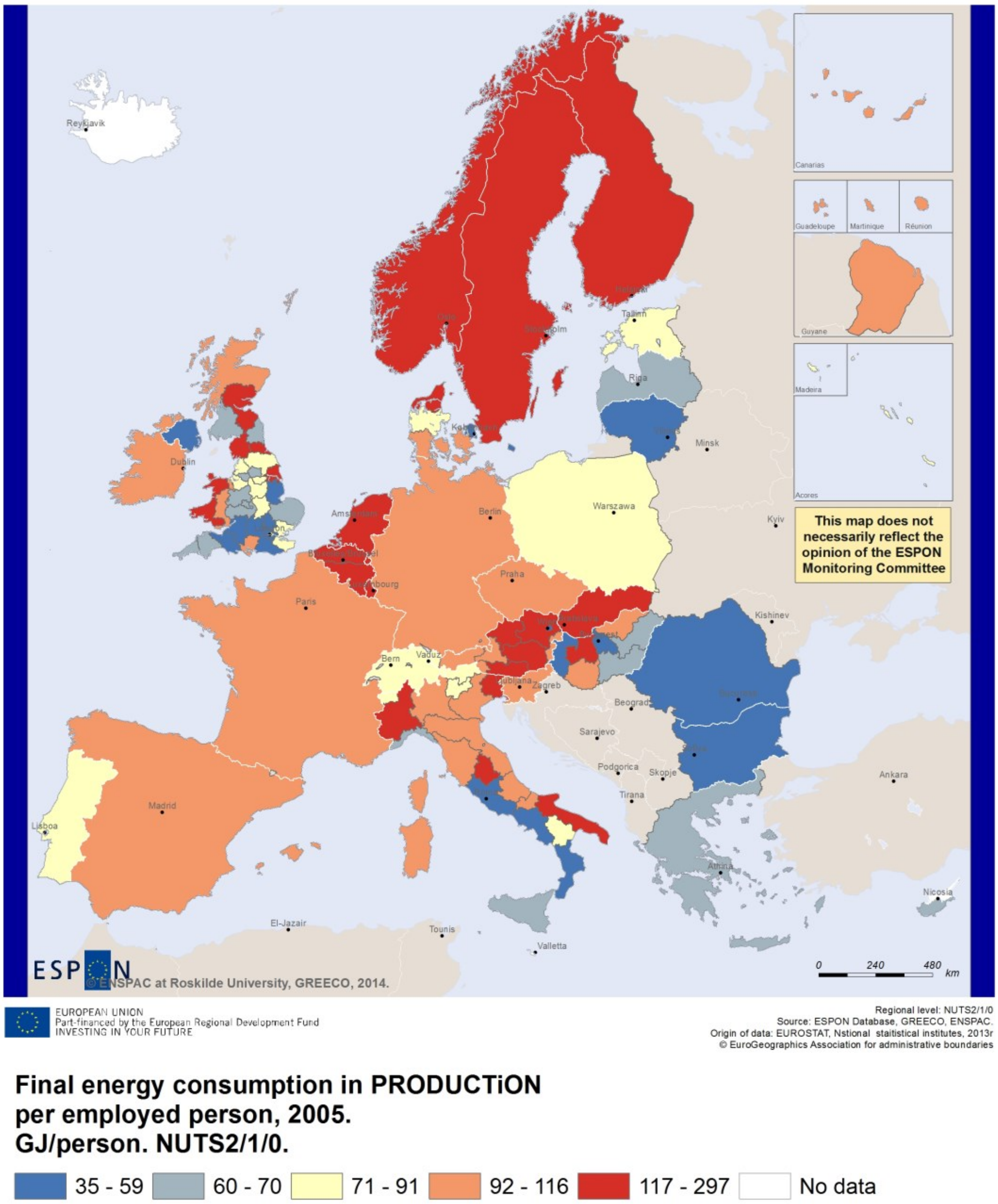
The ratio of final energy used in production to GDP (PPS) is shown in map 46. This is often used as an indicator of resource efficiency in production, but as noted above it is not necessarily socially desirable that all regions should aim at the same intensity of energy use in GDP. The regional specialisation patterns are also reflected in map 46.



Map 46. Final energy use in production per GDP. MJ/Euro (PPS, 2005).

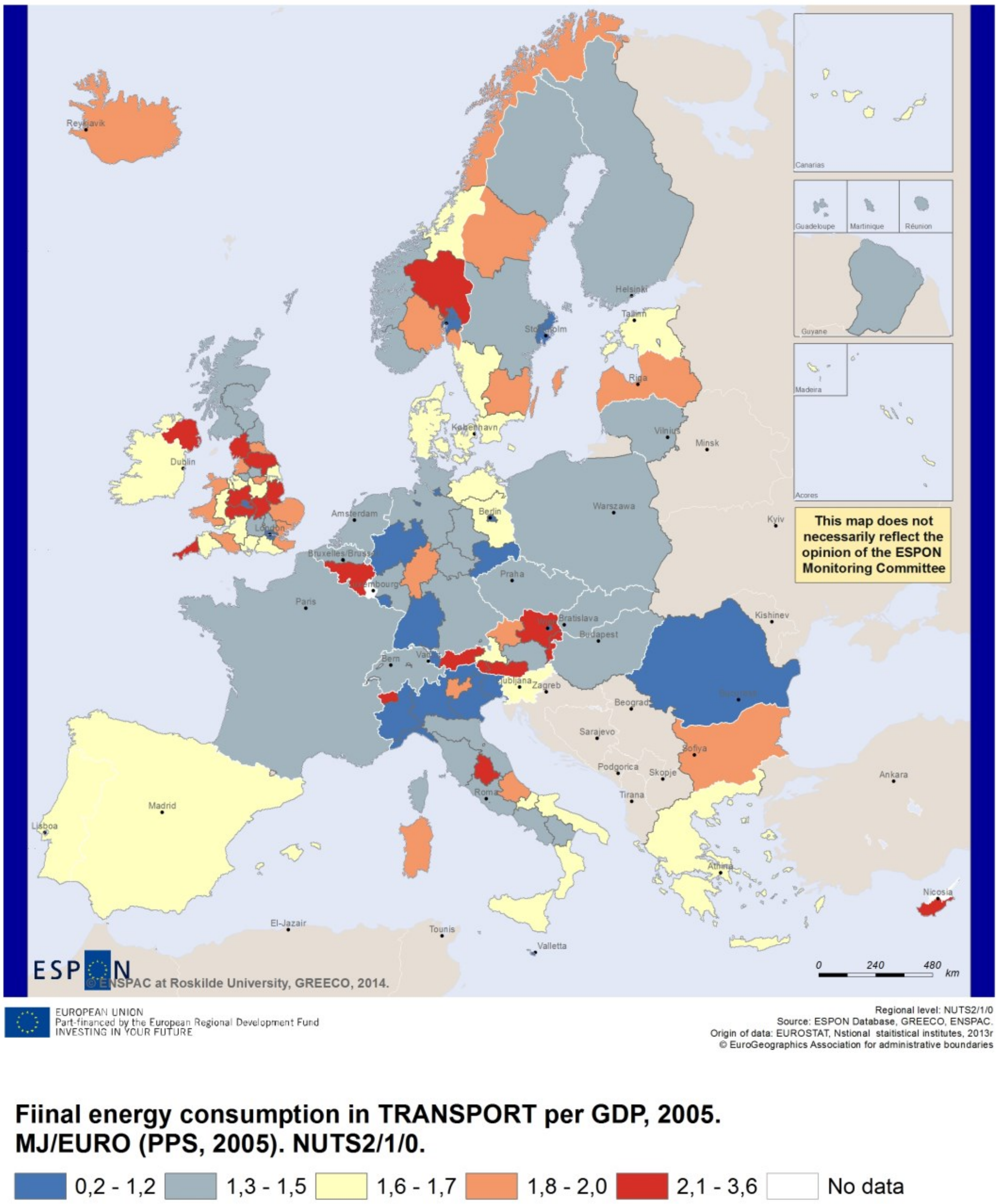
Source: Author's calculations based on GREECO datasets (Hansen 2013b).

A high intensity of energy use in production is, however, not necessarily a high intensity of energy use in employment.



Map 47. Final energy use in production per GDP. MJ/Euro (PPS, 2005).

Source: Author's calculations based on GREECO datasets (Hansen 2013b).



Map 48. Final energy use in transport per GDP. MJ/Euro (PPS, 2005).

Source: Author’s calculations based on GREECO datasets (Hansen 2013b).

For all regions, however, it is important to eliminate wasteful energy use while increasing employment. Moreover, it follows from equation (6) that the resource efficiency has to grow at least the same rate as the economy to stabilise the resulting resource consumption. This means that low-income regions that are expected to catch up with the income level of high-income regions have to increase their energy efficiencies at higher rates than the high-income regions to prevent energy consumption from growing.

12.2. Delinking and resource efficiency catch-up

The catching up process can be analysed in a framework of absolute and relative delinking and relinking against the background of a growing or recessive economy. This approach is inspired by the categorisation used by de Bruyn and Opschoor (1997).

In the model listed in Table 5, materials and energy productivity indices (or resource efficiency indices) relate an economic activity (G) to the physical flows (Z), it depends on. The ratio of G/Y grows approximately at a rate of g-z, where g and z are the growth rates of G and Z, respectively. If $z<g$, the index and the resource efficiency grows. The physical flow is delinked from the growth of the economic activity.

An increasing indicator is, however, not unambiguously an indicator of progress towards a green economy.

First, $z<g$ does not guarantee that the flow is actually reduced to sustainable levels. Thus, we distinguish between relative and absolute delinking, where the latter requires $z<0<g$. That may even not be sufficient to attain the goals of government programmes for development of the economy. If these goals imply $z<z^*$ and $g^*<g$, respectively, the targeted delinking criterion becomes $z<z^*<0<g^*<g$.

Second, even a reduced Z may follow from a reduced G, which is not a sign of sustainable development. Such developments have been observed at numerous occasions in Europe, notably in connection with the economic downturn in Eastern Europe in the 1990s and with the cascade of crises in the recent years.

Third, the undesirable mirror image of delinking is *relinking*, where $g<z$. It comes in a similar set of varieties.

Against this backdrop, it is important to classify regional performance in different categories according to relinking/delinking, recessive/growth and relative/absolute.

The classification of resource efficiency growth patterns is shown in Figure 19.

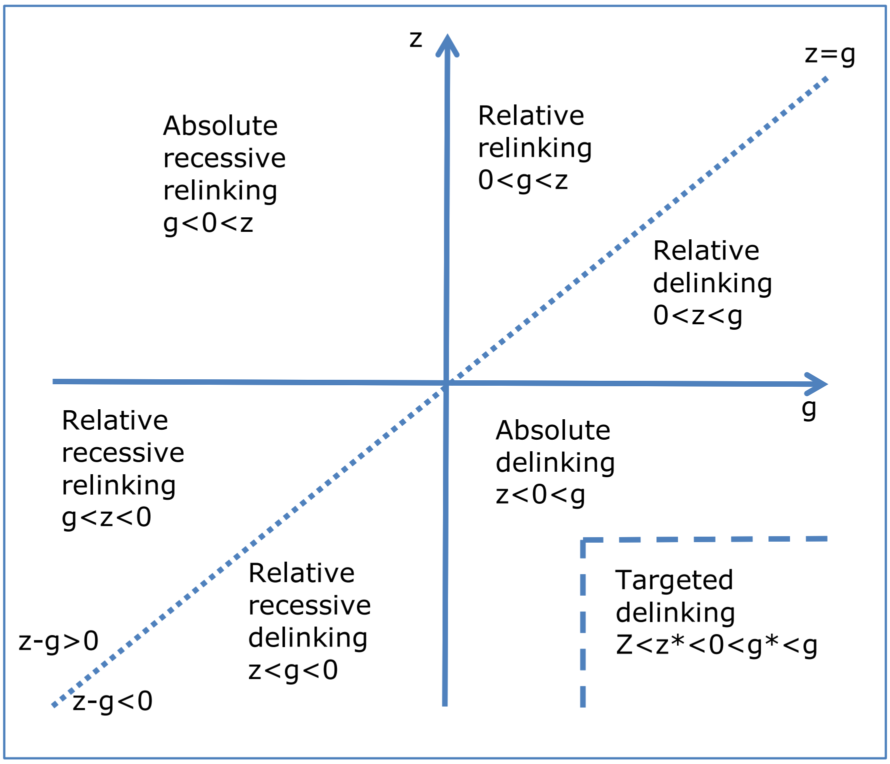


Figure 19. Delinking properties of materials and energy productivity index growth patterns.

All of the indicators in figure 19 can be related to the economic value creation they are linked to. The key resource efficiency indicators appear from figure 19.

The diagonal line in the diagram divides delinking countries from relinking countries: Delinking means that final energy consumption grows less than the unemployment rate whereas relinking is the reverse change. Absolute delinking means that the energy consumption actually declines whereas the employment rate is decreasing. Absolute relinking means the opposite: employment declines whereas energy consumption increases.

The combined progress in energy savings and employment in the EU is top priority in the Europe 2020 strategy, but it is also a set of targets that involve an inherent conflict. The model represented by equation (6) demonstrates the inherent conflicts of the strategy. The energy savings policy reduces greenhouse gas emissions, whereas raising the rate of employment tend to increase greenhouse gas emissions as long as the econosphere links fossil energy to economic activity. Delinking means reducing energy consumption per capita at the same time as it increases the rate of employment and the delinking performance shows the ability of the economy to solve this conflict. The delinking performance of the European economies is shown in figure 20.

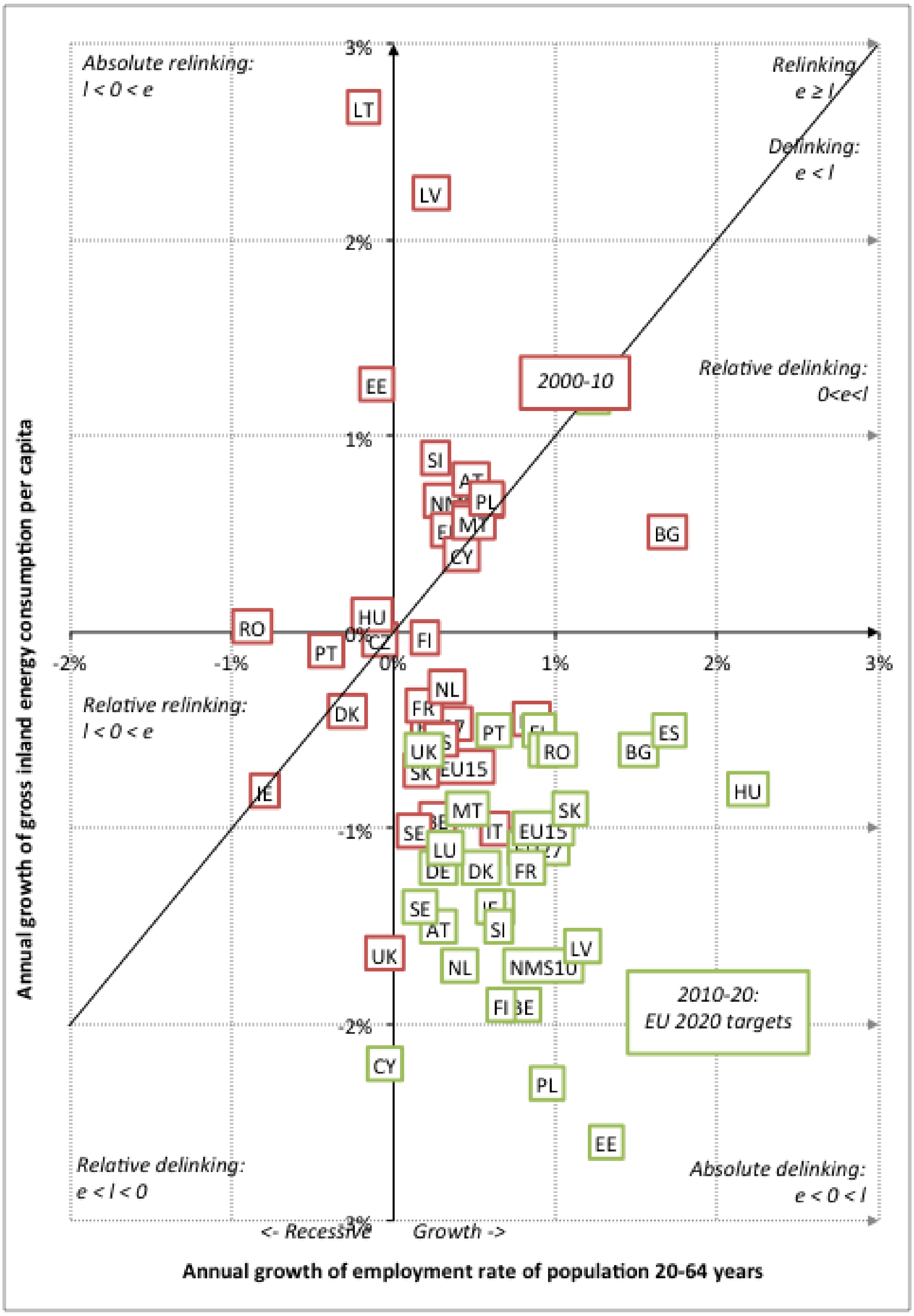


Figure 20. Delinking of final energy consumption from employment growth in 2000-10 and the implicit EU 2020 delinking targets.
Author's calculations based on Eurostat data.

The red boxes in Figure 20 represent the delinking performance of each country in 2000-10. The green boxes represent the delinking targets that must be obtained in the period 2010-20 for reaching the goals of the EU 2020 strategy.

The 2020 strategy targets simultaneously to increase employment per capita (employment rate) to 75% in 2020 and reduce energy consumption by 20% less than the projected energy consumption in 2020. These targets differ marginally by country, but in this analysis, it is assumed that they are equal to all countries. The average annual growth rates of the employment rate and gross energy consumption per capita are denoted *l* and *e*, respectively.

The position of the countries in the map can be used to categorise the delinking performance of each country in the period 2000-10 according to figure 20.

The split between relinking and delinking countries was about 50-50, but many with a very small margin. EU15 countries dominated the delinking side whereas many NMS10 countries relinked. It should be kept in mind that the change in employment and energy consumption through 2000-10 went through a boom period followed by a severe recession.

Some countries experienced a reduction of final energy use alongside with a reduction in employment, but this cannot be characterized as sustainable development. As it follows the reduction in employment, it must be expected to reverse when the employment rises again.

The Europe 2020 targets include the aggregate targets of an employment rate of 75% and a final energy consumption of 20% less than the projected level in 2020. The growth rates required to reach these goals from 2010 through 2020 are calculated based on the actual energy consumption and employment rates in 2010. The targets for many member-states differ slightly from the overall EU target and this is reflected in the employment growth requirements.

The combined employment and energy efficiency targets are important components part of how the EU defines sustainable development.

12.3. Energy delinking in regional economies

The GREECO dataset on final energy use have been used further to analyse the progress of energy efficiency in European regions.

In the dataset the final energy consumption statistics is aggregated to the three broad sectors production, transport and residential. The statistics available for distributing these aggregate on NUTS2 and NUTS1 regions differ by country, sector and years. The resulting dataset thus has a varying coverage in these dimensions.

The delinking of the growth of energy use from economic growth has been examined for total final energy consumption and the results are shown at the map below. Economic growth was represented by GDP per capita in purchasing power parities and deflated with the GDP deflator.

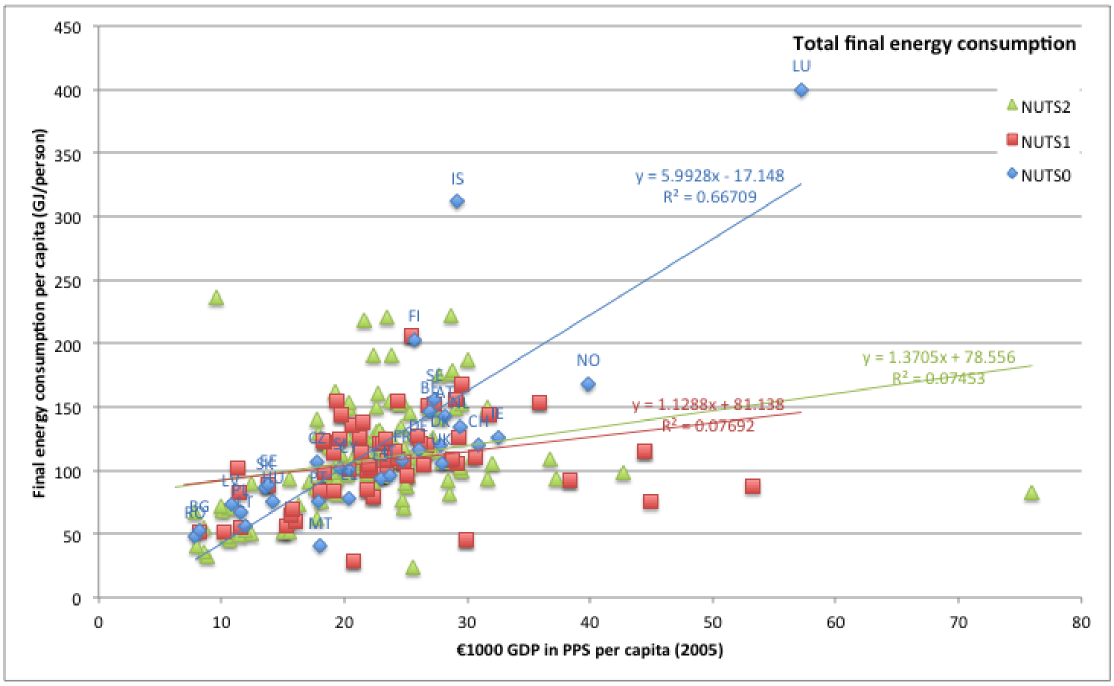
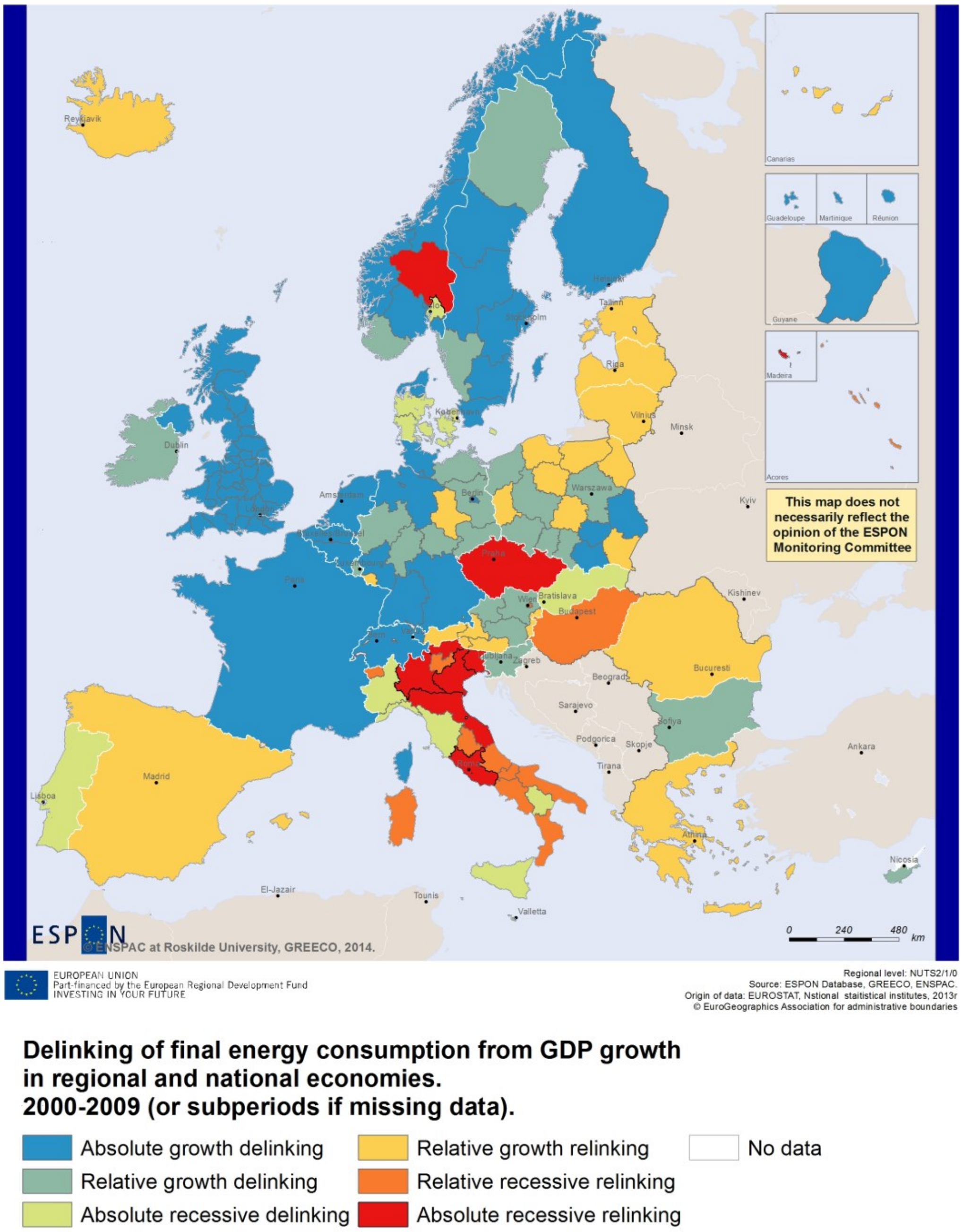


Figure 21. Final energy consumption and GDP per capita, 2005 (GJ/person and PPS€1000/person).
Source: (Hansen 2013a).



Map 49. Delinking of total final energy use from economic growth 2000-2009.

The analysis was carried out for the period of 2000-2009 thus including the period of unsustainable growth up to 2008 and the deep recession 2008-09. The average growth rate over the period as a whole thus averages over cyclical fluctuations. The period, however, has been shortened for some regions due to missing data.

Many European economies did succeed in reducing total final energy consumption relative to the economic growth. They are represented with the green colours on map 49. However, they did not delink in the same way. Some economies did not delink sufficiently to achieve an absolute reduction of energy consumption. Others delinked against a background of negative economic growth, that is, where the recession more than neutralised growth in the preceding growth period.

The energy intensity of the blue colour economies developed in the opposite direction of the EU goals. They became more energy intensive through the period. The delinking performance was not identical for production, transport and residential energy use.

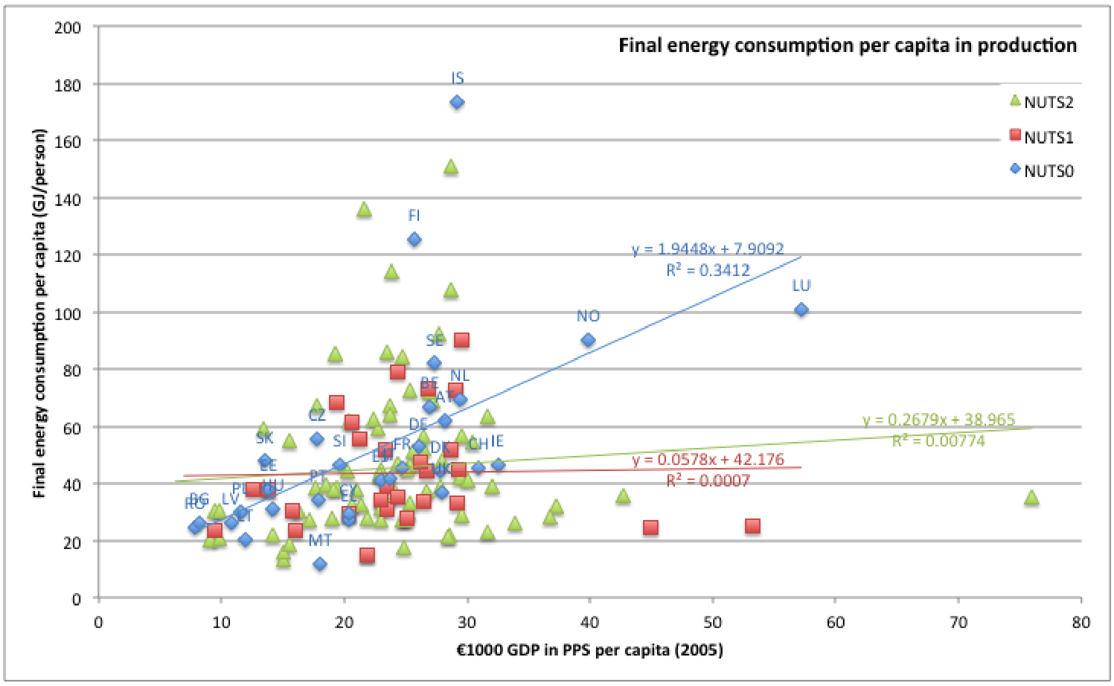
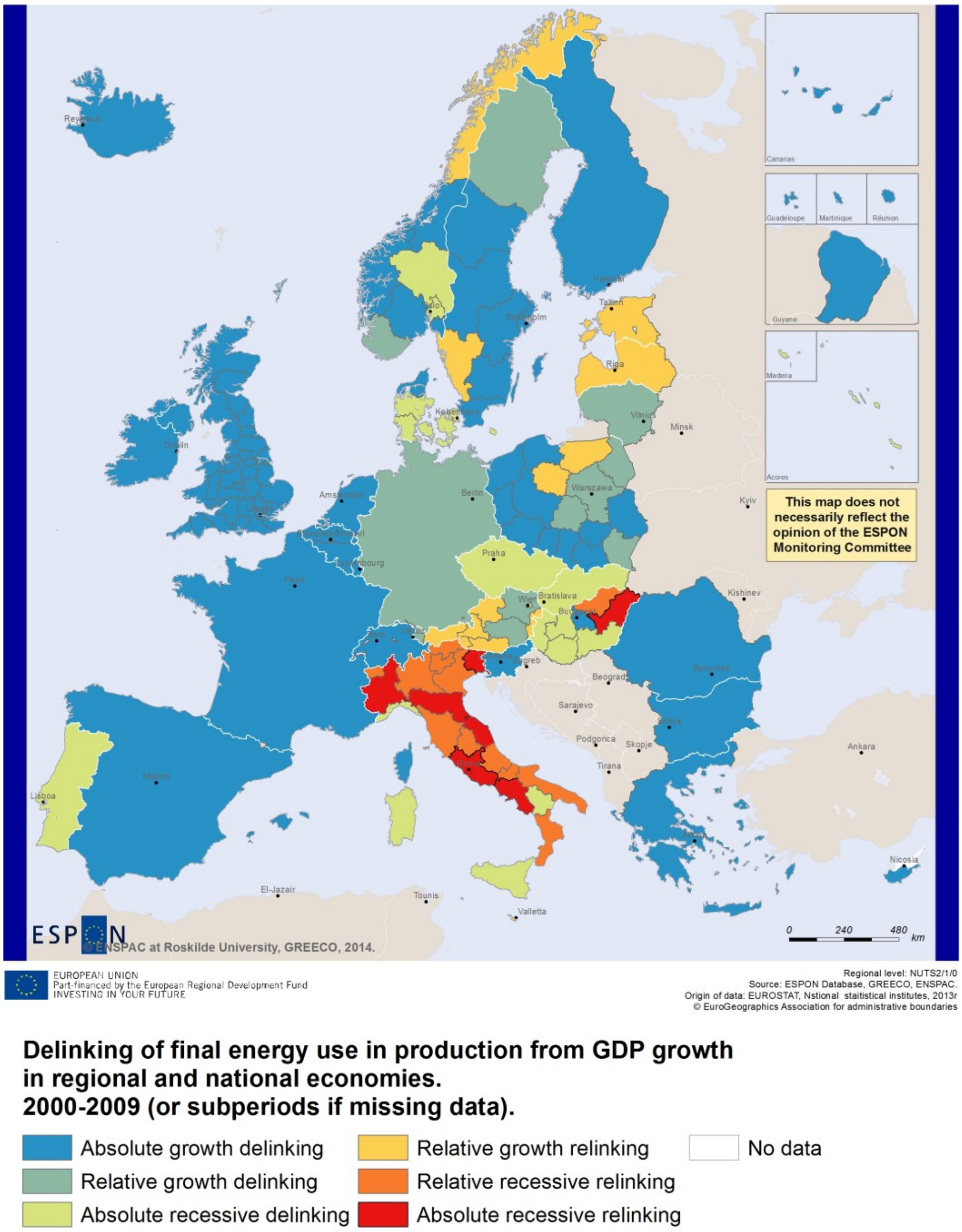


Figure 22. Final energy consumption in production and GDP per capita, 2005 (GJ/person and PPS€1000/person).
Source: (Hansen 2013a).



Map 50. Delinking of final energy use in production from economic growth 2000-2009.
Source: (Hansen 2013a).

The production activities generally became less energy intensive in the period according to map 50.

The analysis was also carried out for the dual goals of on the one hand reducing energy consumption in production per employee, but in the other hand simultaneously raise the rate of employment of the economy. The result is shown below.

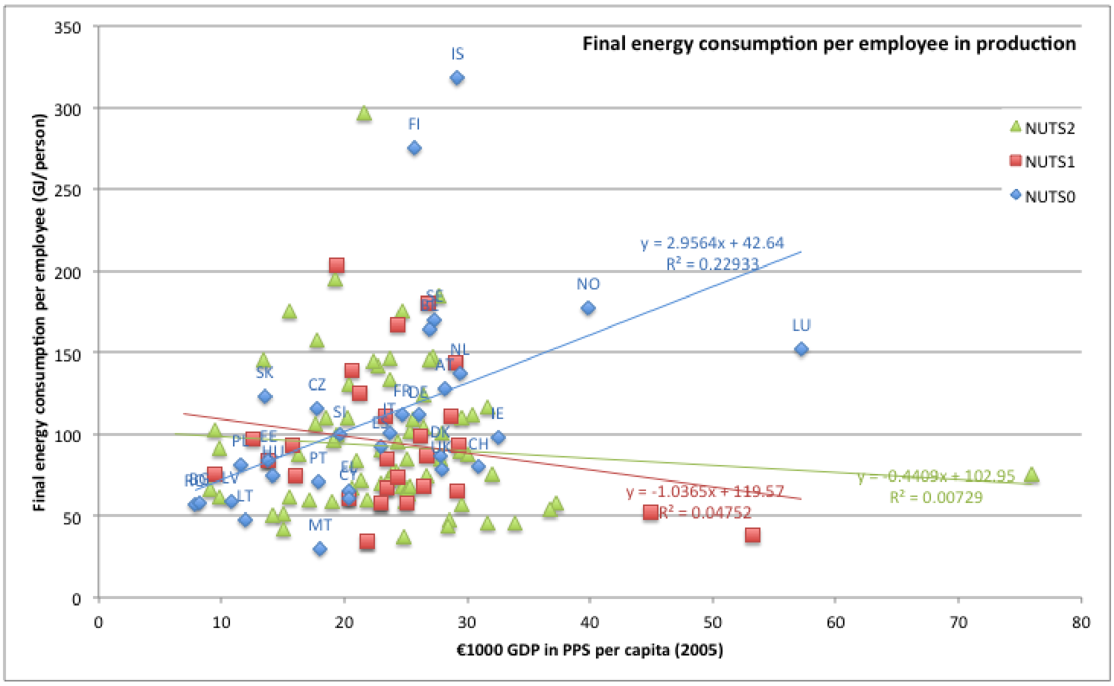
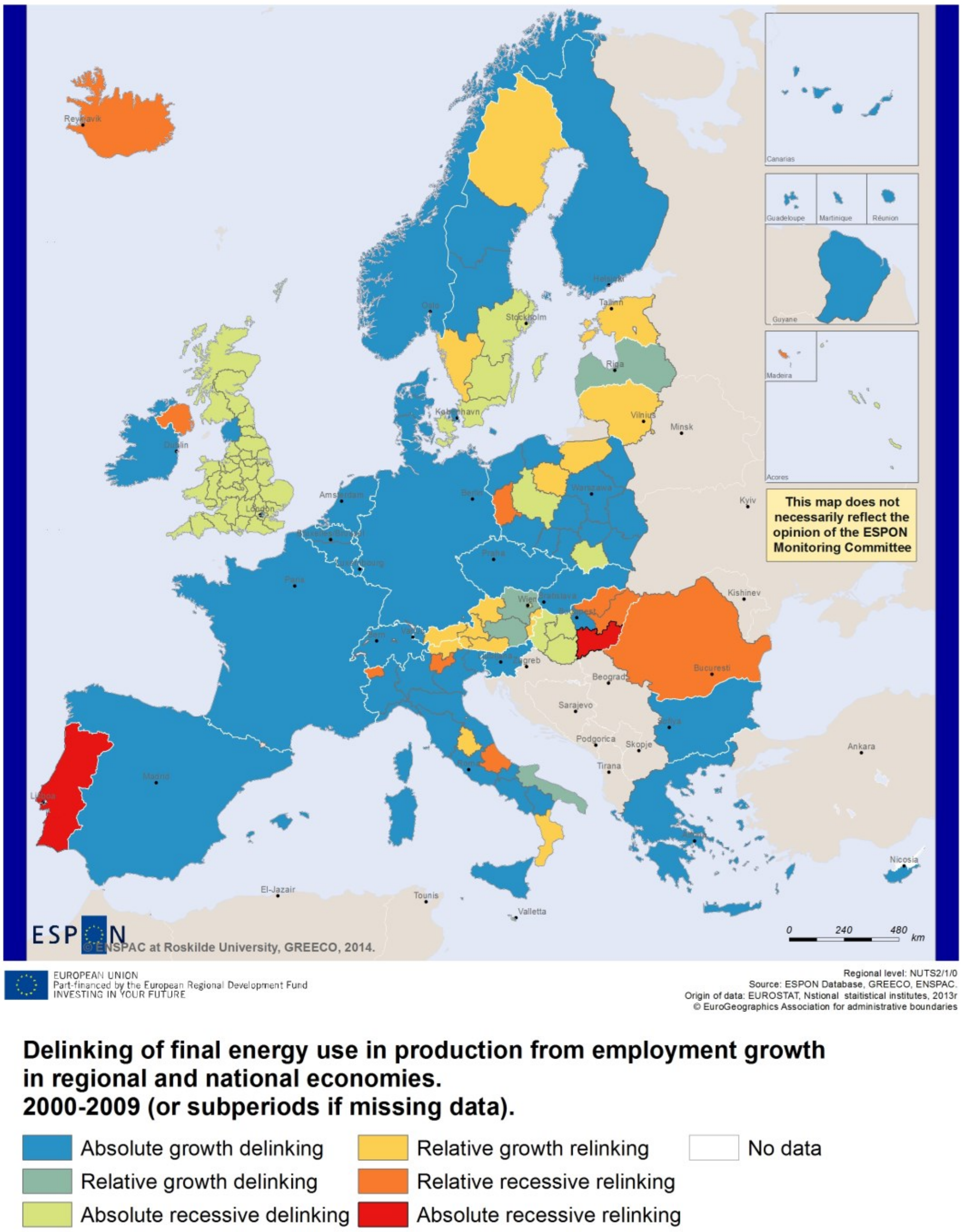


Figure 23. Final energy consumption in production per employee and GDP per capita, 2005 (GJ/person and PPS€1000/person).
Source: (Hansen 2013a).



Map 51. Delinking of energy use per employee in production from changes in the rate of employment 2000-2009.
Source: (Hansen 2013a).

The delinking performance measured in this way is as shown in map 51 also positive in most of the economies, but some economies shift colour from green to blue and *vice versa*.

Energy use in the transport sector grew at a higher rate than GDP in many economies.

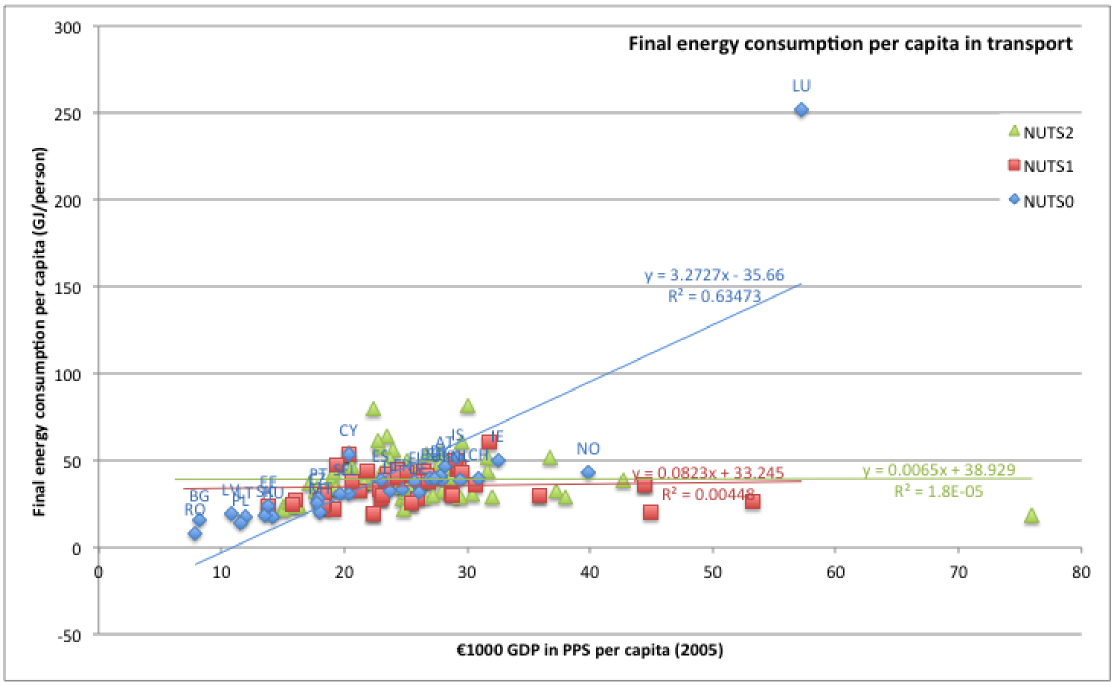
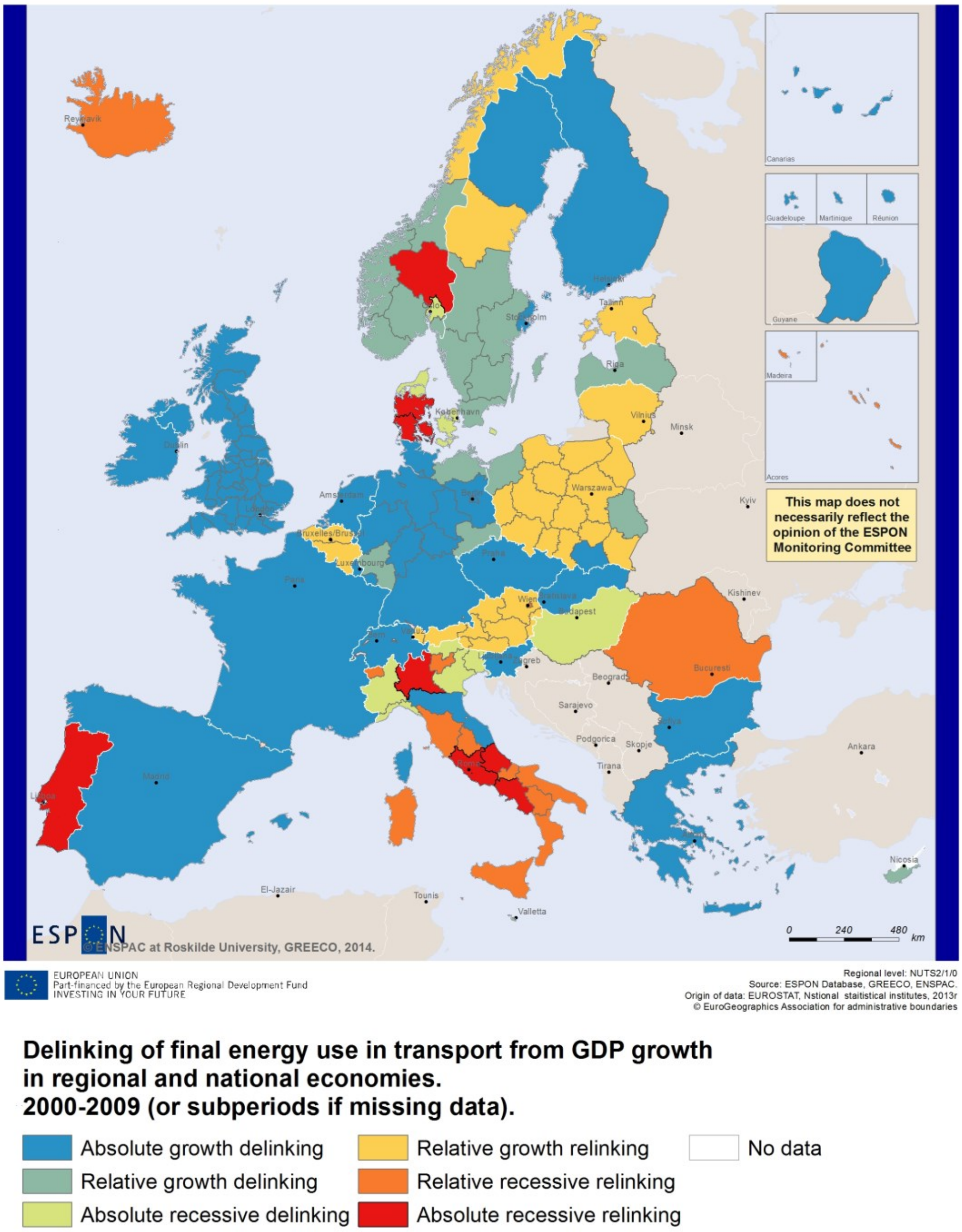


Figure 24. Final energy consumption in transport and GDP per capita, 2005 (GJ/person and PPS€1000/person).

Source: (Hansen 2013a).



Map 52. Delinking of transport energy use from economic growth 2000-2009.
Source: (Hansen 2013a).

Particularly in the south and the east and also in some northern regions of Europe the intensity of transport energy in GDP has risen. In these economies the use of transport fuels have become closer linked to economic growth.

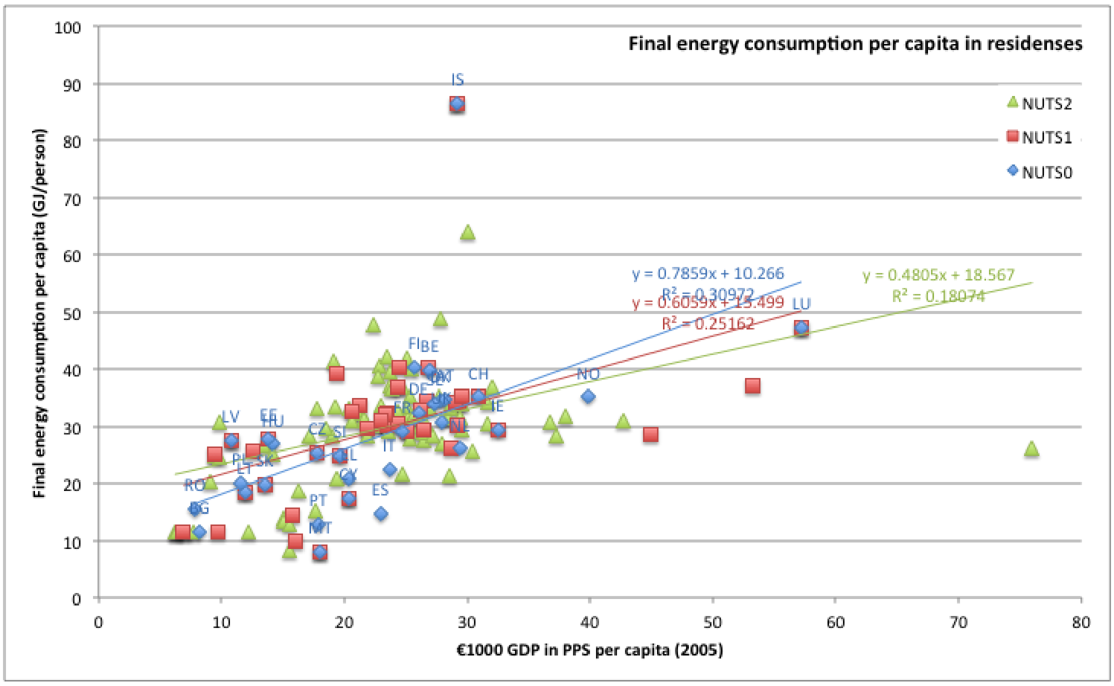


Figure 25. Residential final energy consumption and GDP per capita, 2005 (GJ/person and PPS€1000/person).
Source: (Hansen 2013a).

The delinking of energy consumption in the residential sector from economic growth is shown in the map below.

Most European economies made progress towards a lower residential energy use compared to GDP, but also in this sector some economies moved in the opposite direction.

Residential energy use is, however, also influenced by the temperature and wind. Thus the energy use is not only related to GDP on the map below, but also to adjusted by heating degree days.

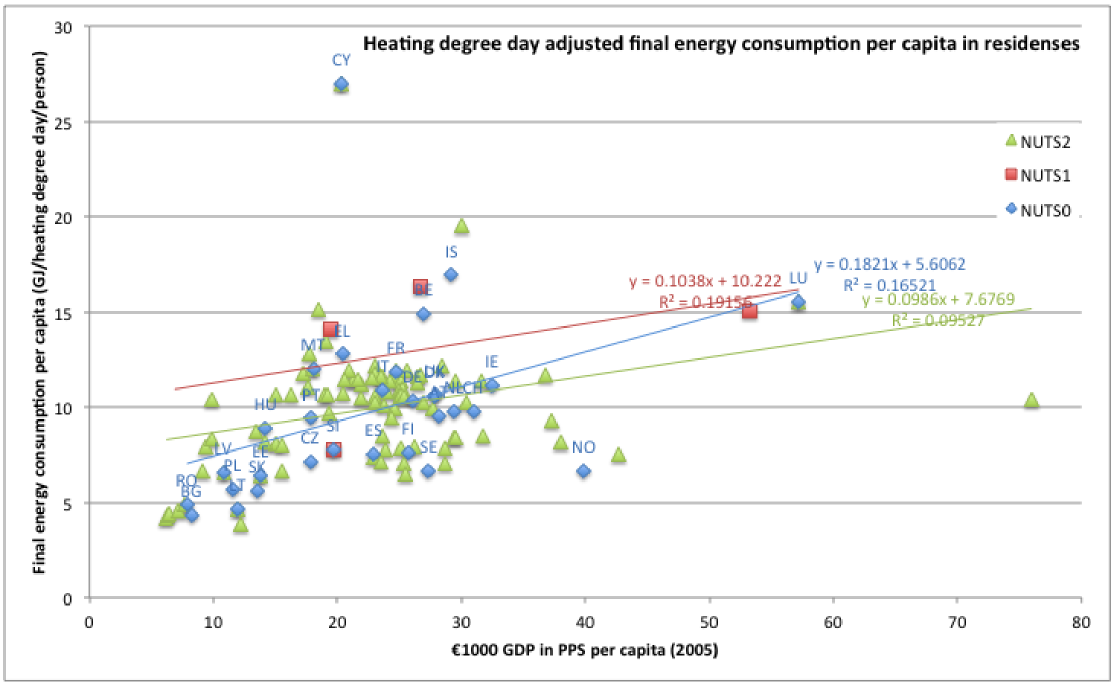
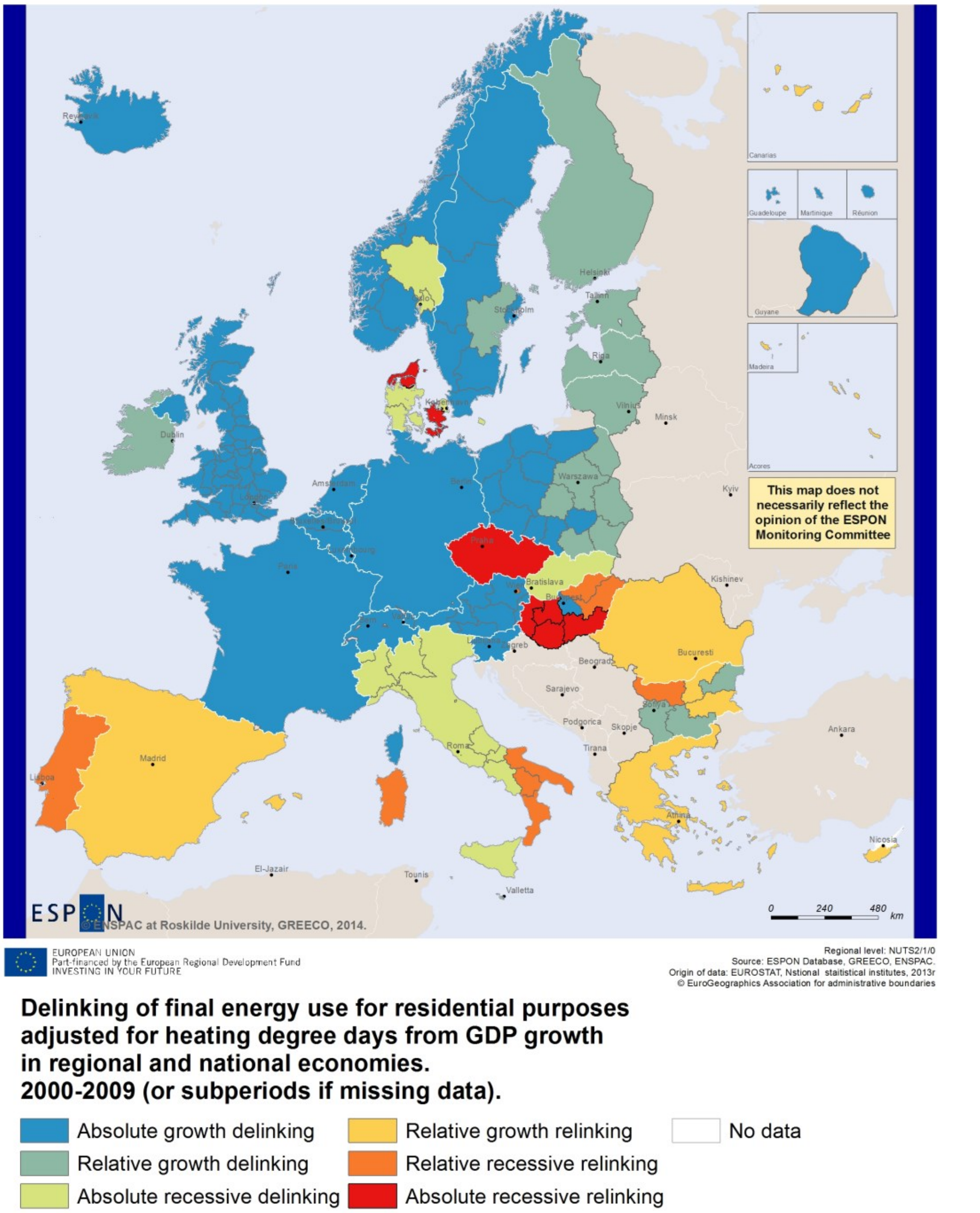


Figure 26. Residential final energy consumption adjusted for heating degree days and GDP per capita, 2005 (GJ/heating degree day/person and PPS€1000/person).

Source: (Hansen 2013a).



Map 53. Delinking of residential energy use (per heating degree day) from economic growth 2000-2009.
Source: (Hansen 2013a).

The delinking performance with respect to energy reviewed in this chapter can be a useful tool in monitoring the progress of decarbonisation. A better and harmonised European energy statistics with full coverage at NUTS2 level can be very useful for regional bodies. It should also include production and capacity statistics on fossil, renewable and nuclear energy.

13. Datasets for monitoring

The transformations of the econosphere from high throughput to low throughput and recycling involves a change in the composition of capital and operating expenditures in the direction of capital. This is because material and energy flows are operating expenditures and because the capital per service unit provided become more expensive. Briefly put, the green econosphere delivers the same services (heated floor area, person kilometres etc) but with higher capital consumption and lower fuel expenditure per service unit.

This transformation can thus be measured by the change in throughputs of the material and energy flows and the changes in the fixed capital stock designed to deliver the services in combination with the flows. Three types of dataset would be desirable to shed light on these transformations at the regional level:

- the *investment* in the green versus the conventional solutions,
- the resulting change of the *flows* at entry and exit points of the econosphere and
- the resulting *sets* of capital stock, services and flows

Data on the capital stock changes and investments in green solutions are generally not available at the NUTS2 or NUTS3 levels and not necessarily in comparable form at the national level. The primary data necessary for making the datasets are in some countries collected at a scale that enables the generation of comparable regional statistics and in some countries not. A uniform statistical coverage would be valuable for regional decisions on green economy strategies.

14. Material flow accounting

14.1. Accounting framework

Statistical accounting of the material flows goes back to early studies by Ayres and Kneese (1969). In Europe, the EUROSTAT has been engaged since the 1990s in documenting the material flows through the economy. Figure 27 shows a simplified scheme of the material flow accounting framework.

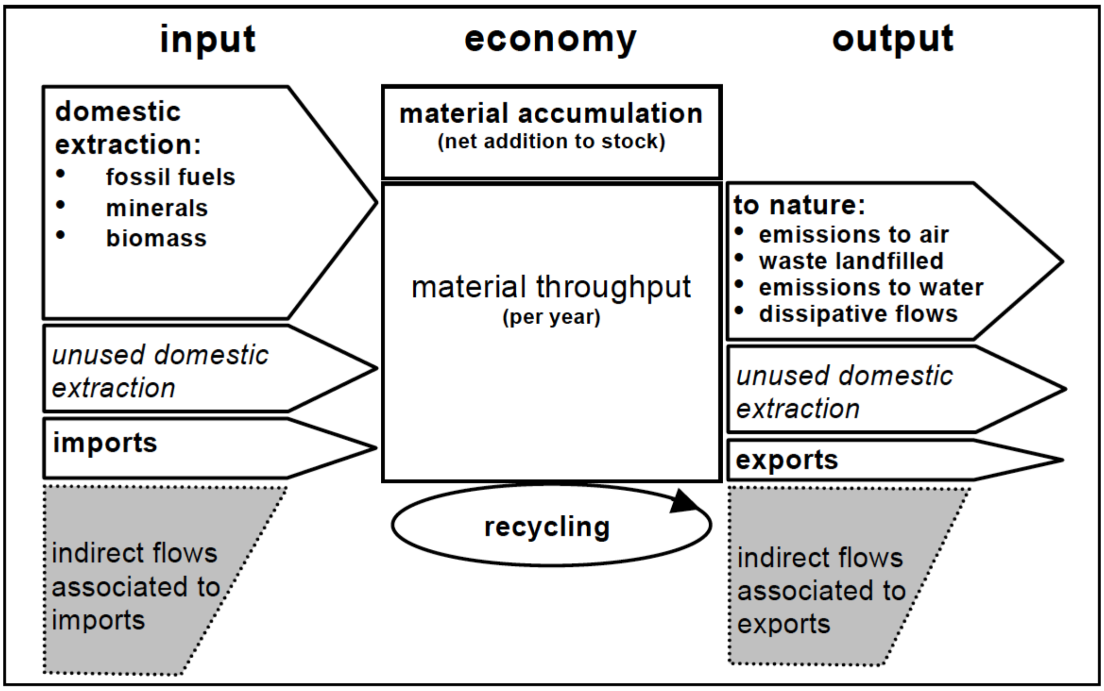


Figure 27. Material flow accounting framework.
Source: (European Commission 2009c; European Commission 2001)

Air and water flows are excluded from the scheme, but they play an important role in the material balance. Evaporation is, for instance, an important balancing item.

The Direct Material Inputs (DMI) is the aggregate weight of materials entering the economy. Unused domestic extraction includes materials that are moved with a purpose and using technology. Examples include overburden from mining and quarrying, soil and rock excavated during construction and dredged sediments from harbours. These flows do not enter into final products but are side effects of the primary production of materials and investments and maintenance of the capital stock. Indirect flows include material flows derived from the imported and exported materials.

Domestic Material Consumption is a key indicator in monitoring the flow of materials through the economy.

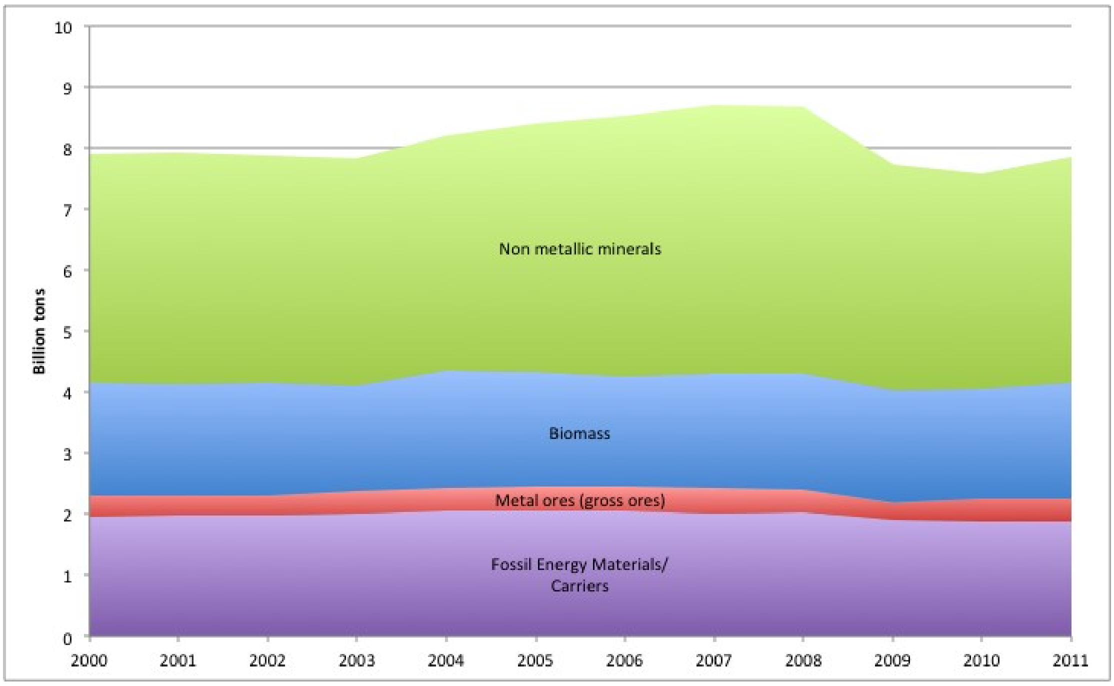


Figure 28. Direct Materials Input (DMI) in EU27. Billion tons.
Source: (European Commission 2014b)

Figure 28 shows the aggregate weight of *all* materials entering the EU27 economy through the 00s to 2011. Water, air and materials that are moved, but not used as, e.g., metal ores are excluded from the accounts.

Roughly half of the materials flow measured by weight consists of non-metallic minerals, primarily raw materials used for construction purposes: Sand and gravel, limestone, clay etc. Consequently, these flows vary according to the investment rate of the economy.

Most of the other half is split between biomass and fossil fuels.

As can be seen from the figure, fossil energy is not only the physical condition for transporting, processing and storing such large amounts of materials (16-17 tons per capita). It is also constitutes a major flow itself. Fossil fuels make up roughly about 25% of the material flow throughputs measured at the entry points to the European (EU27) economy. Replacing fossil energy fully by renewable energy from non-combustible sources would in other words reduce the need for handling materials in Europe by 25%. Non-metallic minerals and metal ore would on the other hand increase. To the extent that not only biomass waste, but also dedicated biomass will be an energy source, the weight of biomass flowing through the economy will also tend to rise. Thus, a low carbon economy will have a different composition of flows. It is difficult to predict the aggregate weight of these, but they will not necessarily involve over-consumption of sources, sinks and space.

The links between economic growth and throughput growth as measured by DMI change similarly to the links between greenhouse gas emissions and GDP growth as shown in figure 6 and figure 7.

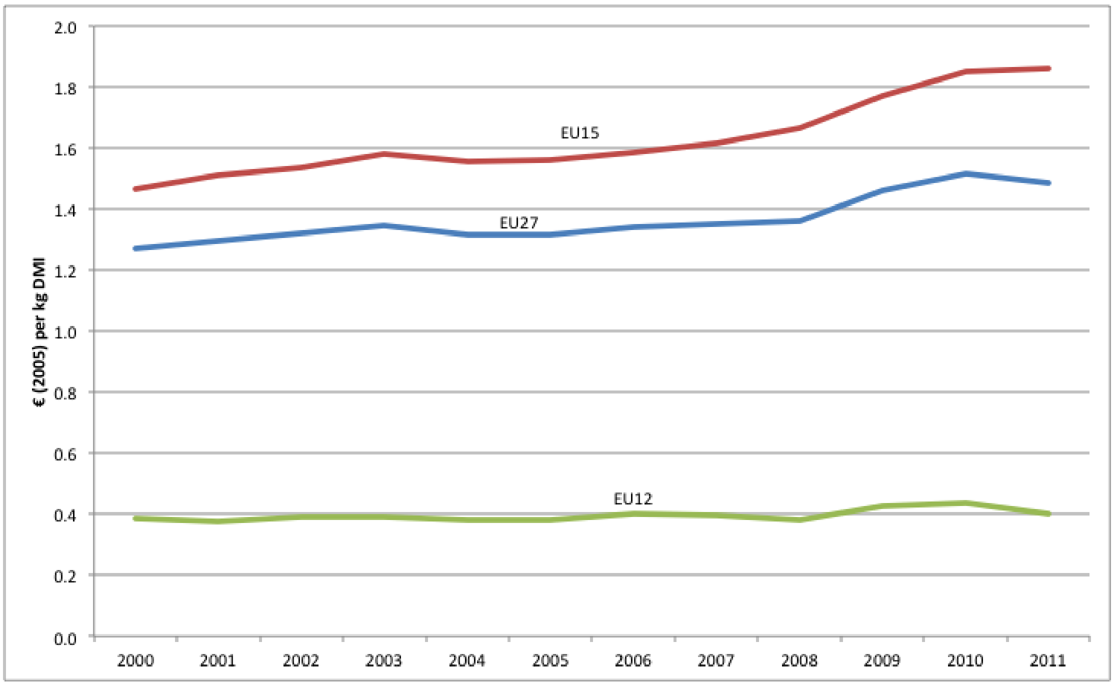


Figure 29. DMI resource productivity in EU27, EU15 and EU12, 2000-11. € (2005-prices) per kg DMI.
Source: (European Commission 2014b)

As can be seen from figure 29, the resource productivity has been continuously rising through the 00s in EU15. In the new member-states (EU12), however, it has been relatively stable. It implies that the link between DMI and GDP is close to proportionality in the new member-states, whereas delinking progresses in the EU15 as a whole.

The aggregate weight is of limited informative value as to the resource scarcity and environmental pressures related to specific materials. It does not directly relate to overconsumption of sources, sinks and space. Overconsumption of sources depends on the abundance of the resources and the prospects of substitution. Overconsumption of sinks depends on waste treatment and emission control, the toxicity of the materials and other risk factors. Emissions of air pollutants, persistent organic pollutants and heavy metals, for instance, are more important than demolition waste per ton. Overconsumption of space depends on actual land use decisions and thus the spatial extent of the infrastructure underlying the flows.

A considerable share of the fossils fuels are used transporting and processing these materials – including fossil fuels. The amount of transport and process energy necessary to handle the flows is not necessarily proportional to the weight of the throughputs.

(Ayres and Warr 2009) use *exergy* (measured in energy units) as a common and more relevant unit for energy and non-energy materials. The *exergy* of a given material flow, however, depends on the specific physical environment in which it is consumed. This is difficult to operate with for aggregate statistics.

The non-renewable resources – metals and fossil fuels – cause source as well as sink problems. The aggregate weight of these remained almost unchanged through 2000-2007. This shows that at least it is technically feasible to derive an increasing volume and quality of the services we need without increasing the tons of materials with non-renewable origin through the econosphere.

An increasing weight of biomass flows could even be socially preferable the biomass substitutes non-renewable resource flows, e.g., when pellets substitute natural gas. In many other cases, a green economy is supposed to use biomass instead of mineral materials due to its low carbon, non-toxic, recyclable and biodegradable properties. But the moisture content of biomass can easily cause the gravimetric resource productivity to increase. For instance, it can be considered a progress towards a green economy if 2 tons of biomass replace 1 ton of lignite. Depending on the energy density (gravimetric) the resource productivity could go either way. A rise in the investment rate due to a higher pace of transformation to a green economy will be reflected in a high ratio of DMC to GDP although it will in the longer perspective reduce the flows of materials and energy.

At a higher level of detail, the accounts can be very useful in tracing throughputs and flows. The combined benefits of saving environmental damage and high cost resources can be comprehensively accounted for on solid basis.

The level of detail at the subnational territorial level does, however, not allow for an intensive use of this statistics for the green economy analysis. Primary data on flows and capital stocks designed for high or low flows of fossil energy and other materials are either not collected at all or not processed according to the harmonised standard for energy statistics in the EU.

14.2. Resource efficiency

Resource productivity and *eco-efficiency* indicators are used to analyse progress towards the delinking of the unsustainable physical flows from the final and valuable services. They include resource productivity, energy intensity, emission intensity and other indicators. These indicators relate the economic performance to the environmental pressure.

Thus, the statistical description of the progress towards a green economy needs a range of economic variables as well as variables describing the physical environment. The concept of resource efficiency involves all three categories of economic activities: Production, investment and consumption.
In the process of *production*, materials and energy are used as inputs and useful products as well as waste and emissions are the outputs. The standard measures of the efficiency of these processes include, e.g.,

- resource productivity (ratio of materials inputs to production volume or value added)
- energy intensity (ratio of final or gross energy to consumption to production volume or value added)
- conversion efficiencies (ratio of energy contents of output to inputs)
- emission intensities (ratio of emissions or waste to production volume or value added)

In the process of investment, i.e., at the micro-economic level, the standard measures of economic sustainability and optimality include, e.g.,

- energy resource shares of conversion capacity (renewable or non-renewable, combustible or non-combustible)

- levelized cost (cost per designed energy production at normal use during the life-time of the investment)
- levelized services (designed energy or materials flow per unit of services produced or per value of services produced)
- rate of return (ratio of profits to circulating and fixed capital stock relative to alternative investments - Return on Investments, Internal Rate of Return, Net Present Value)
- payback ratio (economically and for energy producing/saving equipment the time it takes to generate or save energy enough to balance the energy consumed in the investment process)

In the process of consumption, standard measures include, e.g.,

- Direct and indirect material flows lifecycle impact of global energy and material flows set into motion by the consumption per value of consumption
- Flows bypassing valuable final services (food waste rates, drinking water leakage)
- Mobility to direct and indirect energy use rates

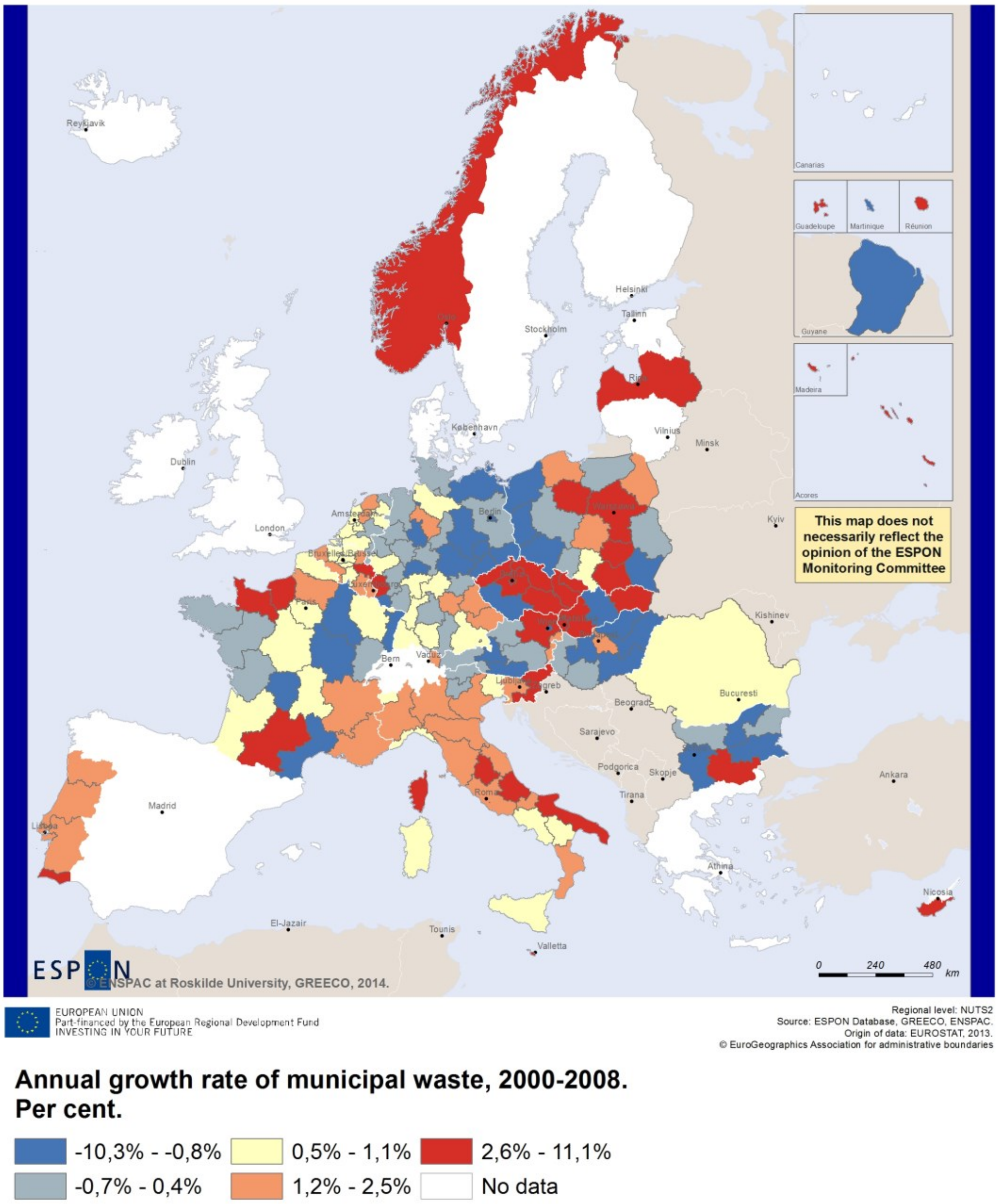
Against this backdrop, it can be concluded that changes in the aggregate materials flows measured by weight are not very accurate as indicators for regional progress towards the green economy. They are, however, very useful for analysing the specific materials intensity of the economy, which varies by the natural resources endowments of the countries.

14.3. Materials flows, waste and wastewater

Another feature of the 20th century econosphere that is unsustainable is that part of the materials flows end up in land-ills and other deposits. The limited reserves of non-renewables as well as the limited land available for landfills and deposits represent obvious constraints on the growth of material flows.

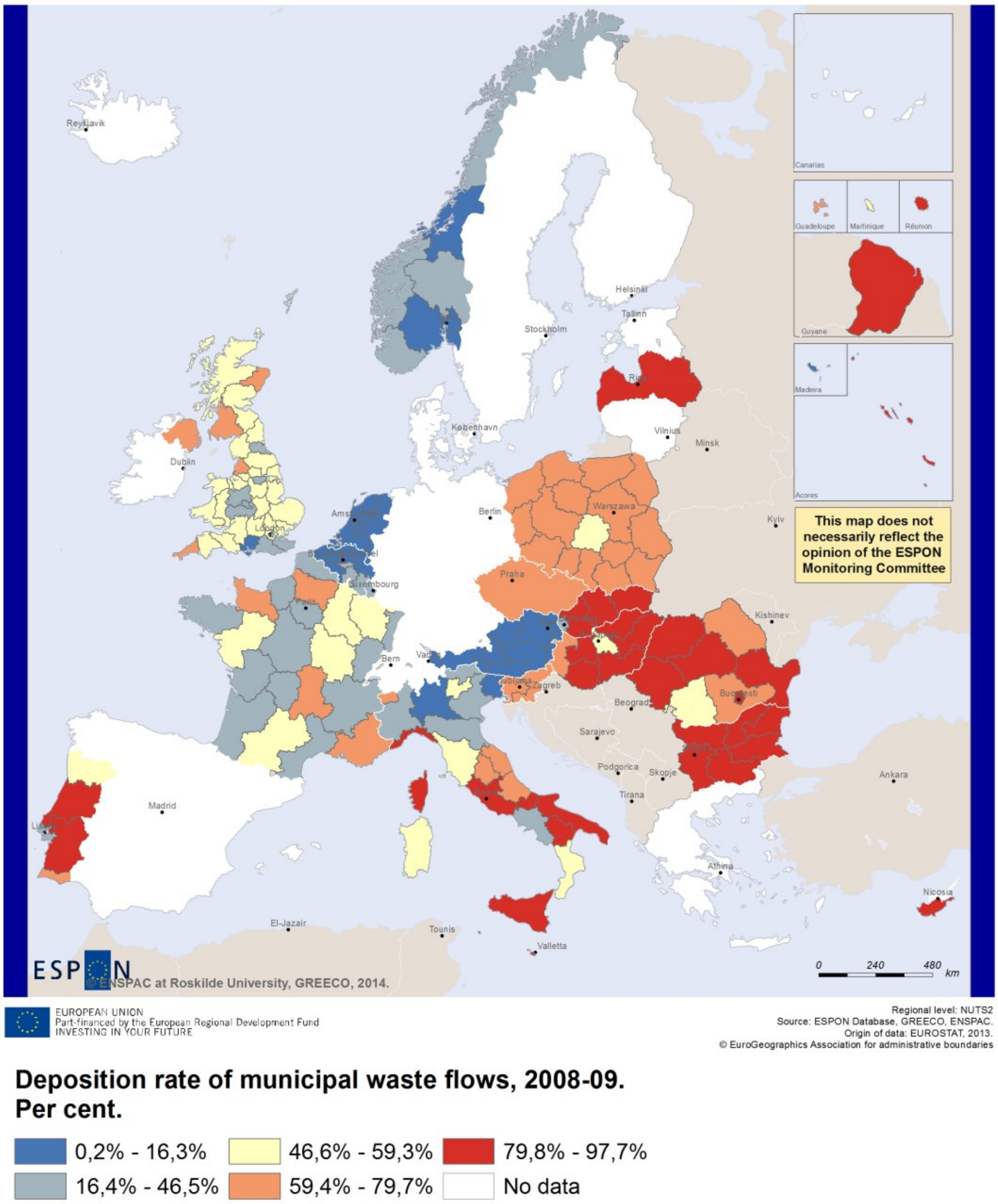
Material flows statistics are only available at national level and information on the recycling of materials is difficult to derive from the statistics. The Materials flow statistics divide materials into four groups: Biomass, Metal ore (gross), Non-metallic minerals and Fossil fuels. The throughputs of these flows are accounted for at the entry and exit points of the economy. Major exit points are emissions and waste.

The available statistics on the growth rates of municipal waste is shown in map 54.



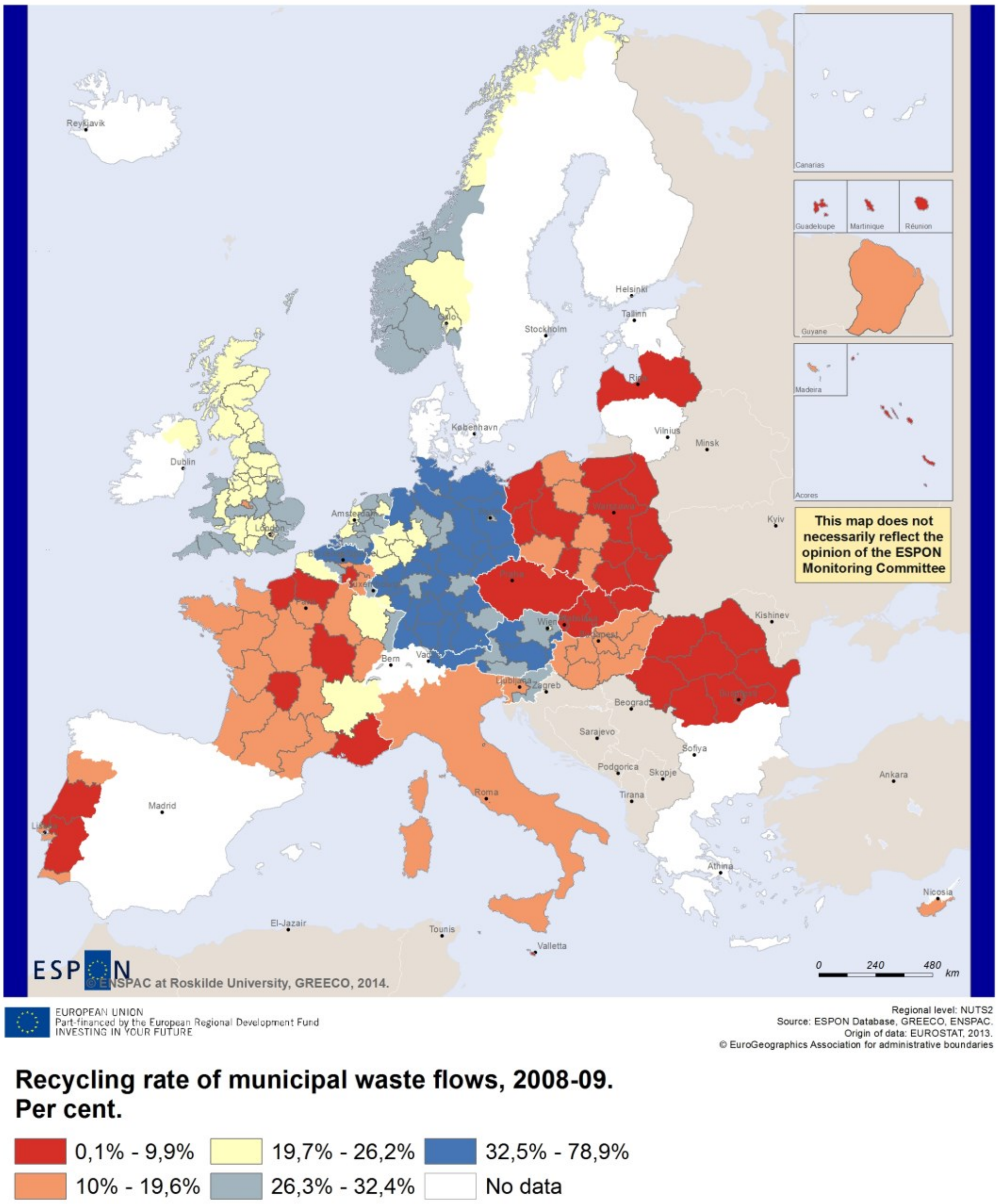
Map 54. Annual growth rate of municipal waste 2000-08. Per cent.
Source: EUROSTAT (European Commission 2013k)

The consumption of ecological values entailed by municipal waste depends on the treatment of the waste flows. Deposition involves serious environmental damage and the rates of the flows that are deposited ar e shown in map 55.



Map 55. Deposition rates of municipal waste flows. Average 2008-2009. Per cent.

Source: Author' s calculations based on EUROSTAT data (European Commission 2013k).



Map 56. Recycling rates of municipal waste flows. Average 2008-2009. Per cent.
Source: Author' s calculations based on EUROSTAT data (European Commission 2013k).

15. Restoration of natural ecosystems

15.1. Biodiversity loss

The third major area for transformation to a green economy is the interface between the economy and the natural ecosystems. The EU policy goal is to halt and reverse the decline in biodiversity by 2020. Important contributions to this end include the water framework directive and the nature conservation policy.

The trend of nature scarcity expressed as area left for nature purposes per capita emphasises the importance of the EU biodiversity strategy. The central target of the strategy is "*to halt the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, restore them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss*". This target is set after the EU failed to attain its previous target on halting biodiversity loss by 2010. Target 2, however, on "*maintaining and restoring ecosystems and their services*" aims at "*by 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15 % of degraded ecosystems*" (European Commission 2011b).

In the following three physical properties that are important for this goal will be addressed. They include the emissions to the aquatic environment, the allocation of land between economic purposes and natural ecosystems and

15.2. Allocation of land between economic and nature

In Europe the area covered with artificial surface, i.e., land used for urban purposes, continued a growing trend from 2000 to 2006 at the expense of agricultural and semi-natural land cover (OECD 2012). Despite the evidence that land-use for economic purposes is the major cause of terrestrial biodiversity loss, the EU biodiversity strategy contains no targets as to land-use. The Committee of the Regions proposes to give regional and local authorities a key role in pursuing local and regional sub-targets on environmental pressure and land-use (European Commission 2010e).

The pressure for increasing land-use for economic purposes will increase through the 21st century as a result of an increasing world population with increasing demand for, also increasingly, animal food. This pressure can result in a higher human take of the primary production and smaller areas available as habitats for species and ecosystems.

The land-use changes that must be associated with progress towards a green economy necessarily differ from region to region according to their biodiversity and potentials for biodiversity, environmental amenities, access to nature experience etc. and the potential gains from economic use of the areas.

15.3. Human appropriation of net primary production (HANPP)

The human take on the primary production can be analysed by a new accounting framework accounting the actual human appropriation of net primary production (HANPP).

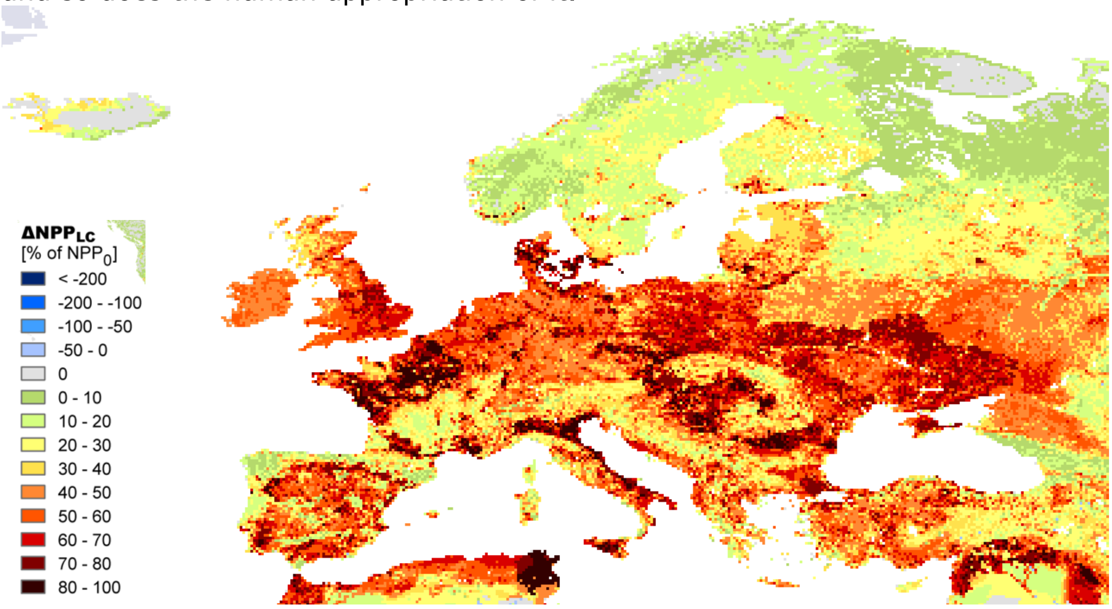
The net primary production of a territory is the generation of organic material from carbon. The "net" refers to cell respiration loss. This net primary production is the basis for all other life in the biosphere as the carbon passes along through the food chain. "Human appropriation" designates share of it that is used for food, fodder, timber, fibres and any other input to economic activities.

An early estimate of the HANPP was 40% (Vitousek et al. 1986), but there is still far from a scientific consensus on how to define "human appropriation" and thus on the actual share (Haberl et al. 2007).

A NASA research team has applied satellite data to estimate NPP and the matched them with human use of organic material from the FAO database. The found that the HANPP was 20% in 1995 rising to 25% in 2005 and with the prospect of 55% in 2050 (Imhoff and Bounoua 2006).

This HANPP framework for analysis of the ecological-economic structures invite to further studies of territorial variation in NPP-carbon-efficiency and of inter-territorial NPP-carbon-flows.

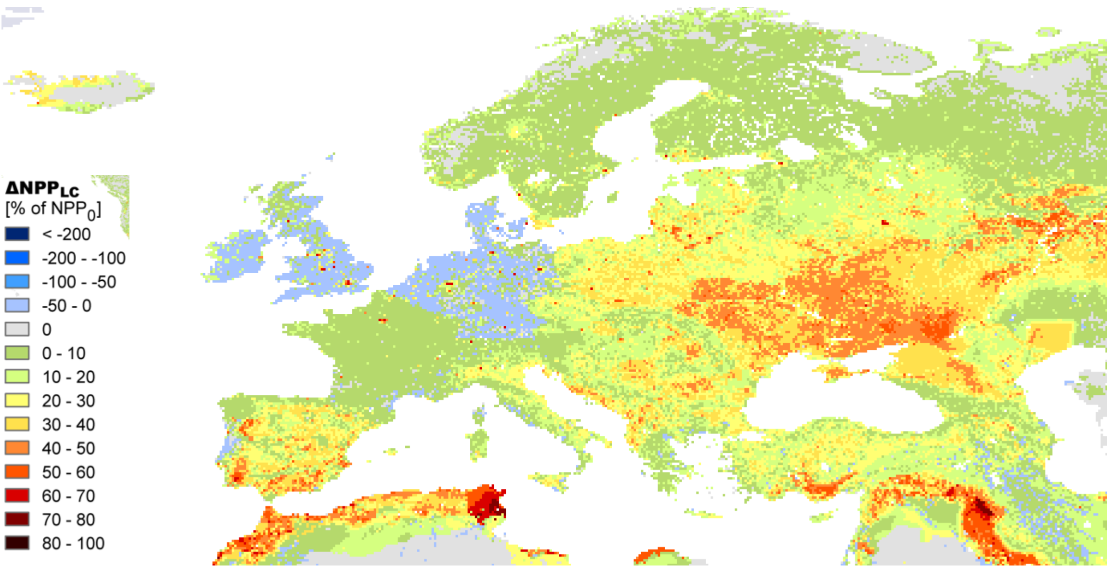
The net primary production of biomass per area varies across European regions and so does the human appropriation of it.



Map 57. Human Appropriation of Net Primary Production in Europe (%), 2000.

Source: (Haberl et al. 2007).

The NPP is also affected by the change in land use as shown at the following map.



Map 58. Change of net primary production due to land-use (%), 2000.

Source: (Haberl et al. 2007).

Whereas the HANPP provides a scientifically well-founded aggregate measure of anthropogenic pressure on ecosystems, it is not obvious how to define a sustainable HANPP at the regional level except for the fact that the HANPP obviously cannot increase indefinitely.

Map 58 shows that the sharing of land between use for economic purposes and for natural ecosystems impacts HANPPP as well as the habitat function.

15.4. Allocation of land between the economy and nature

In growth economies, the space required for economic activities seems to grow. The spatial patterns of growth of urban land are to a very high extent coincident with the growth regions of the period.

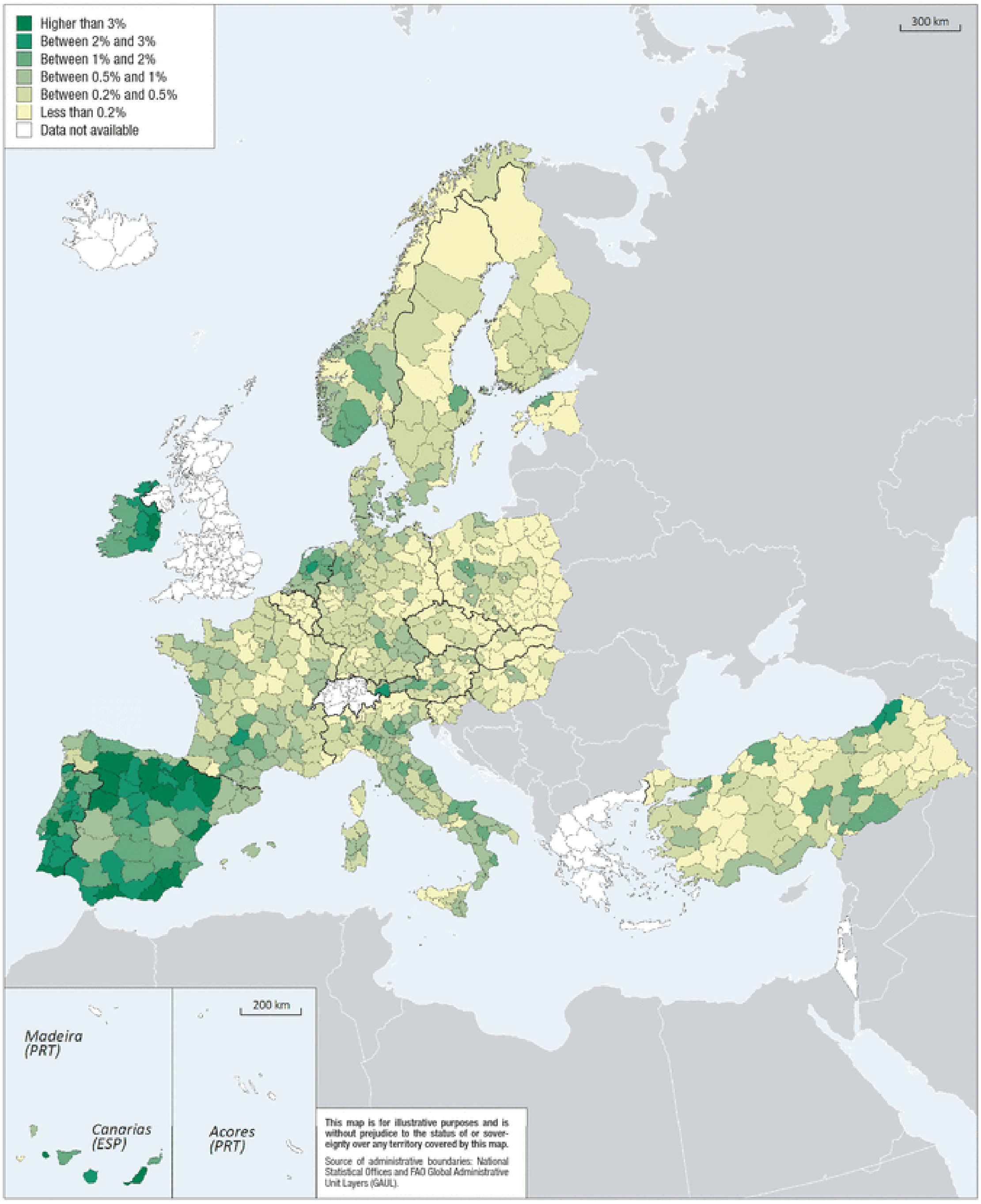


Figure 30. Annual average growth of urban land in Europe's TL3 regions 2000-06.
Source: OECD.

The growth of urban land replaces primarily agricultural surface with artificial surface and it has continued through 2000-06. If more land becomes cultivate

The sharp distinction between land areas by single functions is, however, not necessarily the most appropriate analytical approach. Multi-functionality of land areas is often a more adequate approach to understand the impacts of land-use and the balances between economic activities and nature.

15.5. Nature areas

The ecosystem services available to the European citizens include the biodiversity, the cultural values of access to nature of high quality, the regulatory services such as the cleaning function in the hydrological cycle and the provision of materials and energy to the economy. With the present allocation of land between nature and the economy, additional land use for economic purposes (whether provision of materials and energy or urban purposes) is typically at the cost of the former three ecosystem services.

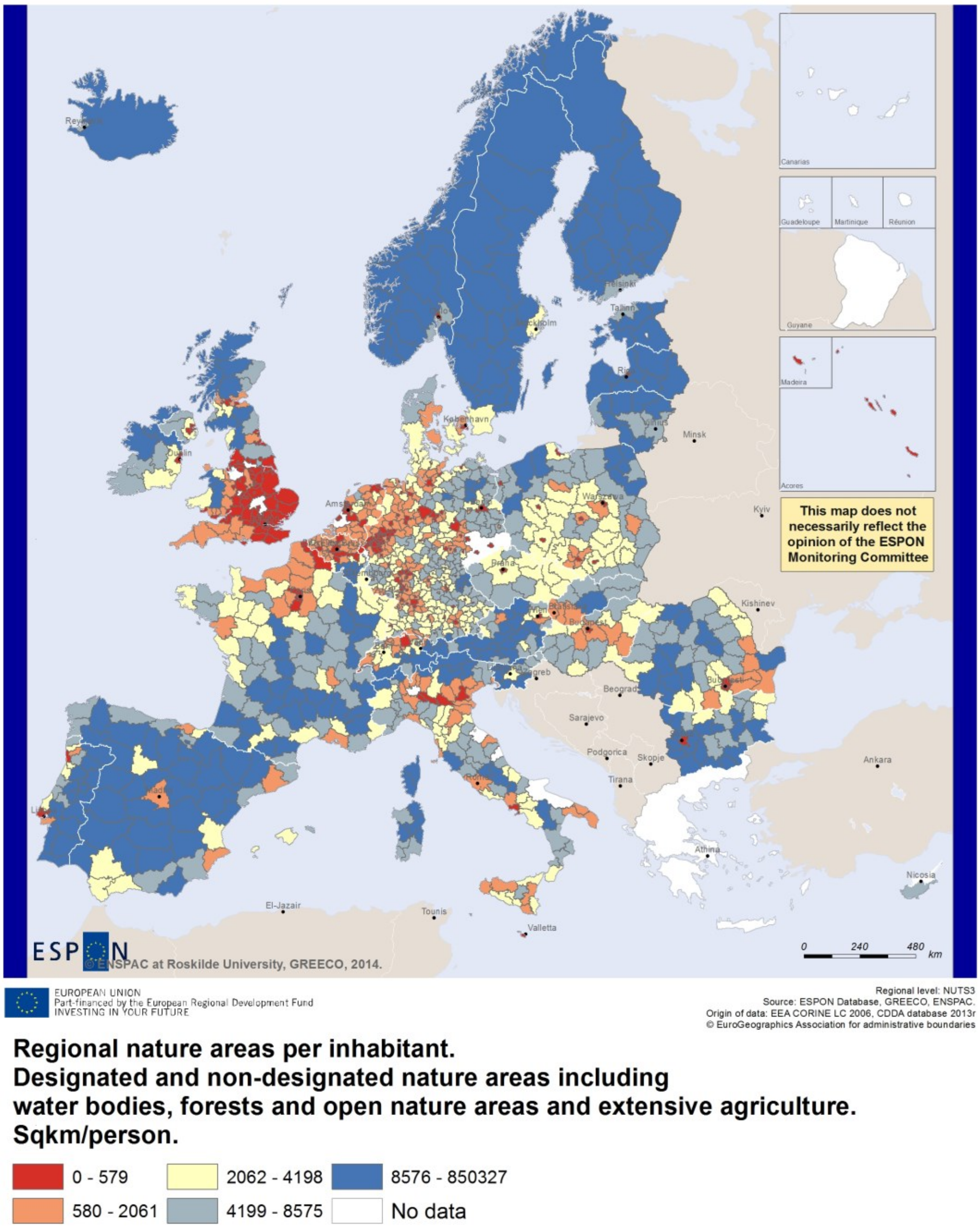
The ratio of the regional nature area to the regional population - "per capita nature" – is rough indicator of the regional availability of ecosystem services that is explored in the following.

The biodiversity strategy is supplemented by other legislation related to nature protection, integrated management of river basins and the common agricultural policy. The Natura 2000 network based on the birds and habitats directives provides instruments for reserving areas for nature purposes (European Commission 2010b; European Commission 1992). This is because habitat area is an essential condition for the species and ecosystems we want to preserve.

The member-states protect far larger areas than Natura 2000. In the following we consider any form of protection as "protection" regardless of it only protect some aspect of nature and allows some economic activity to take place in balance with the ecosystems in the same area.

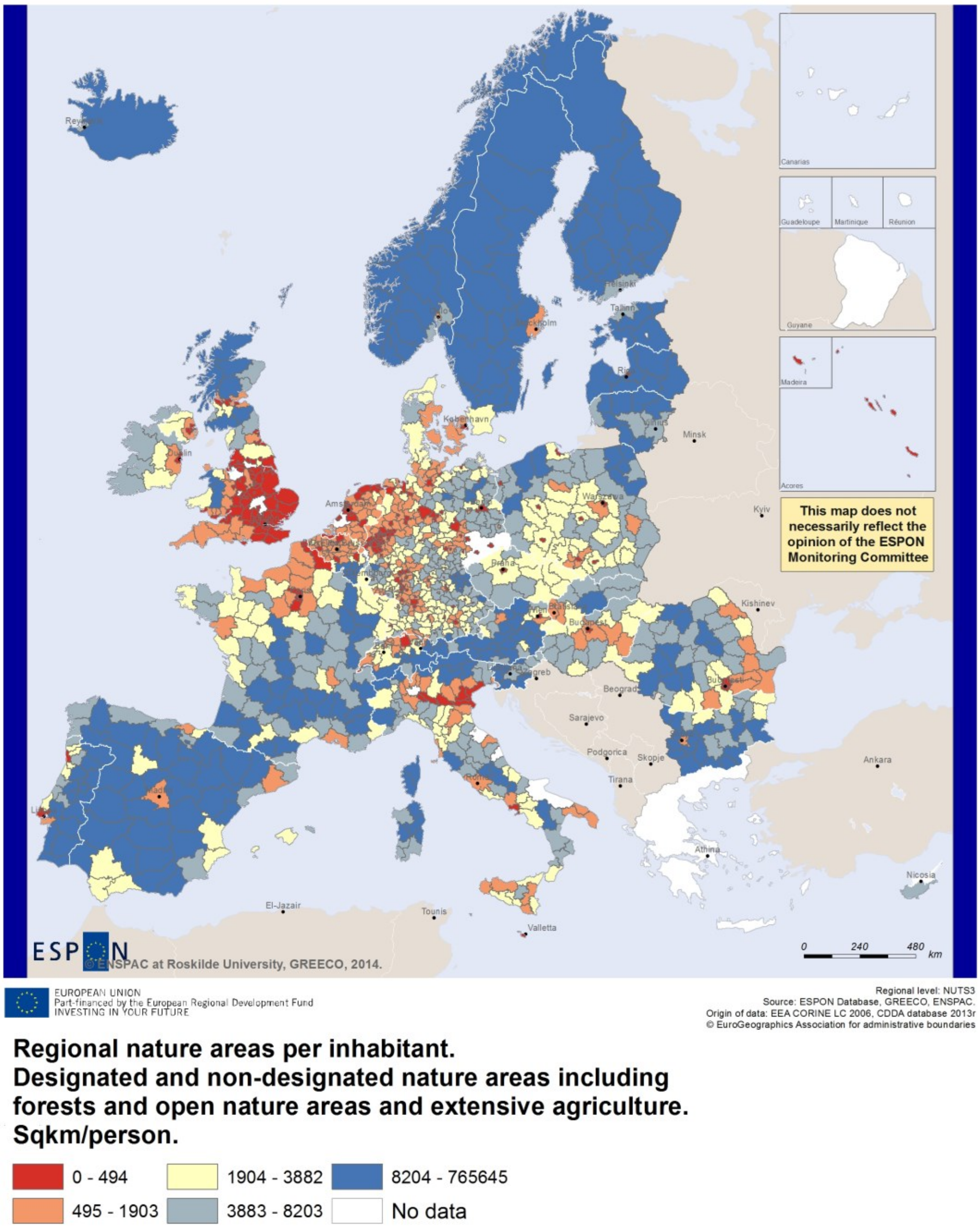
The European Environmental Agency (EEA) has merged the Natura 2000 database with a database of nationally designated nature areas. Based on the combined database the allocation of land between natural ecosystems and economic activities is studied below. "Nature" is defined as the corine land-cover classes of forest, water and extensive agriculture areas (pastures, meadows etc). These areas include areas that where economic activities have priority as well as areas where natural ecosystems have priority.

Thus, the following maps show the availability of nature areas per inhabitant within the NUTS3 territories where nature areas are further defined as terrestrial (forest, open land, extensive agriculture) or water bodies and as areas designated for nature purposes (national or NATURA 2000) or not designated for nature purposes.



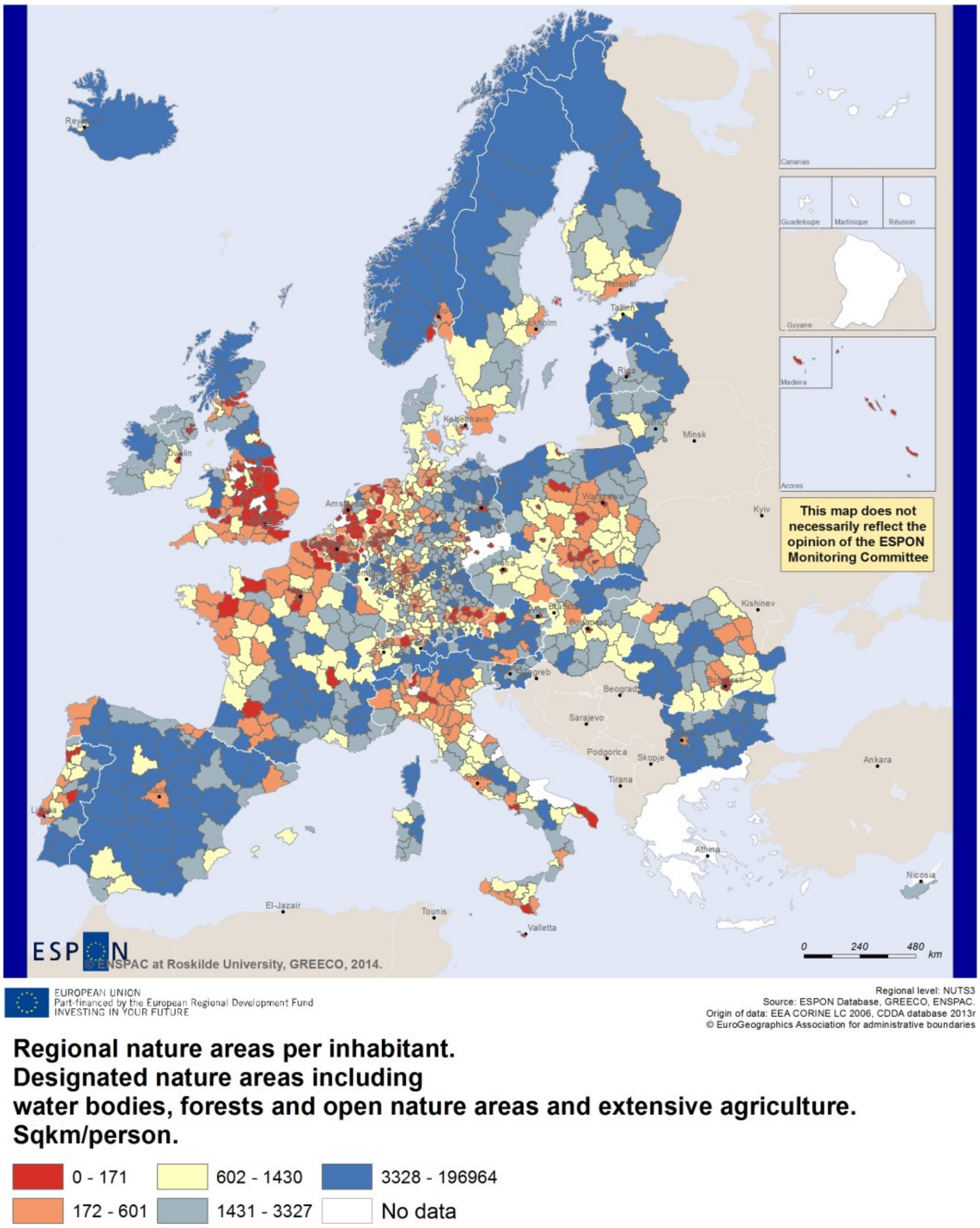
Map 59. Nature (forest, open land, water and extensive agricultural) area per capita, 2011. Km^2/person. Designated and non-designated nature areas.
Source: Author's calculations based on CLC and designated nature databases (see Hansen 2013a).

The regional endowment of nature measured in area per person coincides (inversely) with the population density.



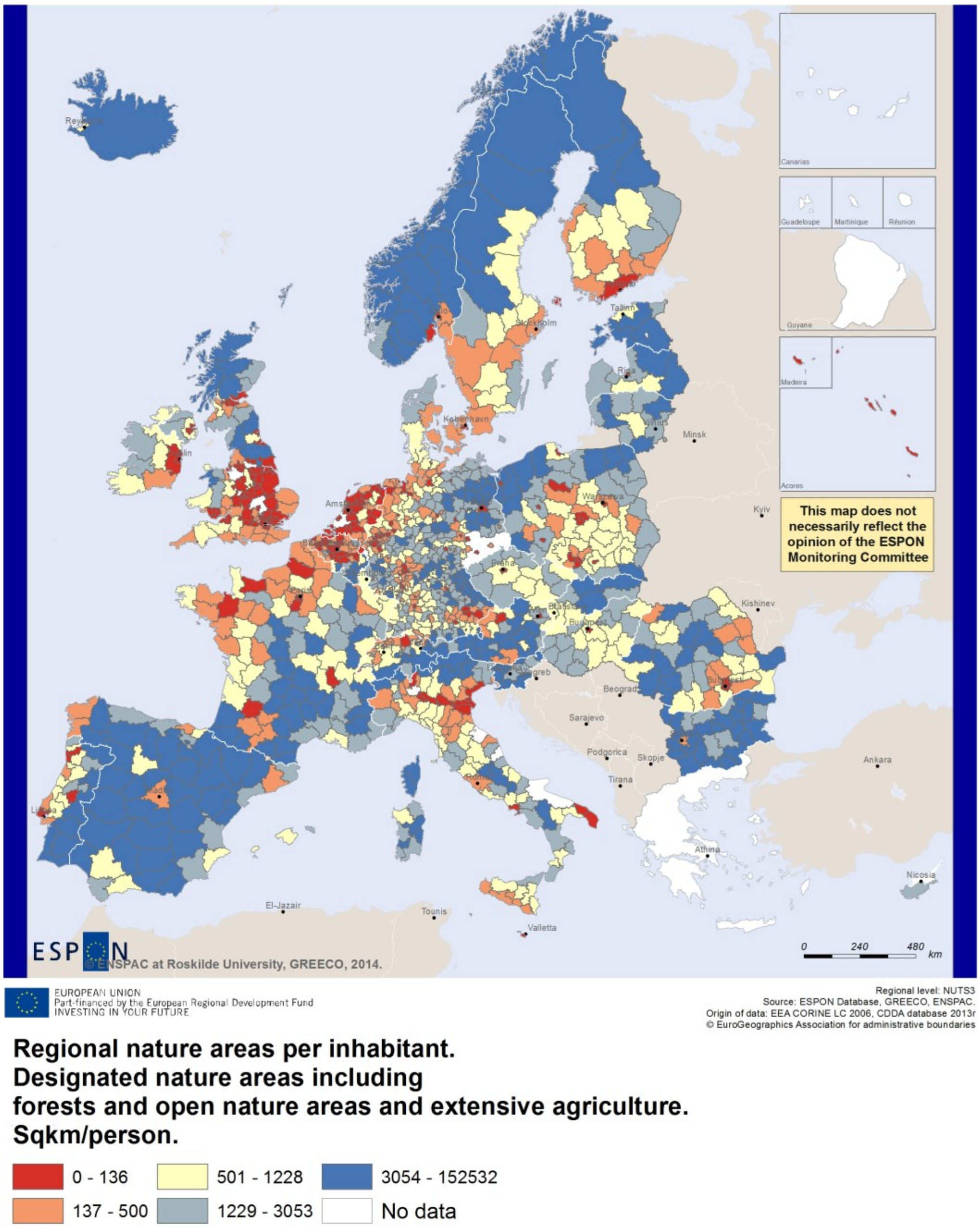
Map 60. Terrestrial (forest, open land and extensive agricultural) nature area per capita, 2011. Km^2/person. Designated and non-designated nature areas.

Source: Author's calculations based on CLC and designated nature databases (see Hansen 2013a).



Map 61. Designated nature (forest, open land, water and extensive agricultural) area per capita, 2011. Km^2/person.
Source: Author's calculations based on CLC and designated nature databases (see Hansen 2013a).

Map 61 shows that when the concept of "nature" is delimited to areas that are designated for nature, that is, where natural ecosystems have precedence to economic activities, the areas with poor rates of nature per capita becomes larger.



Map 62. Designated terrestrial (forest, open land and extensive agricultural) nature area per capita, 2011. Km^2/person.
Source: Author's calculations based on CLC and designated nature databases (see Hansen 2013a).

In map 62, the "nature" area has been reduced to include only terrestrial areas. This reduces the indicator value to 150,000 km^2/person in the most richly endowed region.

The weakness of this indicator is that many NUTS3 regions are delineated by urban morphology. Thus, the inhabitants of such regions may have access to lots of nature just outside the NUTS3 boundaries. On the other hand, the regions that are poorly endowed with nature areas seem to cluster and thus being neighbours to each other.

An alternative could be to calculate the indicator at NUTS2 level. This would, however, generate the same problem, just on a higher level and for spatially large regions the access to nature in one end of the region is of limited relevance to residents in the other end of the region. Consequently, the indicator should be developed using an accessibility approach to calculate measures of nature accessibility.

16. Environmental national accounts

16.1. The System of Environmental-Economic Accounts (SEEA)

Another set of statistical material on the process innovation side of the green transformation is provided by the efforts of integrating environmental and energy aspects in national accounting.

The development of this system was initiated in the 1970s based on a concern for environmental and other dimensions of our well-being that are not covered by the conventional System of National Accounts (SNA) statistics such as the GDP.

The early decisions on the development of such statistical frameworks followed recommendations from experts on developing separate physical and monetary accounts (United Nations 1977).

These early efforts were in 1993 combined in a comprehensive framework, the System of Environmental-Economic Accounts (SEEA) as a response to the Agenda 21 recommendations of the UN Conference on Environment and Development (UNCED). The 2012 revision (United Nations 2011) will describe the until now most comprehensive framework including definitions, classifications, accounting rules etc. The main components of the SEEA can be grouped as in Table 6.

Table 6. Environmental-economic flows in national accounting.

Physical/monetary accounts	**Ecological-economic category**	**Accounting methods**
Physical accounts: The throughputs linked to economic activities.	Natural resource requirements	Land use statistics
		Energy statistics
		Materials Flow Accounts
	Residuals to sinks	Emission statistics
		Solid waste statistics
Monetary accounts: The value of environmental goods and services (EGS)	Environmental Goods and Services (EGS) supply: Production value	Environmental Protection Activities (CEPA)
		Resource management activities (CREMA)
	EGS demand: Environmental protection expenditure	Investment costs
		Operational costs

The physical accounts are often referred to as satellite accounts. That is, changes in the use of nature as source or sink do not cause feedback effects on the economic accounts. Satellite accounts assumes no causal link from the “satellite” to the economy - the link of causation is one way.

The Classification of Environmental Protection Activities (CEPA) is composed of nine classes whereas the Classification of Resource Management Activities

(CReMA) comprises seven classes. Together they form the 16 classes listed in table 7. This list is the result of discussions at a European level and represents a progress in comparison with the OECD/Eurostat 1999 manual.

Table 7. Environmental and resource activities defining the environmental goods and services sector

Classification of Environmental Protection Activities (CEPA):
1: Protection of ambient air and climate
2: Wastewater management
3: Waste management
4: Protection and remediation of soil, groundwater and surface water
5: Noise and vibration abatement
6: Protection of biodiversity and landscape
7: Protection against radiation
8: Research and development
9: Other environmental protection activities.
Classification of Resource Management Activities (CREMA):
10: Management of waters
11: Management of forest resources
11 A: Management of forest areas
11 B: Minimisation of the intake of forest resources
12: Management of wild flora and fauna
13: Management of energy resources
13 A: Production of energy from renewable sources
13 B: Heat/energy saving and management
13 C: Minimisation of the intake of fossil resources as raw material for uses other than energy production
14: Management of minerals
15: Research and development
16: Other natural resource management activities.

The statistics on green products follow the nomenclature-approach by using the CEPA and CREMA lists in table 7 to identify the codes in the Classification of Products by Activity (CPA) that are or could be used for environmental protection activities.

16.2. Monetary environmental accounts

In addition to the above physical accounts, the system includes monetary accounts from the demand side as well as the supply side.

From the demand side, the Environmental-Protection-Expenditure-(EPE)-approach aims at measuring investment and operating expenditures that can be related to environmental purposes (Muthmann, Olsson, and Johansson 2005). The costs that can be associated with environmental purposes in the private as well as in the public sector are surveyed.

From the supply side, the Environmental-Goods-and-Services-(EGS) approach, however, aims at measuring the market turnover of commodities and services that can be characterised as “environmental” (European Commission 2009d; Steenblik 2005). The EGS statistics uses the nomenclature approach to identify the codes in the Classification of Products by Activity (CPA) that are or can be used for environmental protection activities.

This statistical material however only contains data at the national level and even at the national level there are large data gaps.

16.3. European environmental goods and services statistics

EUROSTAT conducted in 2009 a pilot data collection among the national statistical institutes of the relevant European countries and received 11 replies. The total environmental expenditures defrayed for the purpose of environmental protection in the EU amounted to more than 2 per cent of the GDP, cf. table 8.

Table 8. Environmental expenditure in the EU27, 2009. Per cent of GDP*).

Environmental expenditure, of which	**Total**	**Investment**	**Current expenditure**
Industry (except recycling) (CA10 to DN36 and E)	0.42	0.12	0.31
Private and public specialised producers of environmental protection services (DN37 and O90)	0.99	0.21	0.78
General government	0.60	0.15	0.45
Total	2.05	0.51	1.54

*) Provisional value, EUROSTAT estimate

Source: Author's calculations based on Eurostat data (European Commission 2012b).

According to the results displayed in table 8 around a fourth of the environmental expenditures are investments whereas three fourths are current expenditures. These proportions are equal in industrial and government sectors alike. Apparently, these figures do not include environmental expenditure in agriculture, forestry and fisheries.

In addition to actual investment and operational expenditures, the data include fees and purchases and receipts from by-products minus subsidies/transfers and revenues. The fees included are only the earmarked fees, that is, fees that are dedicated to the finance of environmental expenditure. The actual use of these funds for financing of environmental expenditure should be covered by the subsidy/transfer accounts. This property makes it difficult to compare countries where environmental expenditure are financed by general taxes from countries where environmental expenditures are financed by ear-marked taxes.

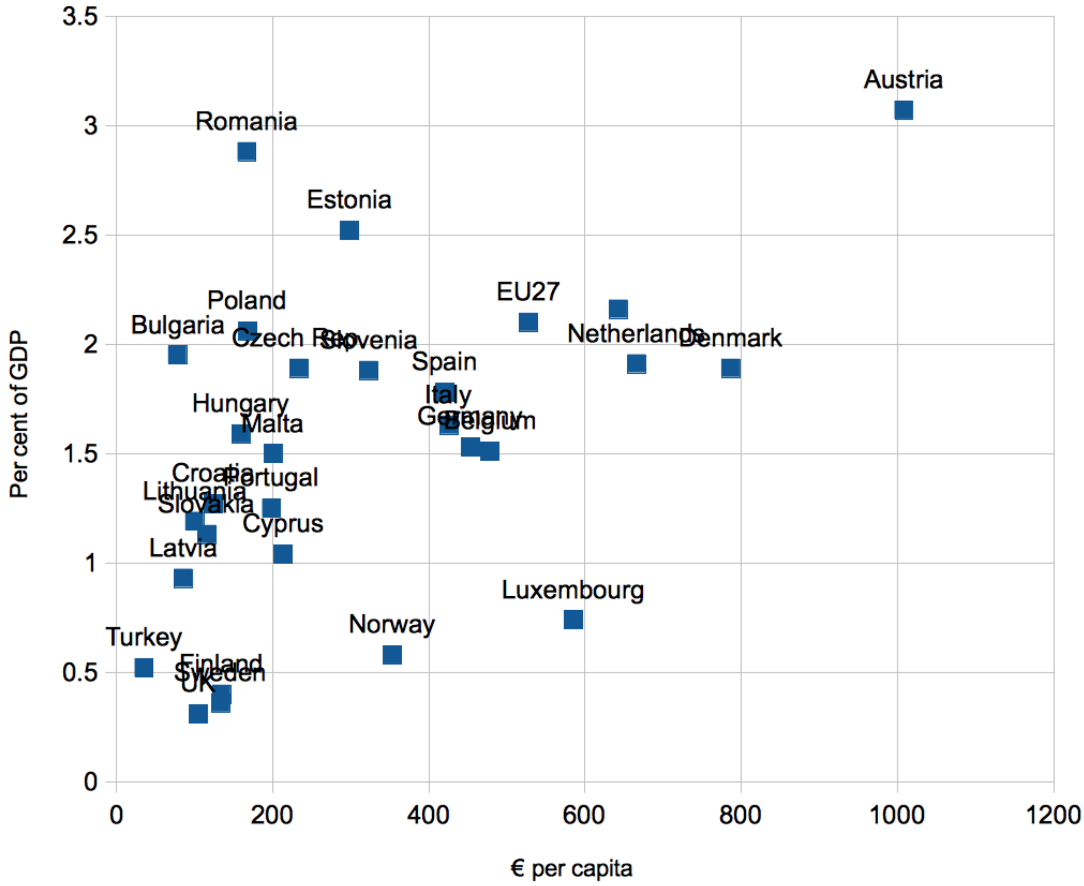


Figure 31. Environmental protection expenditure in the EU in 2007. Per cent of GDP and € per capita.
Source: Author's calculations based on Eurostat data (European Commission 2012b).

The ranking of EU member states according to their environmental protection expenditure appears from figure 31. The highest share of environmental protection expenditure in GDP is found in Austria, Romania and Estonia, whereas the lowest shares are found in the UK, Sweden and Finland. The highest absolute environmental protection expenditure per capita was found in Austria, Denmark and the Netherlands, whereas the lowest absolute expenditures were found in Turkey, Bulgaria and Latvia.

The interpretation of expenditure statistics as an indicator of progress towards a greener economy is difficult. A high level of expenditure can be caused by a particularly high level of environmental pressure or a particularly high level in restoring ecosystems to an acceptable state.

Table 9. Employment share of the environmental goods and services sector in total employment. Per cent.

Netherlands	2007	0.1%
Germany	2007	0.3%
France	2007	1.2%
Sweden	2006	1.5%
Belgium	2004	1.5%
Poland	2007	2.2%
Romania	2006	2.5%
Austria	2008	3.5%

Source: Author's calculations based on Eurostat data (European Commission 2012b).

The environmental expenditures – inside as well as outside the EU – lead to employment in the environmental goods and services sector. Few of the countries have supplied sufficient data for accounting for the employment in the environmental goods and services sector. The aggregate data available are shown in table 10 calculated as a share of total employment. The countries with the highest share of EGS employment are again Austria, Romania and Poland, whereas the countries with least EGS employment shares are Netherlands, Germany and France.

For some countries, detailed accounts are available. The employment data from France are shown in table 10.

Table 10. Employment in the environmental goods and services sector in France. 2007. Full time equivalent employment.

	Total environmental goods and services sector	Ancillary activities	Market activities				
			Environ-mental specific and connected services	Connected goods	Adapted goods	End-of-pipe technologies	Integrated technologies
Total environmental protection activities	209,142	29,391	156,634	11,106	19,700	21,501	n/a
Protection of ambient air and climate	10,305	4,483	7,471	522	n/a	2,312	n/a
Wastewater management	75,317	9,062	55,085	5,998	n/a	14,333	n/a
Waste management	70,412	5,127	63,173	2,383	n/a	4,856	n/a
Protection and remediation of soil, groundwater and surface water	27,491	4,222	7,491	n/a	19,700	n/a	n/a
Noise and vibration abatement	12,931	n/a	11,398	1,533	n/a	n/a	n/a
Protection of biodiversity and landscapes	3,774	n/a	3,774	n/a	n/a	n/a	n/a
Protection against radiation	2,619	204	1,949	670	n/a	n/a	n/a
Research and development (R&D) for environmental protection activities	6,293	6,293	6,293	n/a	n/a	n/a	n/a
Total Resource management activities	103,710	n/a	63,244	10,019	23,825	n/a	7,265
Management of waters	6,430	n/a	5,497	1,576	n/a	n/a	n/a
Management of fossil energy resources	97,280	n/a	57,747	8,443	23,825	n/a	7,265
of which production of energy from renewable sources	38,571	n/a	9,462	2,406	22,968	n/a	3,735
of which Heat/Energy saving and management	28,275	n/a	19,144	5,601	n/a	n/a	3,530
resource as raw material	30,434	n/a	29,141	436	857	n/a	n/a

Source: Author's calculations based on Eurostat data (European Commission 2012b).

The employment in the environmental goods and services sector as far as environmental protection is concerned is again dominated by employment in management of waste and wastewater. Resource management activities are similarly dominated by production of renewable energy, energy saving and other activities aiming at reducing the use of fossil fuels.

Table 11. Value added in environmental protection activities. Netherlands 2007. Pct. of total.

	Total environmental goods and services sector	Ancillary activities	Market activities: environmental specific and connected services	adapted goods	end-of-pipe technologies
Total Environmental protection activities	**100%**	**9%**	**91%**	**3%**	**n/a**
Protection of ambient air and climate	4%	4%	n/a	n/a	n/a
Wastewater management	19%	2%	16%	n/a	n/a
Waste management	63%	1%	61%	n/a	n/a
Protection and remediation of soil, groundwater and surface water	7%	1%	2%	3%	n/a
Noise and vibration abatement	0%	0%	0%	n/a	n/a
Protection of biodiversity and landscapes	1%	0%	n/a	n/a	n/a
Other environmental protection activities	5%	1%	12%	n/a	n/a
Protection against radiation	0%	n/a	n/a	n/a	n/a
Research and development (R&D) for environmental protection activities	1%	0%	n/a	n/a	n/a
Total Resource management activities	**100%**	**n/a**	**17%**	**27%**	**63%**
Management of waters	1%	n/a	n/a	n/a	n/a
Management of forest resources	0%	n/a	n/a	n/a	n/a
of which management of forest areas	*0%*	*n/a*	*n/a*	*n/a*	*n/a*
Management of wild flora and fauna	n/a	n/a	n/a	n/a	n/a
Management of fossil energy resources	85%	n/a	n/a	15%	63%
of which production of energy from renewable sources	*16%*	*n/a*	*n/a*	*15%*	*n/a*
of which Heat/Energy saving and management	*69%*	*n/a*	*n/a*	*n/a*	*63%*
Management of minerals	12%	n/a	n/a	12%	n/a
Research and development (R&D) for resource management activities	1%	n/a	n/a	n/a	n/a
Other resource management activities	1%	n/a	0%	n/a	n/a

Source: Author's calculations based on Eurostat data (European Commission 2012b).

The data from Netherlands in table 11 shows that the economically most important environmental protection activities are waste and waste-water management. The economically most important activities related to resource management are activities directed towards energy savings and production of renewable energy.

It must be emphasised that the above data are collected in pilot exercise and that the national statistical institutes have applied different methods in obtaining them.

16.4. The potentials of the environmental accounts statistics

Most of the environmental protection expenditures and the related employment and value added are spent on waste and wastewater treatment. Increasing expenditures for these purposes are, however, not necessarily indications on progress towards a green economy. If unsustainable waste treatment such as landfilling or incineration of recyclable materials due to larger flows of waste increases, it may result in higher expenditure without transformation to sustainable flows. The economic activities of these sectors are also covered by the general economic statistics.

17. Green product innovation

17.1. Green products in international trade agreements

The process towards assigning the label "environmental" to a set of commodity (and service) code numbers has been driven partly by the need for tools for analysis of an expanding sector of the economy and partly by trade policy.

The WTO decided in 2001 to include negotiations on "the reduction or, as appropriate, elimination of tariff and non-tariff barriers to environmental goods and services" in the Doha agenda.

The ensuing negotiations were complicated by the fact that the WTO members have different trade interests and still, in 2013, a conclusion has not been reached. The national accounts branches of OECD, UNSTAT and EUROSTAT, however, have developed and refined definitions and manuals since 1992.

The issue has also been raised in the negotiations on the Transatlantic Trade and investment Partnership (TTIP). The tariffs in transatlantic trade are low and eliminating them will probably not have radical impact on trade. It may, however, lead to a "green nomenclature" that can be interesting from a statistical point of view.

There is a growing interest in the The growth of industrial branches that are innovative in, e.g., components of renewable energy plants or building insulation materials are much easier to assign to a demand derived from the transformation of the economy to a green economy. Turnover and jobs in the solid waste collection and disposal industry is not as strategically interesting as turnover and jobs in a firm taking an international lead on the technology in question. Statistical analysis of the growth and location of jobs in the latter industries, however, can be very useful for analysing territorial dimensions of the progress towards a green economy.

The environmental industries identified to be used for the purpose of accounting for turnover and employment of the green industries in Europe comprise 27 industrial branches that are fully "environmental" and 300 branches that are partly "environmental". How to estimate the degree of being "environmental" is up to the discretion of the national statistical institutes. This property of the EGS approach assigns the data with a methodological uncertainty that makes comparisons doubtful.

Environmental activities identified in the CPA - and thus the EGSS - does not include important processes in the transformation towards a green economy, e.g., public transport. There is little doubt that a modal shift from individual car transport to public transport will be part of a green economy in the congestion and air pollution prone cities of Europe. Yet such products are not identified as environmental activities. Thus, it is clear that "environmental goods and services" are not identical with "processes towards a green economy".

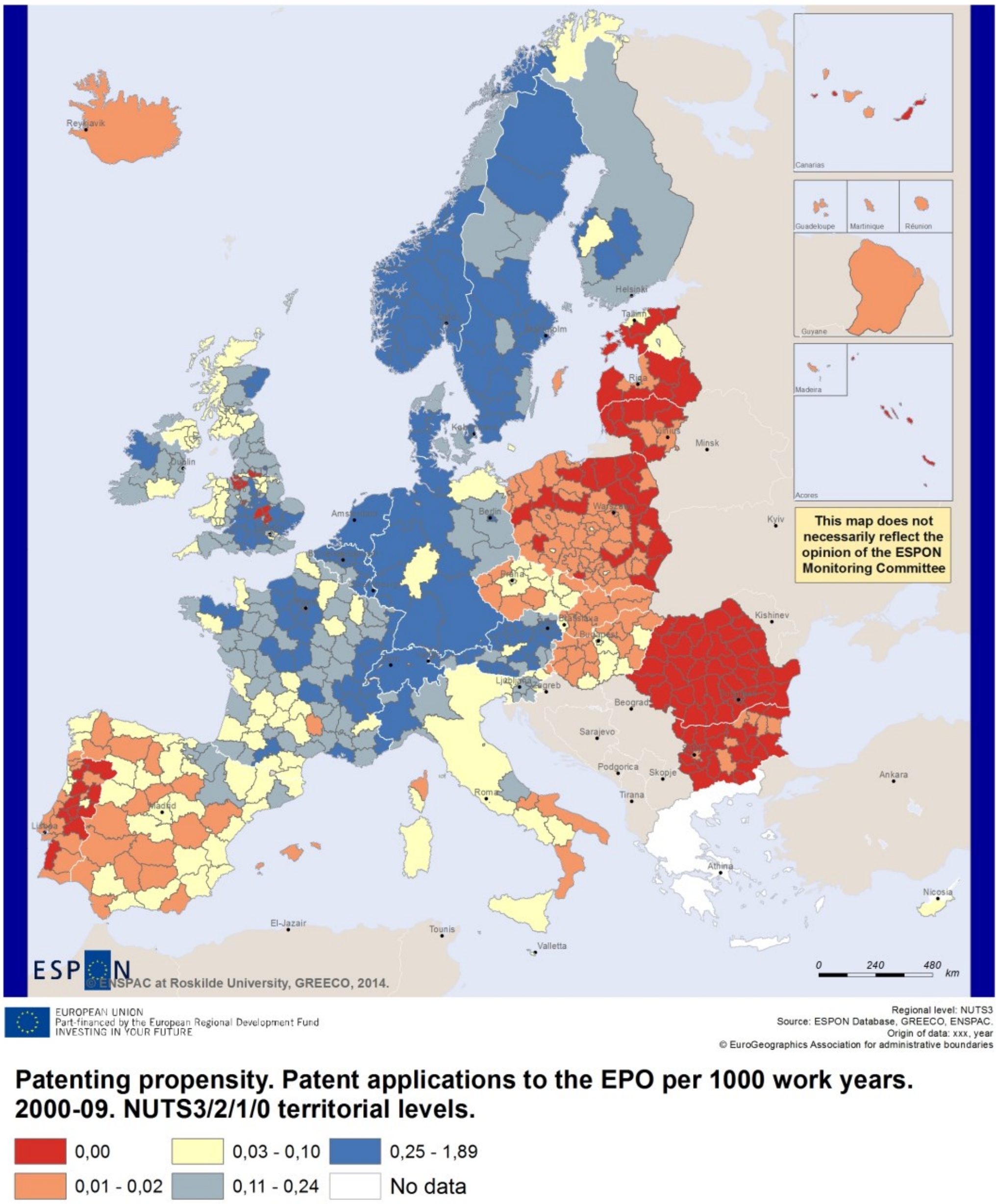
17.2. Green patent applications

Innovation of the green solutions that replace the conventional resource intensive econosphere is difficult to quantify. Patent statistics is a widely used source of data on innovation. The weakness is that they comprise small and large innovations, very valuable and close to valueless patents alike. On the other hand the patent statistics provide consistent data will full coverage over long periods.

The OECD has processed the patent application data from the European Patent Office (EPO) and has succeeded in categorising them according to green and other applications. The data also contain applications filed under the Patent Cooperation Treaty (PCT), but many these never become real patent applications and they are excluded from the analysis.

In the analysis of the regional patterns of the innovation of green solutions, two main problems are of interest. First, the propensity of a regional economy to apply for patents. Second, the share of patent applications that can be classified as green.

The regional patterns of propensity to apply for patents can be measured as the ratio of the number of patent applications filed in a period to the number of work years performed in the period. The period chosen is the 10 years 2000-09 as the detailed NUTS3 statistics otherwise would be too thin.

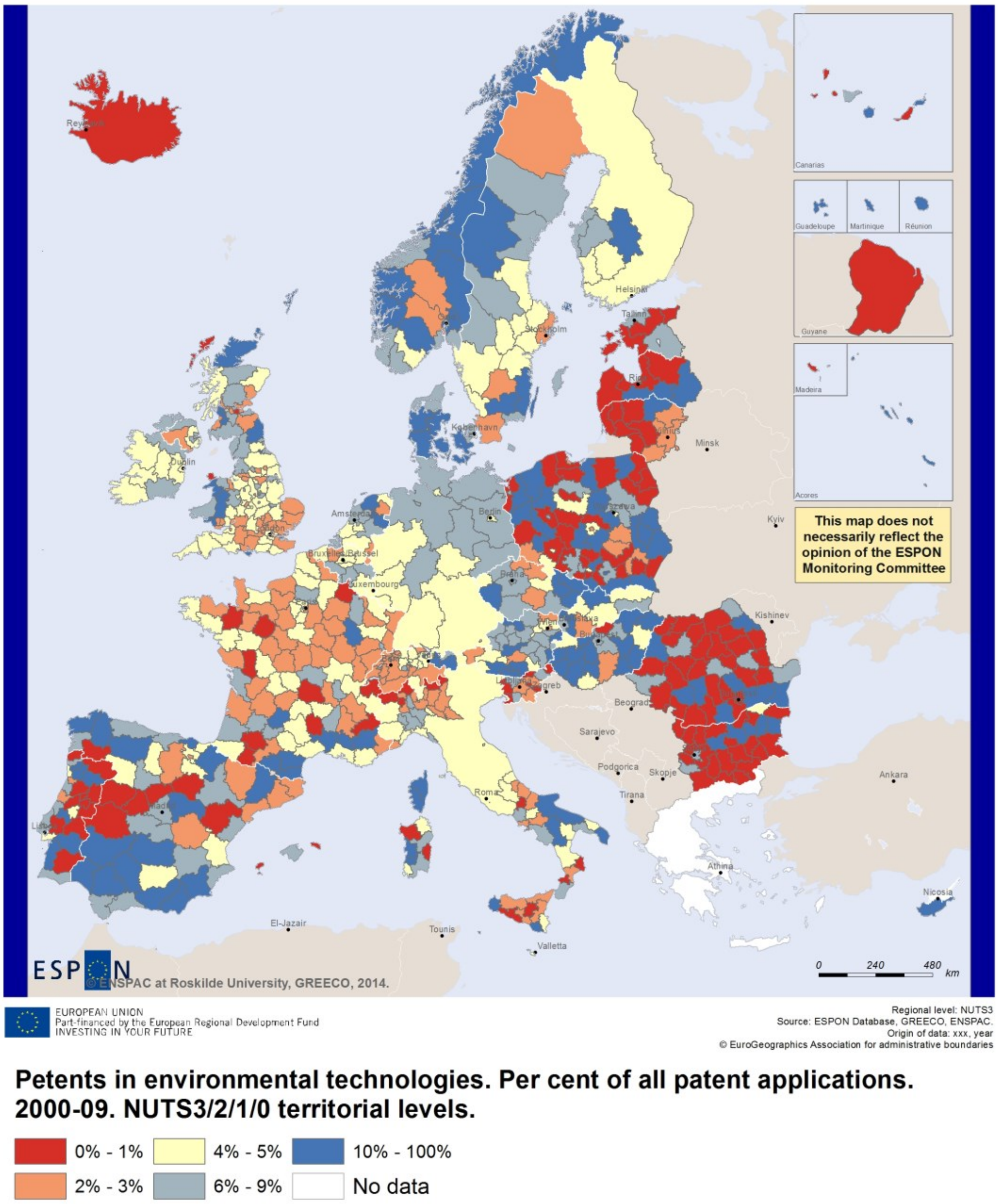


Map 63. Patenting propensity 2000-09. Patent applications per 1000 work years.
Source: Authors calculations based on the GREECO datasets (Hansen 2013a).

Map 63 reveals a clear divide between the "old" EU15 and the new member-states (NMS10) and also differences between the South of Europe and the North. The innovative capacity of the economy is an indispensible prerequisite for progress in the transformation of the econosphere. Thus, unless the regions and countries with low patenting propensity specialise in green innovation, the map reveals serious disparities in the ability of the regional economies to deliver green solutions.

The OECD has used the International Patent Classification (IPC) to identify the patent applications that concern green technologies. Green technologies can be classified in general environmental management technologies (water, air, waste) and energy efficiency and non-fossil energy technologies. The latter comprises technologies specific to climate change mitigation, combustion technologies with mitigation potential (e.g. using fossil fuels, biomass, waste, etc.), energy efficiency in buildings and lighting and energy generation from renewable and non-fossil sources.

The regional patterns of specialisation in green innovation appears from map Map 64.



Map 64. Share of green innovations in patent applications to the EPO. 2000-09. Per cent.

One of the interesting patterns in Map 64 is that many of the regions with a relatively low patenting propensity have a high share of innovations in the green technology fields.

18. Employment and transformation towards a green economy

18.1. The green transformation and economic recovery

The development of GDP and GHG-emissions in figure 6 and figure 7 shows that a considerable part of the seemingly progress towards a low carbon European economy is caused by the Great Recession and the ensuing close-to-zero-growth state of the European economies. Consequently, there is a risk that the recovery will be accompanied by high rates of GHG emissions. The risk can be mitigated by investing in renewable energy and energy efficiency.

A surge in green investments may support progress in the economic dimension along with the progress in the ecological dimension in several ways. Economic progress and indeed employment vary in long waves over the centuries. The all-encompassing renewal of the econosphere could be a carrier of such a long wave. The historically low level of investments in the aftermath of the financial crisis gives rise to opportunities for advancing future green investments to the present. At the EU level, the substitution of fossil by renewable energy and of energy loss by energy efficiency translates to economics as substitution of imported fuel commodities by domestically produced investment goods. The following sections will elaborate on these aspects in more detail.

18.2. The green transformation as carrier of a long wave?

The *investment* activity is the key component of final demand determining the course of economic change: recession or recovery. At the same time, investments build future productive capacity measured as the fixed capital stock. It is partly in making up for used or obsolete capacity and is thus properly measured by the *net* capital stock.

The historic co-variation of the rate of GDP invested in the fixed capital stock, the growth rate of the net fixed capital stock and the overall rate of economic growth is shown in figure 32 for the EU15.

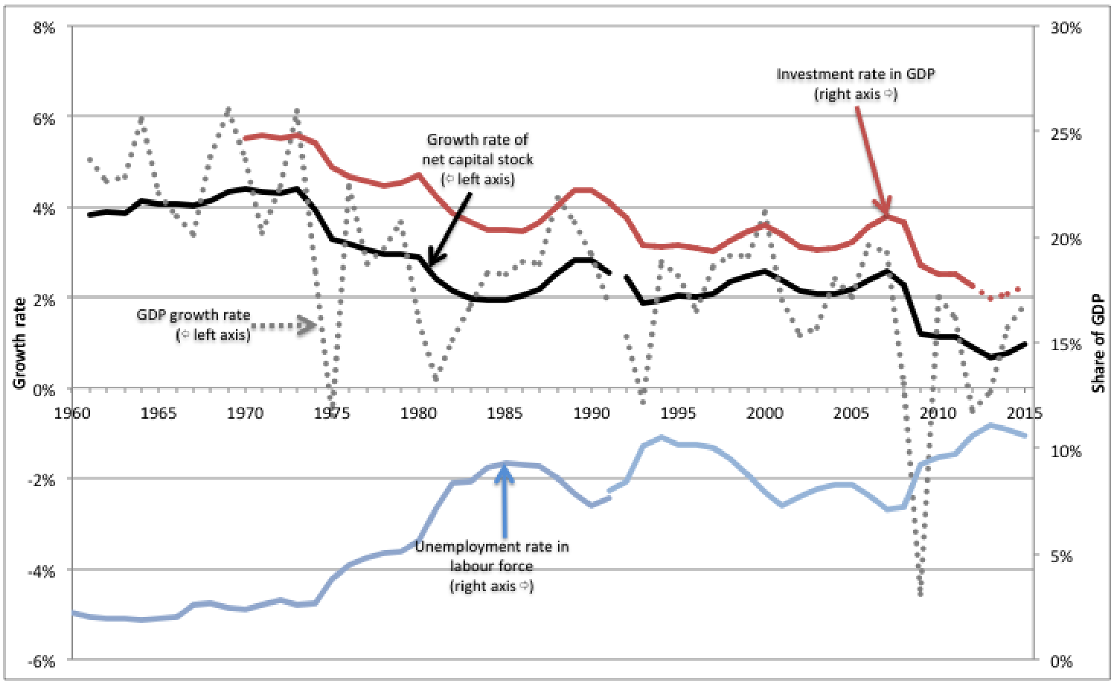


Figure 32. Growth rates of the fixed capital stock (net) and GDP compared to the rates of unemployment and of investment in EU15, 1960-2015. (2005 prices). Per cent.

Note: Growth rates in per cent change from previous year, investment rate in per cent of GDP and unemployment rate in per cent of the labour force. Unified Germany after 1992, FRG before. Investment data are from the OECD database. EU Commission projection 2011-15.

Source: Author's calculations based on the AMECO-database (European Commission 2014c) and the OECD database (OECD 2014).

Figure 32 shows that GDP growth rates over the period 1960-2015 in the EU15 were closely linked to the growth rates of the capital stock. The after-war reconstruction of the capital stock and the building up of the physical basis of the modern oil economy progressed in a high pace – growing around 4% annually - through to the early 1970s. Unsurprisingly, the diagram also shows that the growth rate of the capital stock is closely related to the rate of GDP invested in it.

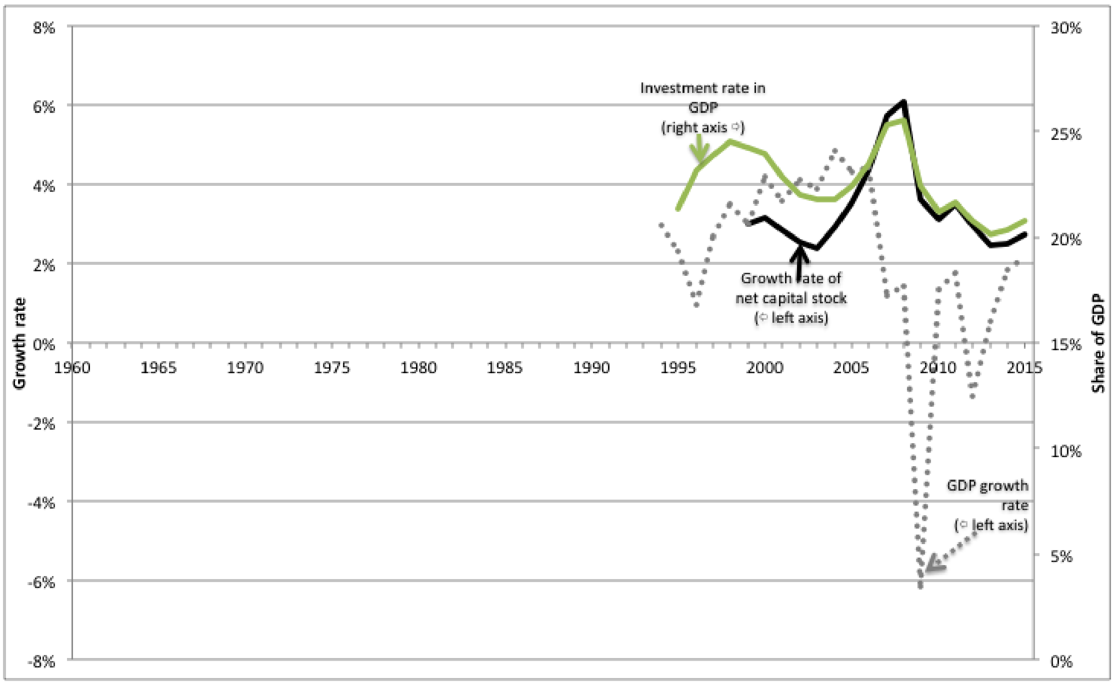


Figure 33. Growth rates of the fixed capital stock (net) and GDP compared to the rate of investment in NMS10, 1995-2015. (2005 prices). Per cent.

Note: Growth rates in per cent change from previous year, investment rate in per cent of GDP and unemployment rate in per cent of the labour force. The database does not contain data for NMS10 before 1993. Projection 2011-15.

Source: Author's calculations based on the AMECO-database (European Commission 2014c).

The data available for the 10 new member states that formerly belonged to the CMEA only go back to the mid 90's as shown in figure 33. The diagram reveals a similar strong link between the rate of investment in GDP and the growth rates of the net fixed capital stock and the GDP. In these member-states, a higher share of the GDP is invested and the net fixed capital stock has grown at a higher rate than the GDP during the years of recession.

For both groups of EU countries, however, the investment rate seems to fall short of 2-3 %-points in the recent years.

History shows reoccurring waves of economic growth stretching over 45-60 year called the Kondratieff cycle (Schumpeter 1961; Schumpeter 1954). The high growth rates through the 60's to the 70's and the subsequent period of low growth rates is often seen as the end of the 4th Kondratieff wave.

The long wave patterns of economic growth can be linked to financial, demographic or econospheric transformations. Many of the waves are linked to energy econosphere transformations such as the use of coal in steam machines and heavy industries such as steel production, the use of oil products for transport and for building heating etc. and the associated infrastructures (Ayres 1990a; Ayres 1990b; Wilson and Grubler 2011). In particular, the period of high growth from the 50's to the 60's coincided with the transformation of the energy econosphere from biomass and coal to modern fuels (oil, gas and electricity).

It is important to underline that energy is not the only factor explaining the long period of high growth until the mid 70's. The potentials of technology and new forms of social organisation that had been stemmed up by the WWII were now being unfold. Communication and transport technologies, education, health, science, changing role of women in family and formal economy, expansion of public sector, expansion of corporate sector and multinational corporations etc. all contributed to high rates of growth.

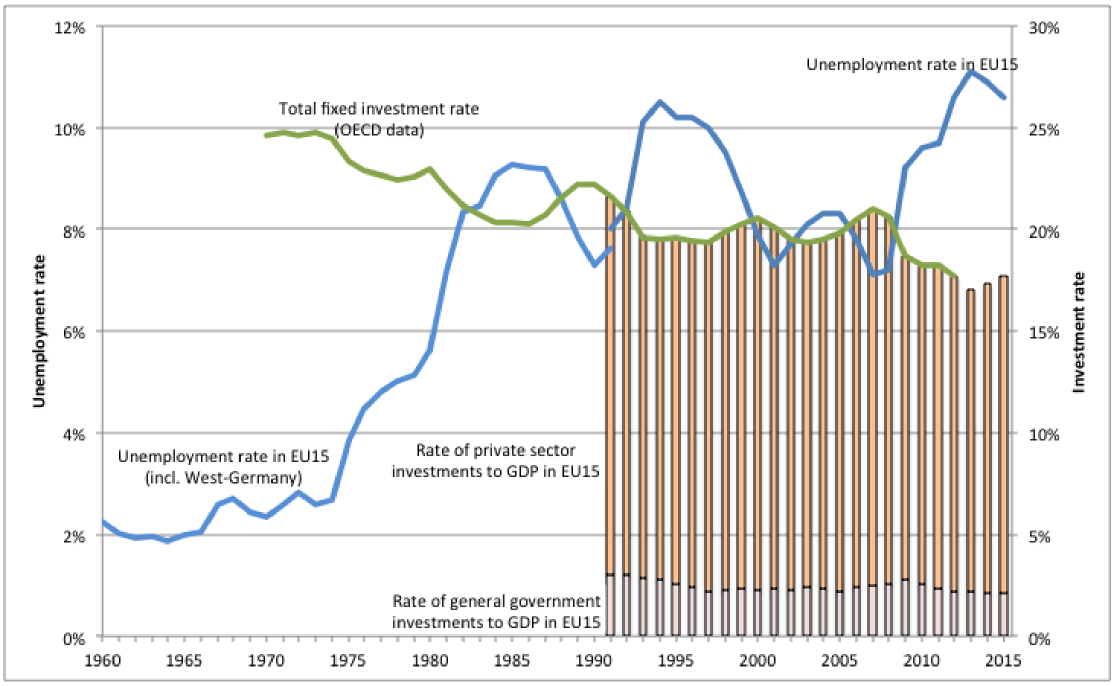


Figure 34. Rates of public and private investment compared to the unemployment rate in EU15, 1960-2015 (projection 2011-15). Per cent.
Notes and sources: See figure 32.

Figure 32 and figure 34 show that the rate of unemployment in the EU15 historically has been strongly (negatively) correlated with the aggregate rate of investment in GDP in the period for which data are available. A higher rate of investment implies a lower rate of unemployment.

Ideally, public (tax financed) investments could be used counter-cyclically to stabilise the economy and dampen fluctuations. Figure 34 shows that public investments have only to a limited extent been used to stabilise final demand. Three smaller peaks in investment activity can be observed since 1990.

The figure also shows how small the public or "general government" investments are compared to the private investments. Changes in investment activity entail a series of impacts on value creation and employment upstream along the value chain. These impacts have derived impacts on other final demand categories and eventually on private investments too. However, changes in general government investments will hardly be sufficient to restore the level of investments. Government, however, also control some of the private investments directly and control the conditions that enable and drive private investments.

18.3. Investments in future transformations

The transformation processes in the private sector include among others decarbonisation, delinking, dechemicalisation and recycling. They replace the inherited solutions to energy and materials processing, consumption, transport and storage by green solutions. The key dimensions in this process are investments in innovation (including in organisation) and in fixed capital.

Section 2.9 above identifies some economic properties of the green transformation of the econosphere. They include

- substitution of harmful substances with harmless substances
- substituting capital for energy and resource use in the production of commodities and services
- using capital and labour for recovering and recirculation of energy and recycling of materials

These types of green solutions are more capital-intensive than conventional solutions. A wind energy farm or a building retrofitted to near-zero-energy standard, for instance, require considerable upfront investments in return for savings of coal and natural gas expenditures down the road. The "price" of an economy that is less intensive in materials and energy flows or in other words, much more resource efficient is a long period with a high rate of investment.

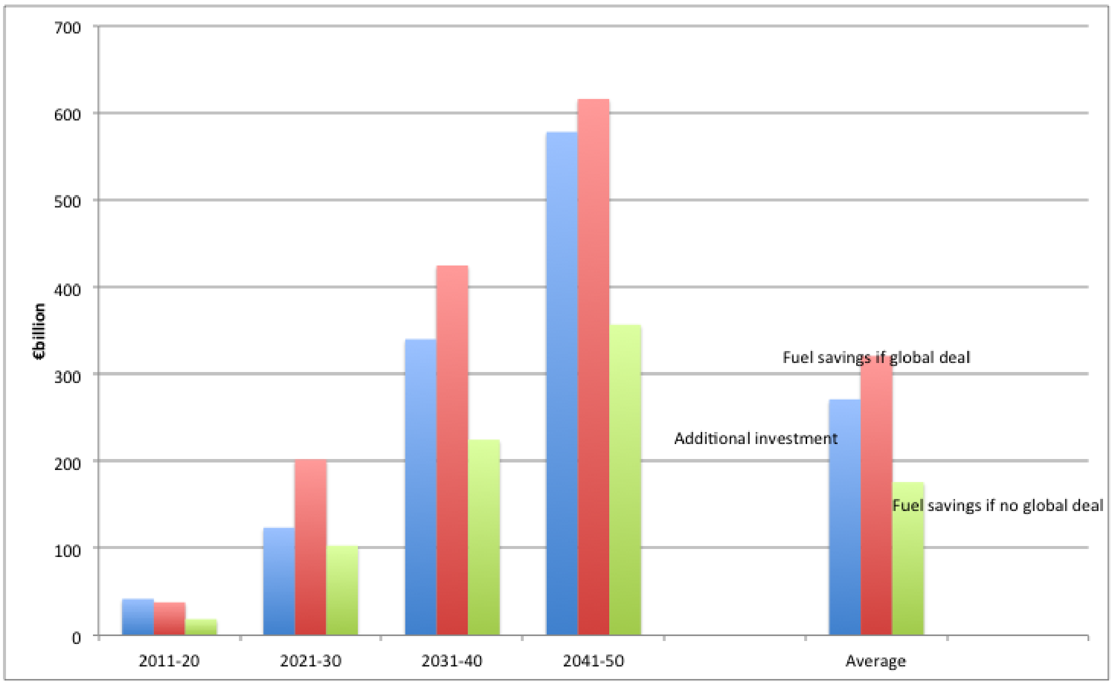


Figure 35. Annual additional investments and saved fuel expenditures depending on global climate deal, 2011-50. €(2010-prices) billion.
Sources: (European Commission 2011a).

Figure 35 shows the magnitudes of additional investment in low carbon econosphere and the saved fuel expenditures in the transition to a low carbon economy as estimated by the EU Commission. The fuel expenditures saved depends on whether the EU and the rest of the world are synchronised in this transition. If the rest of the world and the EU join forces in a global climate agreement and transform the world economy synchronised, then the estimated savings of fuel expenditure will more than finance the additional investments in the EU 2011-50. If not, only most of the additional investments will be financed in that period.

The shifting of expenditure for increasingly imported fuels to expenditure for investment goods and installation services of mostly European origin will have employment impacts beyond the balance of expenditures.

In sum, the European economy needs investments for recovering from the financial crisis, the great recession, the sovereign debt crisis and the austerity recession. At the same time, the transformations in the future are very capital intensive. Advancement of some of these investments could bring about a recovery with little risk for returning to high rates of CO_2-emissions.

Despite the recovery expected to take of in 2014-15, there are several reasons for promoting additional investments.

First, the unemployment rates are still in 2014 very high in parts of Europe and while recent indicators point to an end of the recession, growth prospects are still modest.

Second, the employment rates targeted by most member-states are higher than before the crisis. Returning to the 2007 level is not sufficient.

Third, the economic setback since 2008 has advanced the retirement of many of the plants using out-dated and/or energy intensive technologies. This trend is likely to be reinforced through the next decades due to the span between the energy prices available to European producers and their North American and Chinese competitors. The International Energy Agency expects that European energy prices will be a factor 2-3 higher than their overseas competitors through to 2035 (International Energy Agency (IEA) 2013b).

This will cause market shares of energy intensive products to shift towards North America and China. It will be beneficial for European industries to specialise in something else than energy intensive industries. Industries that compete with North American, Russian or Chinese industries will need superior resource efficiency. If they do not differ in any other way from their competitors, they will in principle need twice the resource efficiency. In this perspective, it is urgent to advance the investments of the green transformations.

Some of the green transformations – in particular, building refurbishments – represent investments that are suitable for this purpose.

A building erected in the 1960s in Northern Europe would be designed to consume a throughput of heating oil, lighting electricity and cooking and other energy appliances that would determine the energy consumption for the lifetime of the building. As a rule of thumb, a house in Northern Europe would be designed to loose energy through its lifetime of 100 years and thus consume heating oil corresponding to the volume of building. Today, it is possible to build near-zero-energy buildings delivering the same building-services at comparable or lower costs. It will be mandatory for new buildings in all of the EU from 2020.

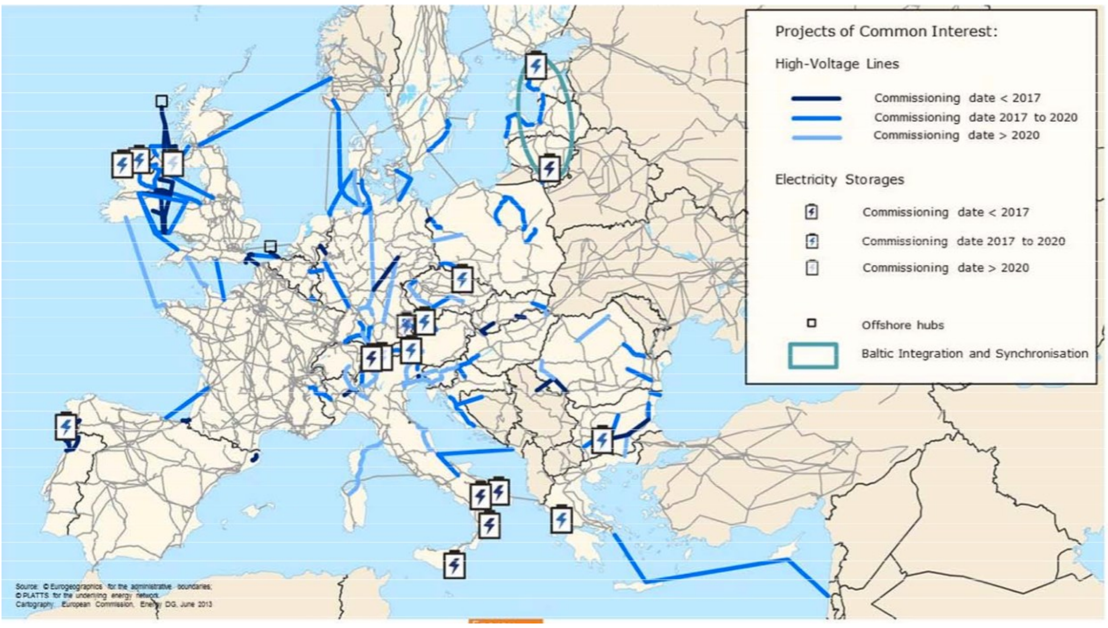
With a rate of renewal of the old building stock of on average 1% per year, the transformation to an energy efficient building stock will be too slow. A recent assessment of the potential for advanced energy refurbishment of the building sector operates with a scenario of accelerating the pace of transformation from 1% to 2.5% until 2020. It is estimated to raise the cumulated investments from €bn107 to €bn252 and generate an average of 600,000 jobs annually (Buildings Performance Institute Europe (BPIE) 2011).

Virtually all member-states have introduced technical regulations, financial incentives, information measures and/or increased support for energy efficient buildings as a response to the need for a green transformation of the European building stock as to energy efficiency. The statistical basis for monitoring the transformation is, however, insufficient to determine the potential and pace of transformation at the regional level.

The increasing wind energy generation creates jobs in the production and installation of the wind turbines and the industries supplying these activities. According to the wind industry organisation EWEA, the European wind industry and its suppliers employed almost 240,000 full-time equivalent jobs in 2010 and the number is increasing. The planned installation of offshore wind farms 2014-20 is could amount to up to 4.8 GW annually at a cost of €13-18 billion corresponding to about 75,000 jobs in the production of the wind turbines (The European Wind Energy Association (EWEA) 2013). This level of investment is three times the level of offshore investments in 2013 and the additional employment that can be obtained in the period is thus about 50,000.

The Great Recession was met by proposals on combining a final demand stabilisation policy with the investment challenges of the green transformation. Advancing green investments that would otherwise take place later on would be an effective instrument to restore the investment demand in the economy (Barbier 2009; United Nations Environmental Programme (UNEP) 2009).

The EU Commission called for similar expansionary investment policies in its recovery plan from 2008 (European Commission 2008c), but did and does not control the government budgets required for realising the green new deal. The EU budget available to infrastructure investments is very limited, but could work as a catalyst for engaging larger financial resources. The European Energy Programme for Recovery (EEPR) funds a number of energy projects that are important for energy supply and trans-European transport. The projects for reinforcing the electricity transmission grid and storage capacities are shown in map 65.



Map 65. Electricity transmission and storage projects of common interest in Europe, 2013-20.
Source: (European Commission 2013q).

The investments in the energy infrastructure will give better electricity and gas grid connections between the member-states and more diversified energy supply structures. For such investments, the question is not whether but rather when they will take place. Advancing the investments to an earlier time could thus contribute to a recovery of the European economy. It is, however, often difficult to advance such investments due a long lead-time and dependence on other investments.

18.4. The 2030 framework for EU climate policy

The EU Commission has put forward a proposal for a comprehensive set of policies for the 20'es to succeed the climate and energy package for the present decade. The EU Commission has assessed the impacts of this policy framework on investments, employment and other social key variables (European Commission 2014d).

The impacts of the most ambitious scenario (45/EE/35: 45% GHG emission reduction, energy efficiency policies, 35% renewable energy) on investments (most ambitious) scenario are shown in figure 36 because it illustrates the maximum investment demand that can be generated by advancing the transformation of the energy econosphere.

The package proposed by the Commission is more moderate: 40% GHG emission reduction and 27% renewable energy. This means that natural gas, nuclear energy and coal with carbon capture and storage (CCS) will play a large role than in the ambitious scenario.

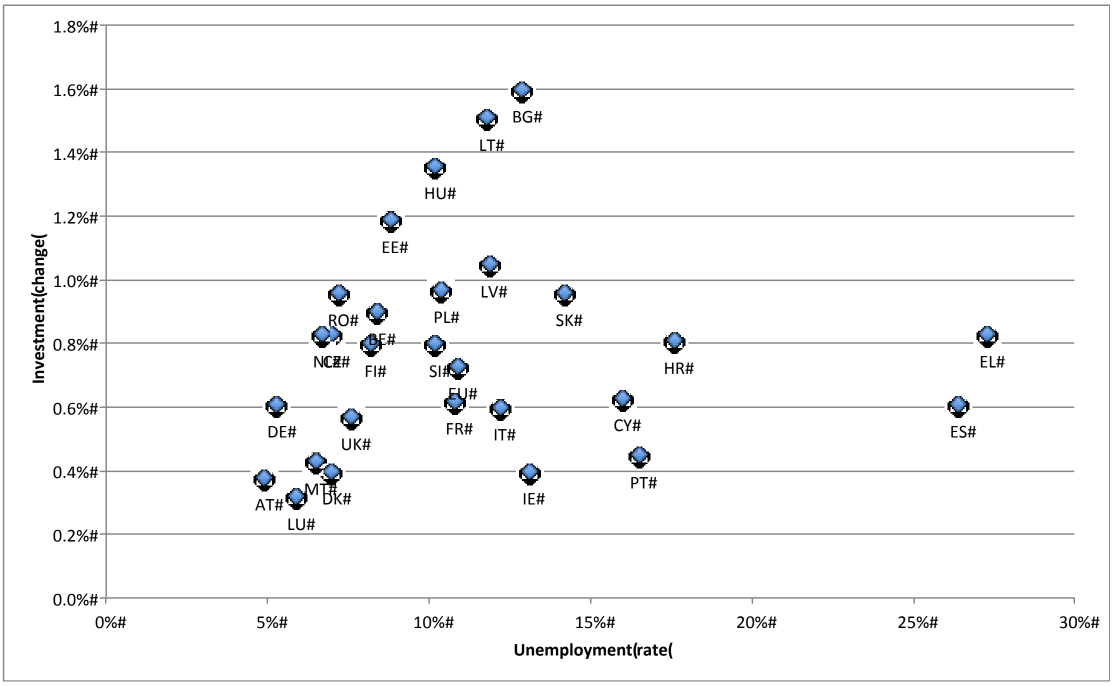


Figure 36. Investment change induced by the 2030 climate policy framework by unemployment rate (2013). Per cent of GDP.
Source: EU Commission impact assessment 45/EE/35-scenario (European Commission 2014d) and the AMECO database (European Commission 2014e).

The more ambitious scenario with 45% GHG reduction and 35% renewable energy involves the highest investments in the production and use of energy. The new member states would face investment increases above the EU average. In the EU15, the average investment rate in per cent of GDP was 20% in the period 2000-07 and 18% in 2009-12. Thus, a higher investment rate of 0.3-1.6% can make a considerable difference in for the level of employment in the EU economies.

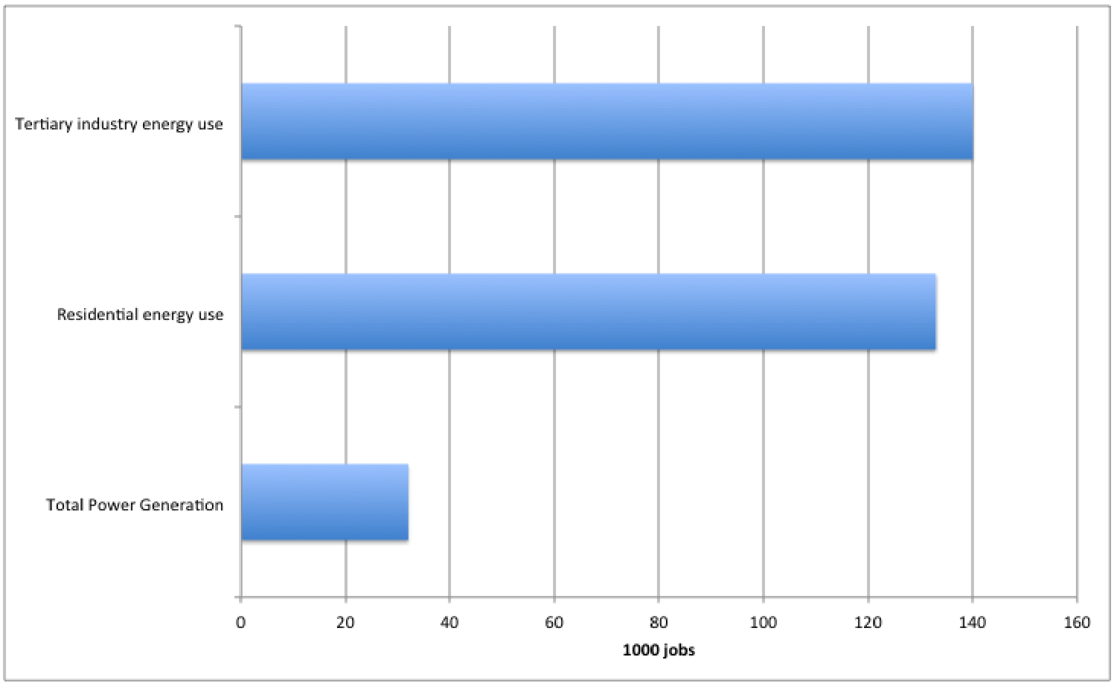


Figure 37. Impact on annual employment in EU28 of the 2030 climate policy framework, 2020-30. 1000 jobs.
Source: EU Commission impact assessment 45/EE/35-scenario (European Commission 2014d).

Figure 37 shows that transformations of the econosphere delivering energy services in the tertiary industries (the service sector) and for residential use - both are primarily building services – represent far most of the potential for job growth that will be realised with the EU Commission proposals.

The employment impact in the power sector is relatively small, partly because it involves fewer employed in building of fossil and nuclear power plants and more employed in the construction of renewable energy generation facilities cf. **table 1**.

Table 12. Power sector employment impact in EU28 of additional investments in the 2030 climate framework by energy source, 2020-30. 1000 persons, annually.

	Non-renewable	Renewable
Non-combustible	-18	36
Combustible	-13	26

Source: EU Commission impact assessment 45/EE/35-scenario (European Commission 2014d).

18.5. Energy import shares

A key challenge of the EU economy is the increasing dependency of imported fossil fuels. It causes a geo-political asymmetry that is regarded as socially undesirable by the individual member-states and the union as a whole. In addition to this, it represents an increasing drag on the income available for other uses.

The share of the total income generated in the EU27 spent on imported fossil fuels is shown in figure 38.

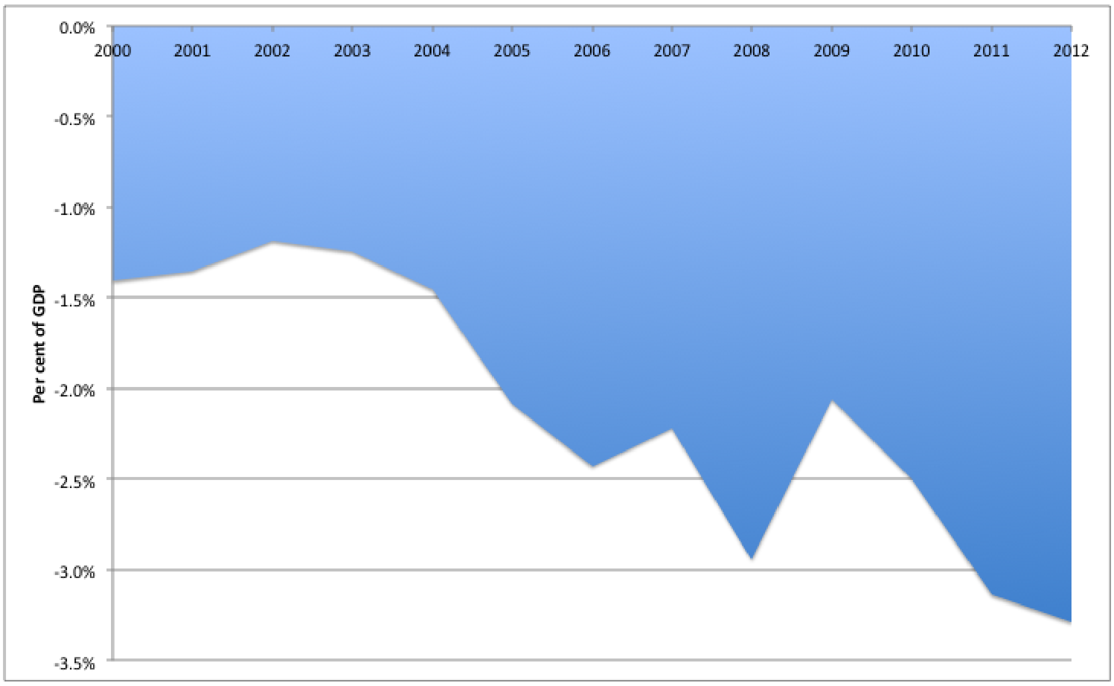


Figure 38. Net import of mineral fuels, lubricants etc. (SITC3) to EU27 in per cent of GDP 2000-2012.
Source: Author's calculations based on EUROSTAT data (European Commission 2013l; European Commission 2013m).

Figure 38 shows that the share of the total economic budget of the EU reserved for import of fossil fuels has more than doubled from the early 2000s to the early 2010s. Most of the net imports consist of natural gas, whereas oil is the second and coal the third largest cost item. This share, however, differs considerably by country.

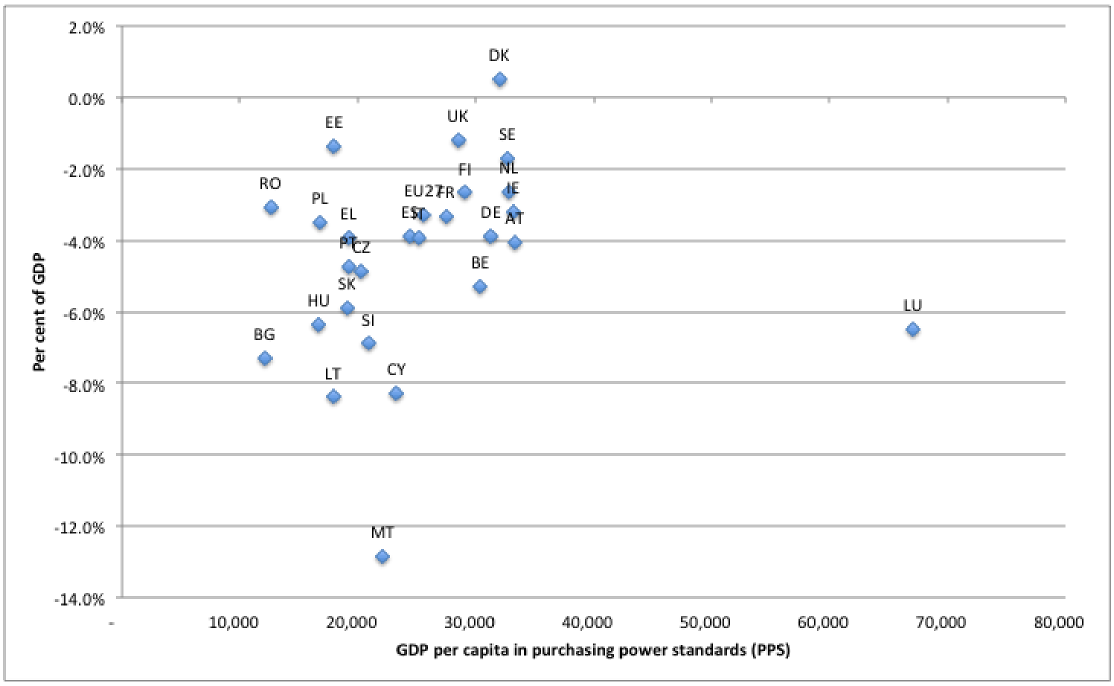


Figure 39. Net import of mineral fuels, lubricants etc. (SITC3) in per cent of GDP to member-states by per capita GDP (PPS*) in 2012.
* PPS is "purchasing power standards", i.e., euros with average EU purchasing power.
Source: Author's calculations based on EUROSTAT data (European Commission 2013l; European Commission 2013m).

Figure 39 reveals a pattern of higher fossil fuel import burden on the economies with the lowest income levels. On the one hand, a high fossil fuel burden impedes self-sustaining growth of the economies. On the other hand it represents a potential for employment and income generation by replacing the imports by indigenously produced renewable energy.

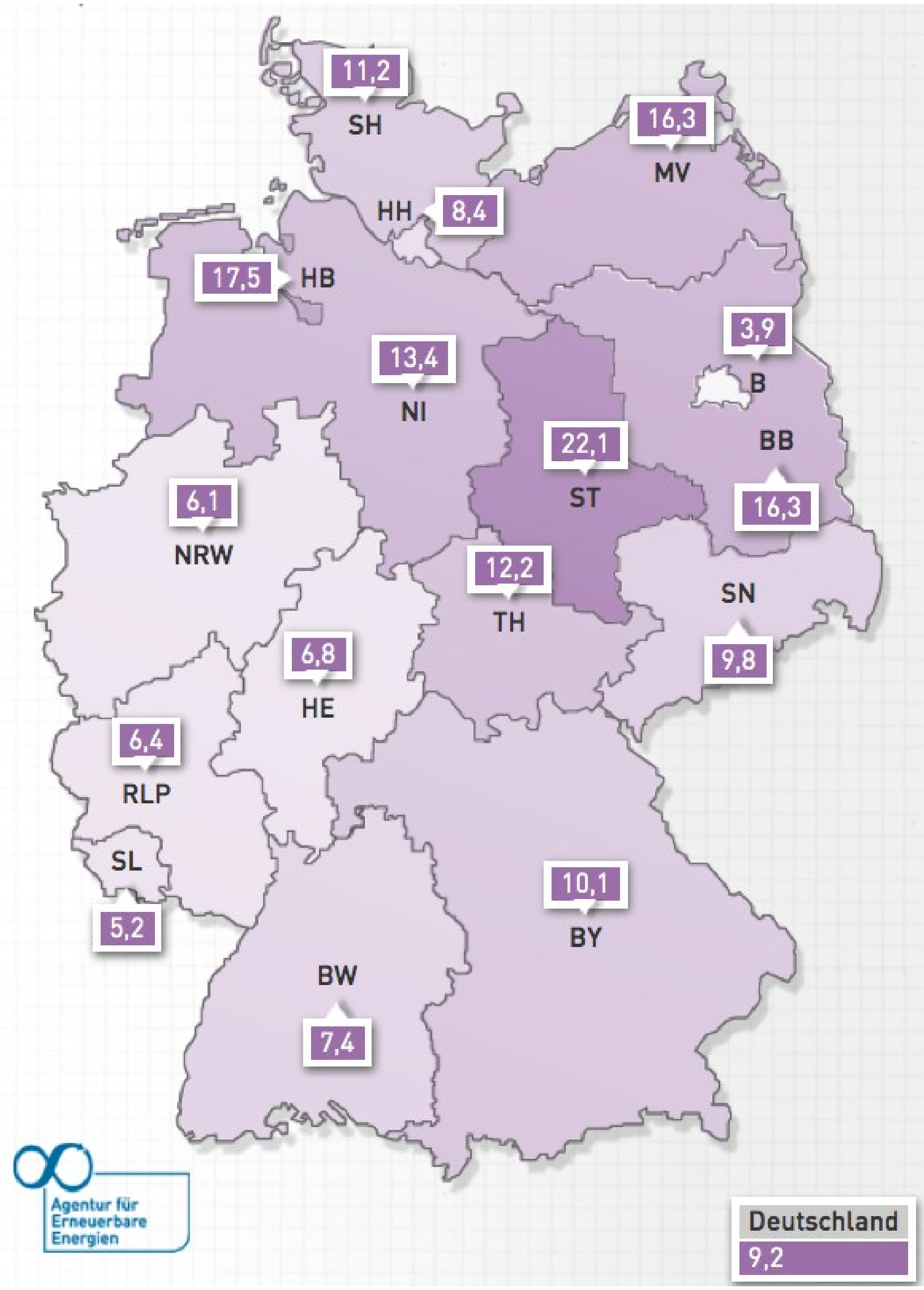
The EU harmonised statistics on fossil fuel consumption is not collected and processed at a level that allows the analysis of the fossil fuel burden on the regional economies as in figure 39. Previous studies have attempted to identify regions with high fossil fuel burdens using the share of energy intensive industries in regional GVA as an indicator for where we could expect to find high fossil fuel burdens (ESPON 2011).

The replacement of fossil fuel consumption by renewable energy is likely to shift the market share of energy services to the domestic economy. This is because Europe always was poorly endowed with fossil energy resources, but a first mover in the massive depletion of them. Non-combustible renewable energy is mostly domestically produced, at least at the EU level. In the longer run, it replaces the flows of income set apart for import of fossil fuels with flows to pay returns to investment in renewable energy solutions.

Reducing the fossil fuel burden represents a potential for employment and income generation related to the direct supply of renewable energy and of energy efficient of energy services. This potential differs by region according to natural resource endowment rather than to energy demand.

18.6. Regional employment effects of renewable energy

The EU data basis is not adequate for assessing the regional distribution of the jobs generated by renewable energy or the employment potential of an ambitious climate policy. Studies in individual member states reveal regional patterns. The result of a German study is shown below.



Map 66. Jobs in production of renewable energy plants per 1000 employees in Germany by Länder, 2012.
Source: (Agentur für Erneubaren Energien 2014).

The variation of the RE-job share around the federal average is caused in some Länder by regional specialisation in production of RE generation technology and in others by regional specialisation in production of renewable fuels.

The study behind these results also showed that only 41% of the employment is directly occupied with the production of plants, fuels, operation and servicing, whereas 59% was employed in indirectly supplying activities, that is, supplying commodities and services to the activities providing renewable energy or RE plants directly (Ulrich et al. 2012).

The regional potentials for generating income from wind power and photovoltaic energy are reported above. The spatial distribution of the employment effects is not identical to the spatial distribution of energy potentials. Manufactured parts may originate from other regions and installation and maintenance may require special skilled labour resident in other regions. The main economic effect in each region is the more general installation works and the potential resource rent.

18.7. Data deficiencies for addressing green transformations at the regional level

In this work, the lack of consistent data describing the capital stock and the energy flows that it produces and uses at the NUTS2 and NUTS3 regional level has been a major obstacle for analysis. Some of the data are collected, but not processed in a consistent and inter-regionally comparable way. In other cases, the primary data are not even collected. The regional and local engagement in decarbonisation and resource efficiency makes it necessary to monitor the regional challenges and progress and the results of the regional endeavours. Thus, it is recommended to develop the statistical framework for this part of the *econosphere* to serve these needs.

The data published from large point sources via ETS registry and IPPC reporting does not contain information on the type of installation and the fuels they handle. Despite recent improvements, they are still incomplete. Data on energy conversion could be derived from the point source statistics if was complete and contained information on inputs and outputs of energy.

Regional data on fuel use from diffuse sources – primarily agriculture, buildings and transport – are in some countries collected from electricity companies, oil companies etc., but not all, and not in consistent format allowing comparisons between regions. Regional level data on production of primary energy from local sources are neither collected.

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Glossary and abbreviations

Table 13. Glossary

Sustainable development	Social progress in each of the economic, ecological and social dimensions
Green economy	An economy that is able to prosper without over-consuming in any of the economic, ecological or social dimensions
Green transformation	The transformation of the econosphere and its sectors to a green economy
Green growth	The innovation and diffusion of green solutions as business cases
Greening institutions and policies	the changes in institutions and policies enabling and driving green transformations and green growth
Governance	The process of governing – coordinating, controlling, deciding on etc – whether by government or other institution
Econosphere	The total anthropogenic materials and energy flows between the four spheres (lithosphere, atmosphere, hydrosphere and biosphere) and the fixed capital and systems transporting and processing them
Socio-technical system	The complex system of infrastructure, other physical structures and organisations designed to provide particular services to the economy
Energy economy	The production and consumption of energy within an economy

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