Note d'étude de la Mission climat de la Caisse des Dépôts

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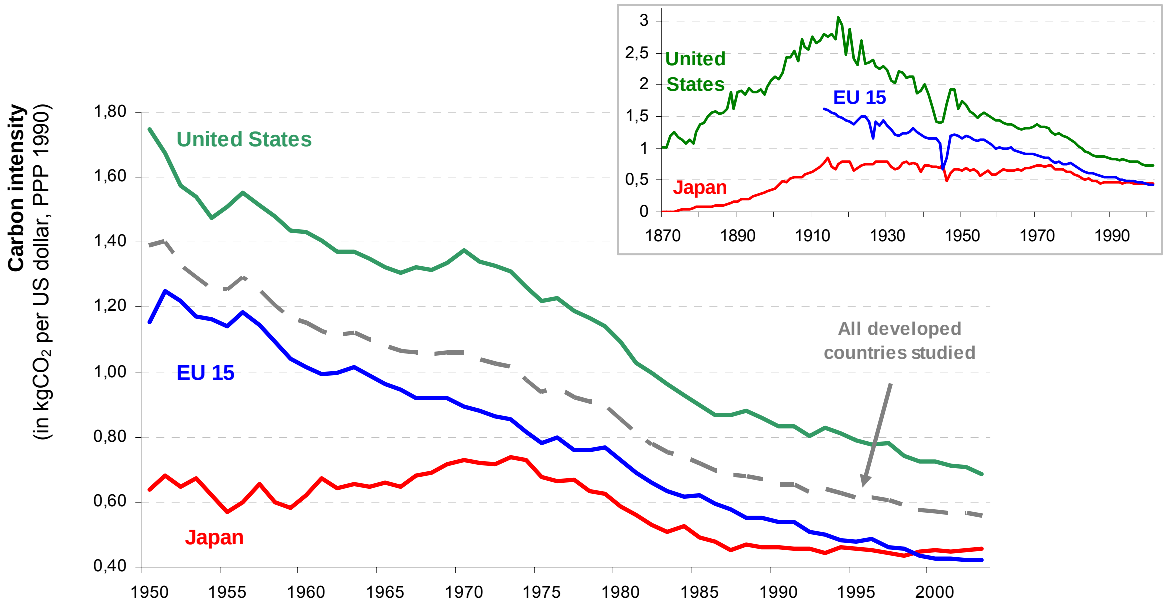
Growth without warming?

The carbon intensity of the developed economies

Over the long term, three factors influence the trajectory of an economy's greenhouse gas emissions: population growth; the variation of per capita production; the evolution of the emissions content of this production, usually called carbon intensity. In developed countries, carbon intensity has significantly decreased in the last fifty years. The pace of these gains accelerated in the wake of the first two oil crises, revealing the impact of energy situations on the carbon efficiency of economies. Since 1990, the rate of improvement has slowed down. The spread of carbon intensities of major economies remained about as high in 2003 as in 1990. On the other hand, within the 15-member European Union, a remarkable convergence of the economies' carbon intensities was observed even before the common instruments for action were introduced by the Kyoto protocol and the CO_2 emissions trading scheme. In the future, a massive drop of the emissions trajectory will require far more stark changes in the carbon intensity of economies if we want to continue to grow without warming the atmosphere.

Figure 1 – CO_2 intensities in a few developed countries between 1950 and 2003.



Source: CDIAC, Groningen Growth and Development Centre and the Conference Board, Maddison.

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Summary

Introduction

The volume of greenhouse gas emissions (GHG) of a country is the product of three factors: the size of its population; the amount of its GHG production per inhabitant; the unit level of the production of greenhouse gas emissions, also called the economy's greenhouse gas intensity or carbon intensity. This relationship can be expressed as:

$$GHG = Pop \times \frac{GDP}{Pop} \times \frac{GHG}{GDP}$$

Greenhouse gas emissions — *Population* — *Standard of living (GDP per inhabitant)* — *The economy's greenhouse gas intensity*

This breakdown is interesting, because it dissociates growth (demographic and economic) from the ecological efficiency of the means of production from an emissions standpoint, in the evolution of an economy's greenhouse gas emissions. Thus, Table 1 shows that the evolution of GHG in the major industrialized economies observed between 1990 and 2003 has been shaped by different factors. In every case, the carbon intensity of the economies has declined, which means that all of the economies have reduced their GHG emissions per production unit during these years. On the other hand, this relative gain was not enough to stabilize the overall volume of emissions, except in the case of the 15-member European Union. In the other developed economies, this relative improvement was more than offset by economic and demographic growth, resulting in an increase in the overall volume of emissions during the period.

Table 1 – Breakdown of greenhouse gas emission growth between 1990 and 2003.

		Australia	Canada	United States	Japan	EU-15
Averages 1990-2003 (%)	**GHG / GDP**	- 0.26	- 0.14	- 0.21	- 0.07	- 0.27
	GDP / population	0.33	0.24	0.19	0.17	0.18
	Population	0.19	0.16	0.13	0.04	0.09
	GHG (sum of the effects of the three explanatory variables)	0.26	0.26	0.11	0.13	- 0.01

Source: OECD, UNFCCC, INED.

The data represent for each country the weight of the various factors in the variation of greenhouse gases (GHG). For example, in the 15-member European Union, the very limited decrease in emissions observed is due to the fact that increases in per capita income and the population were offset by a sharp drop in emissions per unit of GDP.

This study aims at shedding light on the past evolution of GHG emissions intensity in developed economies. To ensure that the data is homogenous and comparable, only long-standing industrialized countries are discussed, leaving emerging and former Soviet bloc countries outside the scope of the study, even those that have joined the European Union. In Part I, we will attempt to determine whether the evolution of carbon intensity has been accompanied by converging or diverging phenomena within developed economies. In Part II, we will focus more specifically on the impact energy choices have had on the trajectories adopted by the developed countries. Finally, in Part III, we will devote special attention to the characteristics of the countries in the European Union, which shows a unique trajectory among developed countries.

I. Evolution of greenhouse gas intensities in developed countries

A. Economic activity, development level and greenhouse gas emissions

The pie charts in Figure 2 give a rough idea of the size of the economies and the weight of their greenhouse gas emissions in the world total (6 gases covered by the Kyoto protocol, without taking into account estimates of carbon dioxide storage- release resulting from forests and soils). Together in 2000, the United States, the European Union and Japan created half of the world's wealth measured by GDP based on purchasing power parity. When Canada, Australia, New Zealand and the non-EU countries of Europe are added, we see that the studied developed countries generated 55% of the world's wealth in 2000. If current exchange rates were used as a yardstick instead of purchasing power parity rates, this proportion would be in the neighborhood of 2/3 of global GDP.

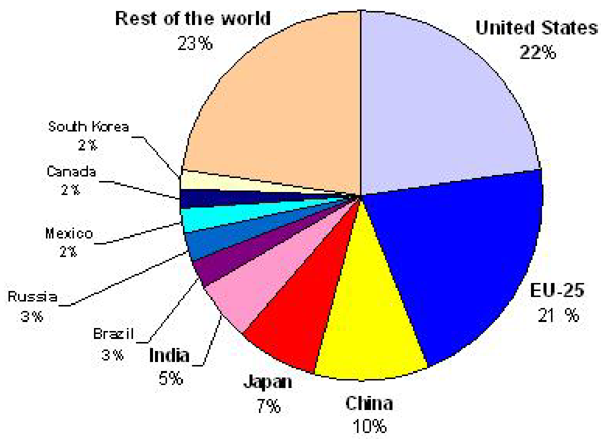
The percentage of these countries in global greenhouse gas emissions is lower than their percentage in global GDP. The United States, the European Union and Japan caused 38% of global greenhouse gas emissions that same year. When the other developed countries are added, the estimated proportion rises to 42%. We should keep in mind, however, that the measurement of emissions, particularly from agriculture and forests, is fraught with uncertainty.

Finally, it should be emphasized that foreign trade can distort comparisons between countries. Some countries may import goods and services with high carbon content and other export goods and services with low carbon content. Hence, the carbon intensity of an economy measured as the ratio between its emissions and its GDP may not reflect the contribution of lifestyles to the greenhouse effect. This bias is likely to be more significant for the small countries that are proportionately more open to international trade.

Figure 2 - GDP and greenhouse gas emissions in the world.

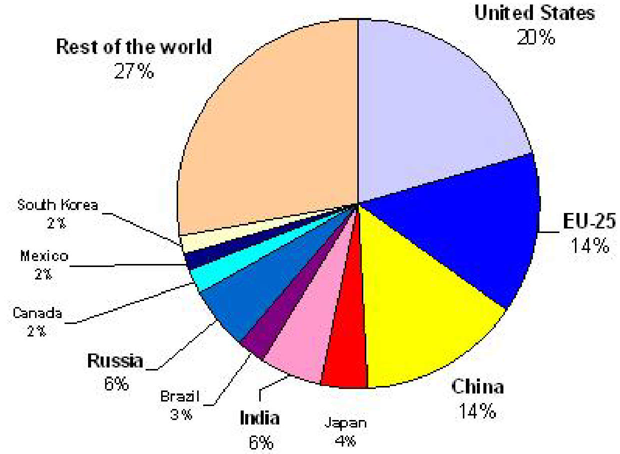
a. GDP, billions of US dollars (PPP[1] 2000), 2000.

Total: 43,600 billion dollars



b. Emissions of greenhouse gas, 2000.

Total: 33.6 billion tCO_2e



The three main economies, namely the United States, the European Union and Japan, produce half the world's GDP and nearly 40% of global greenhouse gas emissions. Their high technological level explains why their greenhouse gas intensity, i.e. the ratio of greenhouse gas emissions to the production of wealth, is lower than that of the rest of the world.

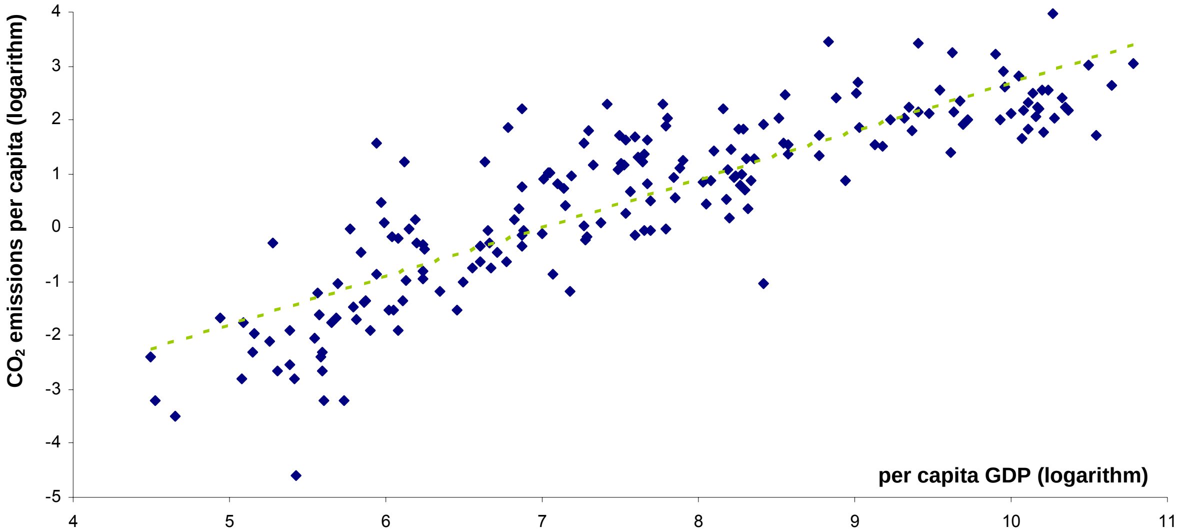
Source: World Factbook 2001, WRI.

[1] See lexicon p.25

Figure 3 adds to the previous overview. It suggests there is a positive relationship between the per capita GDP of a country and its per capita emissions level. But two observations should be made:

- On the one hand, the scattered cloud of points shows that for an identical level of per capita GDP, countries may have quite different emissions levels, which can be explained only by significant differences in the carbon intensity of the economies;
- On the other hand, the slope of the trend line reveals an elasticity[2] of less than 1 (about 0.9), which suggests that, on average, the amount of emissions per capita tends to increase at a slower pace than the level of GDP per capita. In other words, the figure suggests that the carbon intensity of economies declines slightly when the standard of living rises.

Figure 3 – CO_2 emissions per capita according to per capita GDP in the world in 2002.



A 1% increase in GDP per capita leads to an estimated increase of about 0.9% in emissions per capita. The fact that the emissions figure is less than1% indicates that emissions increase at a slower pace than economic growth.

Source: World Bank.

It is logical that a decline in greenhouse gas intensities is associated with an increase of per capita GDP. When the standard of living goes up, certain forms of consumption, especially of essentials, increase more slowly than income (the so called "Engel" law). Energy consumption, which is the source of a major portion of CO_2 emissions, comes under the category of goods that show an elasticity with respect to income of less than one. This evolution is far from linear, however, and should be interpreted with caution:

- a drop in production in a sector that emits CO_2 is not necessarily accompanied by lower consumption of the goods it produces, but it may be the result of a transfer of production: this carbon "leak", which is hard to measure, is reflected in the decline in the CO_2 intensity of developed economies that import a growing fraction of their manufactured products from emerging countries;

- furthermore, the expansion of an economy's service sector does not necessarily imply a reduction in CO_2 intensity. Some service segments, such as transportation and tourism, are the source of sizeable carbon dioxide emissions.

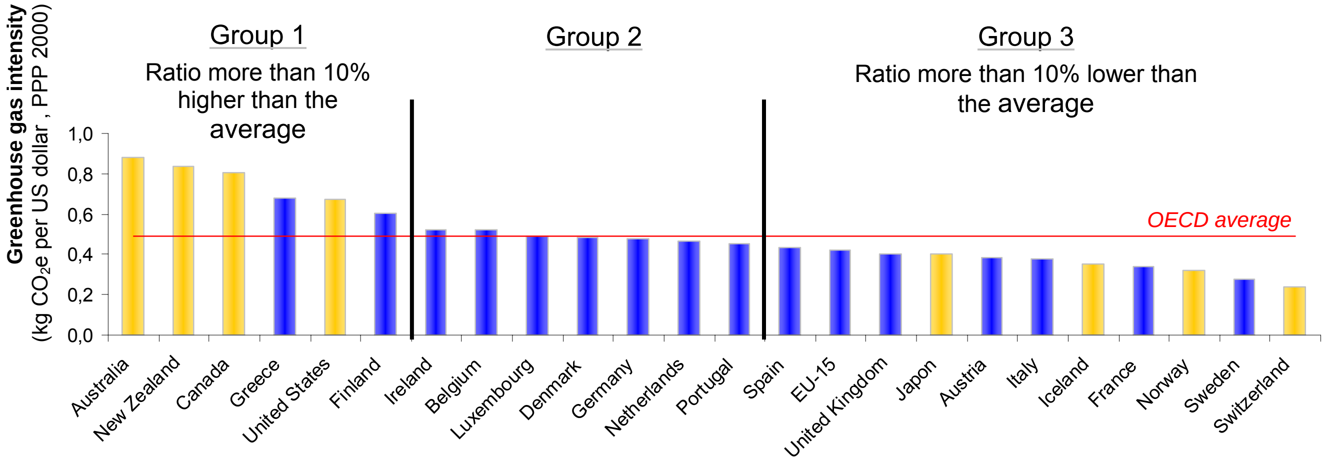
[2] See lexicon p.25

B. *The spread of greenhouse gas intensities within industrialized economies*

Scattered greenhouse gas intensities

The economies of developed countries show extremely varied greenhouse gas intensities. In 2003, the average intensity was 0.5 kgCO_2e / USD. The creation of one dollar of added value was therefore accompanied, on average, by an emission of 0.5 kg CO_2 equivalent[3]. However there was a considerable spread of this value around the mean, since it varied from slightly more than 0.2 kgCO_2e for Switzerland to more than 0.8 kg CO_2e for Australia. The 35% coefficient of variation[4] testifies to this significant spread.

Figure 4 – Greenhouse gas intensities of economies in 2003. The EU-15 countries are in blue.



In view of comparable levels of technological development in the industrialized countries, the explanation has to lie in geographical differences (countries with high demographic density vs. countries with low demographic density), cultural differences as well as in the choice of power generation [5]

Source: OECD, UNFCCC.

The same classification of the countries according to their degree of greenhouse gas intensity for the year 1990 shows a slightly wider spread around the mean, with a coefficient of variation of 38%, and higher intensities: thus, the mean reached 0.64 kg eqCO_2e / USD. The drop in average greenhouse gas intensity was thus – 22% between 1990 and 2003, without any significant reduction in the spread around this mean.

The general decline in greenhouse gas intensities of the economies

Figure 5 relates the evolution of the carbon intensity of the developed economies to their per capita GDP. It shows that a country's level of wealth alone cannot account for its level of greenhouse gas intensity. For example, with the same level of per capita development of 25,000 dollars, the greenhouse gas intensity of the Irish economy was about 0.7 kg eqCO_2e / USD, twice as high as that of Sweden. In this example, the corresponding years are different: the level of technological development and the political and institutional environment (e.g.: recent start of the Kyoto protocol) changed. These political and institutional conditions play a considerable role in the evolution of the countries' greenhouse gas intensities.

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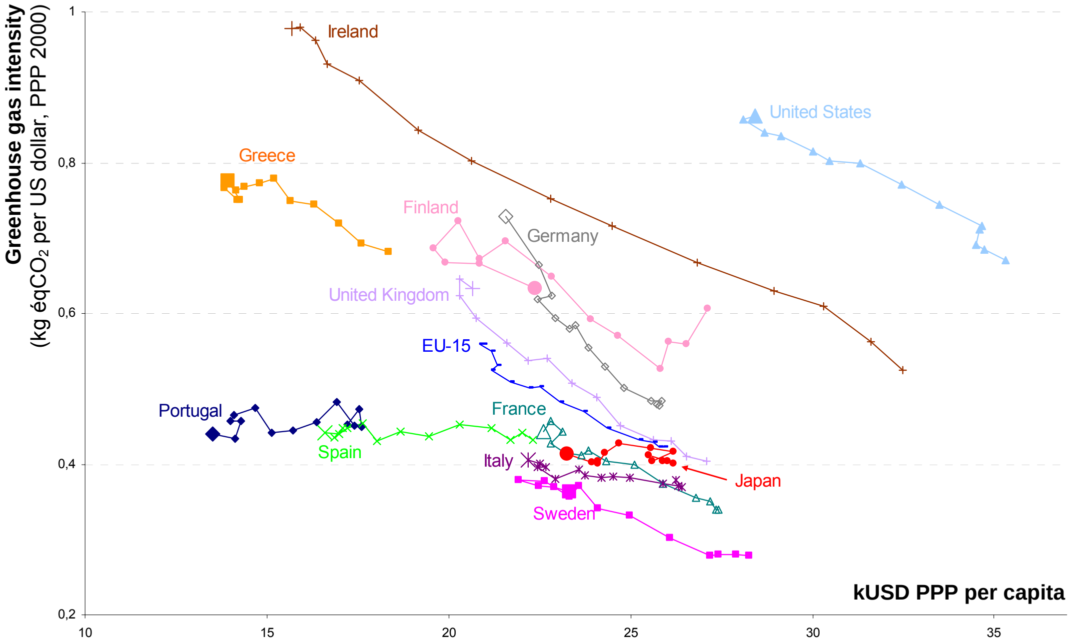
[3] See lexicon p.25

[4] Ratio of the typical variation to the mean. The higher the ratio, the greater the spread of the data.

[5] Climate differences cannot really explain the wide spread observed, as Norway, Switzerland and Sweden do not have a milder climate than Canada or the United States, for example.

Figure 5 – Greenhouse gas intensities and per capita GDP, 1990 – 2003.

N.B: The largest symbol marks the year 1990.



Source: OECD, UNFCCC.

Interesting trajectories can be noted:

(1) In Ireland, for example, the sharp drop in carbon intensity occurred at the same time as considerable development, with a doubling of per capita GDP. At the other end of the scale, the curves for Portugal and Spain – at comparable growth rates – are virtually flat, underscoring limited progress in greenhouse gas intensity reduction, as well as a relatively short trajectory, indicating a less sizeable increase in the standard of living.

(2) Germany's carbon intensity dropped sharply following reunification. The United States also experienced a significant decrease in the carbon intensity of its economy, which accelerated considerably during the period of the Internet bubble.

(3) It should also be noted that the United States and the 15-member European Union show parallel trajectories; despite very different initial levels in the greenhouse gas intensity of their economies and their standard of living, both economies made progress in terms of greenhouse gas intensity without, however, converging at the same level.

C. Convergence of greenhouse gas intensities within the 15-member European Union

To begin with, two groups of countries stand out among the non-European countries (see Figure 4). The first group shows high greenhouse gas intensities (above 0.8 $kgCO_2e$ / USD in 1990): while Australia and the United States recorded sharp intensity decreases between 1990 and 2003, Canada and New Zealand lagged behind the overall trend.

The second group of non-European countries posted the greatest drops in intensity, despite the lowest levels at the outset, particularly in Iceland and Norway. Switzerland, which already enjoyed low carbon intensity, reduced its level by 11%. Japan was the only country with virtually no variation in greenhouse gas intensity.

Table 2 – Greenhouse gas intensities of the economies of non-members of the EU-15.

Country	Ratio of Emissions / GDP (in $kgCO_2e$ / USD)		
	1990	2003	Evolution 1990-2003
Iceland	0.54	0.35	- 34%
Norway	0.44	0.32	- 28%
EU-15	0.56	0.42	- 24%
Australia	1.13	0.88	- 22%
United States	0.86	0.67	- 22%
New Zealand	1.01	0.84	- 17%
Canada	0.92	0.80	- 13%
Switzerland	0.27	0.24	- 11%
Japan	0.41	0.40	- 3%

Source: OECD, UNFCCC.

These disparities in the evolution of greenhouse gas intensities are also found in the European countries, where reductions of greenhouse gas intensity were very significant: the average of European indices dropped from 0.56 to 0.42 $kgCO_2e$ / USD between 1990 and 2003, i.e. a decline of 24%. This decrease was greater than the one observed in non-European countries (- 19%). The only exception was the Portuguese economy, which showed a 3% increase in greenhouse gas intensity.

Table 3 – Greenhouse gas intensities of the EU-15 economies

Country	Ratio of Emissions / GDP (in $kgCO_2e$ / USD)		
	1990	2003	Evolution 1990-2003
Luxembourg	1.07	0.49	- 54% (6)
Ireland	0.98	0.52	- 46%
RU (UK?)	0.63	0.40	- 36%
Germany	0.73	0.48	- 34%
Netherlands	0.62	0.47	- 25%
France	0.44	0.34	- 24%
Sweden	0.36	0.28	- 23%
Belgium	0.66	0.52	- 21%
Denmark	0.59	0.48	- 19%
Austria	0.44	0.39	- 12%
Greece	0.78	0.68	- 12%
Italy	0.41	0.38	- 7%
Finland	0.63	0.61	- 4%
Spain	0.44	0.43	- 2%
Portugal	0.44	0.45	3%

Source: OECD, UNFCCC.

Among the countries with relatively low greenhouse gas intensities, some, such as Sweden, achieved significant decreases (- 23%), whereas others, such as Spain or Italy, showed only a limited decline (- 1.8% and - 6.8% respectively) between 1990 and 2003.

This downward trend produced a certain convergence of the greenhouse gas intensities in developed countries during the 1990s, which proved to be largely due to convergence within European countries. Indeed, the coefficient of variation of the greenhouse gas intensities of European countries dropped by nearly 40% between 1990 and 2003. During the same period, the other developed countries

[6] Luxembourg should be analyzed with caution, due to its limited surface area, its industrial structure and its economy focused on finance. Its greenhouse gas emissions depend to a considerable extent degree on the metallurgy industry: its restructuring during the 1990s led to sharp emissions reductions.

showed a lack of convergence of their greenhouse gas intensities with stagnation of the coefficient of variation of their intensities (0%).

Table 4 – Coefficient of variation of greenhouse gas intensity of the economies, 1990 – 2003.

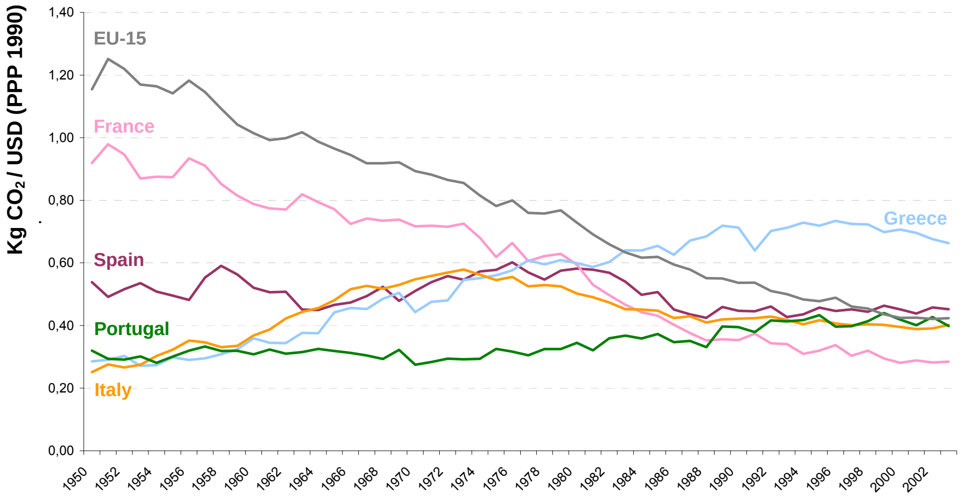
	1990	2003	Evolution
All the developed countries	0.39	0.35	- 9%
15 countries of EU-15	0.34	0.22	- 37%
Non-European developed countries + EU-15	0.45	0.46	+ 2%
Non-European developed countries	0.46	0.46	0%

The variation of the coefficient of variation (see lexicon) of greenhouse gas intensities between 1990 and 2003 enables comparisons between countries to be observed and quantified: a drop indicates a convergence within the group of countries, whereas a rise shows a divergence.

Source: Climate Taskforce.

The convergence of greenhouse gas intensities was not uniform in the European countries. As an example, Figure 6 shows a very strong convergence of the CO_2 intensities of the Mediterranean countries towards the average European level. Nevertheless, two countries stand out: Greece, which had one of the lowest carbon intensities at the beginning of the period, joined the European average in the early 1980s and clearly exceeded it thereafter. In contrast, France, which had the highest carbon intensity of all the Mediterranean countries at the beginning of the period, continued to reduce its emissions per unit of GDP to reach a level distinctly below the average by the end of the period.

Figure 6 – Example of the evolution of CO_2 intensities of the Mediterranean countries.



Source: CDIAC, Groningen Growth and Development Centre and the Conference Board.

The strong convergence of greenhouse gas intensities solely of European countries has therefore yet to be explained. In all likelihood, the introduction of European policies has encouraged similar constraints on the various sectors of the economy. This can only have an indirect effect, however, as the European regulations that harmonize EU action against greenhouse gas emissions were set up only very recently.

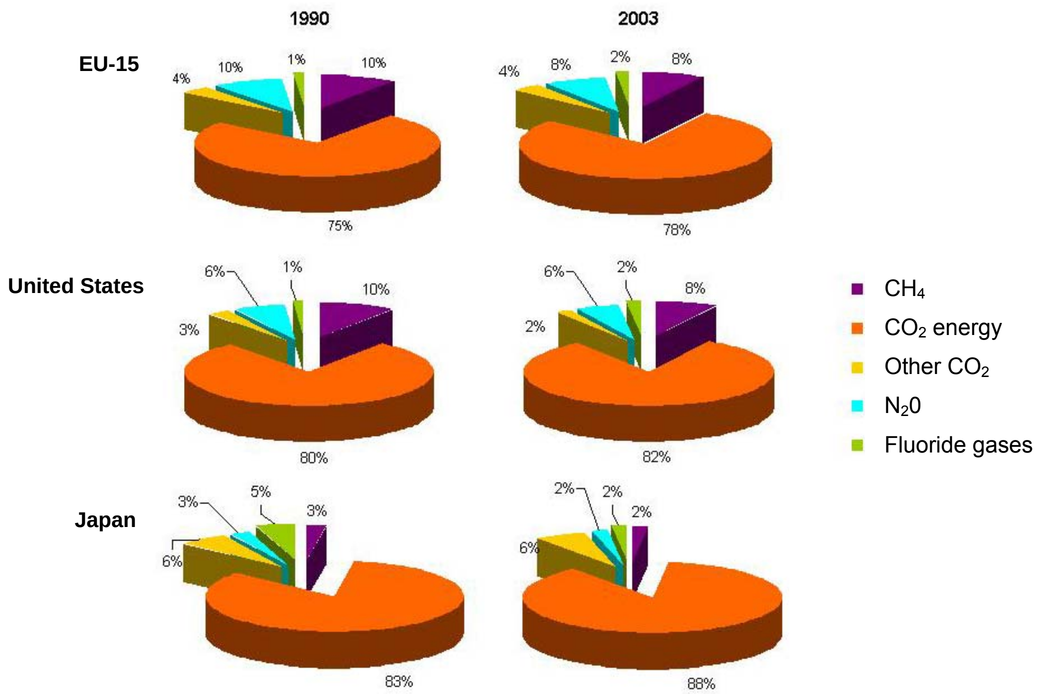
II. Carbon intensity of the developed economies and energy choices

Like population growth and a higher level of development, the choice of sources of energy production has a major impact on CO_2 emissions. For example, the shutdown of nuclear power production announced or already implemented in European countries such as Germany, United Kingdom and Spain, raises the question of what type of energy will replace it.

A. Energy, the main source of CO_2 emissions

Energy-related CO_2, including emissions from power generation and transportation, account for the majority of greenhouse gas emissions. Its portion even increased between 1990 and 2003 in the three main developed regions, partly due to transportation development (see Figure 8). The rise in the relative significance of energy-related CO_2 in greenhouse gas emissions demonstrates what is at stake in the introduction of new constraints on carbon dioxide emissions. Every sector of the economy is concerned: fossil energy is used to produce electricity, heat in industrial combustion plants, etc.

Figure 7 – Greenhouse gas emissions in the 15-member European Union, the United States and Japan.



Source: UNFCCC.

Energy-related CO_2 emissions result from the combustion of carbon materials in the form of a liquid (oil), a gas (natural gas) or a solid (coal). For the same amount of energy released, the amount of carbon dioxide emissions will vary according to the fuel used. For example, replacing coal with natural gas cuts the $C0_2$ emissions in half, but still contributes to the total amount of emissions.

Table 5 – Indication of CO_2 emissions quantities required for the production of one MWh.

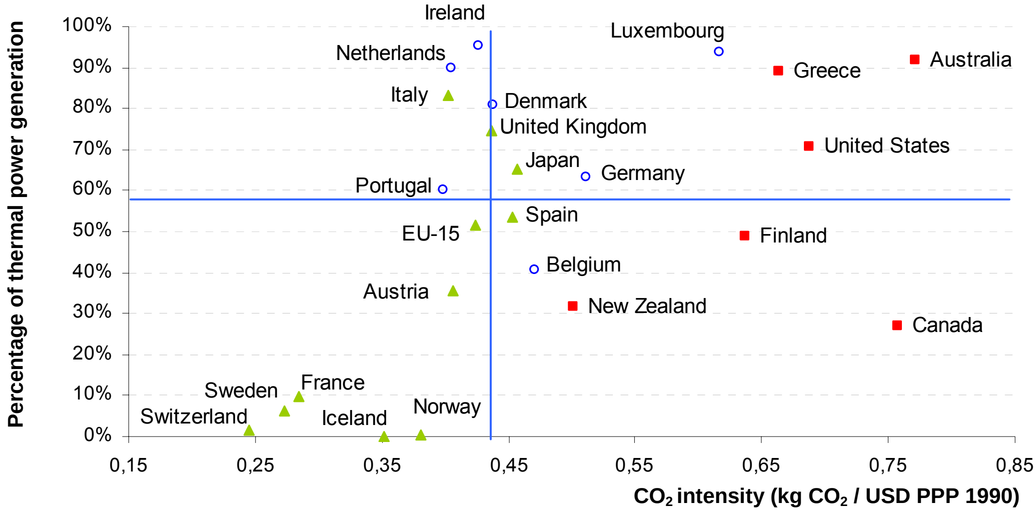
	In kilograms of CO_2
Natural gas	198
Fuel	270
Coal	342

Source: MIES.

B. CO_2 intensities of the economies and power generation

The level of development in countries is not the only factor determining CO_2 intensity, the structure of their energy supply, shown in Appendix II, is also of major importance. The countries have been marked according to their greenhouse gas intensity in 2003 (see Figure 4): high intensity (■), medium intensity (○), and low intensity (▲). They were then placed in Figure 8 according to their CO_2 intensity and the percentage of thermal power generation using coal, natural gas or oil.

Figure 8 – Percentage of thermal power generation according to the CO_2 intensity of the economies in 2003.



Source: Energy Information Administration, CDIAC, OECD

The two blue lines are medians, each one dividing the sample into two groups of countries of equal size. Most of the countries with high CO_2 intensity also show high greenhouse gas intensity and a high level of thermal power generation (upper right-hand quadrant). Most of the countries with low greenhouse gas intensities correspond to countries with low CO_2 intensities and a rather low level of thermal power generation (lower left-hand quadrant).

A few countries do not fit this pattern. The countries in the upper left-hand quadrant use a significant amount of fossil fuels for power generation but have low CO_2 intensities. These countries, such as Ireland, have succeeded in increasing their energy efficiency and are turning to activities that emit less CO_2.

In contrast, the countries in the lower right-hand quadrant show high levels of CO_2, even though the use of fossil fuels as not extensive for power generation. Hence, there must be other sectors involved that would explain this paradox. In all likelihood, their national industries have not achieved energy efficiency gains on a par with those of other countries. Furthermore, the transportation sector undoubtedly plays a very important role: the large size of the countries and low energy tax policies encouraged the development of this sector, known for its high level of CO_2 emissions. In the case of Canada, the significance of emissions are partly due to the meeting of heating requirements from fossil fuel burning (coal or fuel) as a result of the cold climate.

Finally, some countries with medium greenhouse gas intensities are found in the group of relatively high CO_2 intensities, underscoring the fact that the weight of other greenhouse gases is lower than in other countries.

C. Drop in CO_2 intensities since 1950: the stimulus of the oil crises

The impact of energy production on the carbon intensity of the economies was also revealed during prolonged periods of energy market tensions. The oil crises in the 1970s led to structural changes in production and/or more or less extended changes in energy consumption levels. These crises had a visible effect on the long-term evolution of the CO_2 intensity of the economies. For the United States, Japan and EU-15, this evolution has been quantified and broken down into three periods.

Table 6 – Evolution of energy-based $C0_2$ intensity.

CO_2 / GDP	1950 - 1971	1971 - 1986	1986 - 2003	Entire period
United States	- 23%	- 35%	- 21%	- 61%
Japan	13%	- 34%	- 4%	- 28%
EU-15	- 24%	- 33%	- 29%	- 63%

Source: Groningen Growth and Development Centre and the Conference Board.

The drop in CO_2 emissions compared with the creation of wealth accelerated after the oil crises. The trend began to slow down in the mid-1980s, however, especially in Japan and the United States. Over the entire period, the United States and Europe reduced the carbon intensity of their economies in the same proportions, thereby maintaining the gap between them.

The crises in the energy market thus had a more or less lasting effect. There are two reasons for this, according to the International Energy Agency:

- the first reason stems from the fact that replacement by lower carbon-emitting fuels was more difficult in the 1990s: nuclear energy development stagnated and the use of natural gas, while continuing to increase, was not sufficient to lower significantly the use of coal;

- the second reason is that the pace of the reduction of industrial energy intensity declined once they became accustomed to high energy prices.

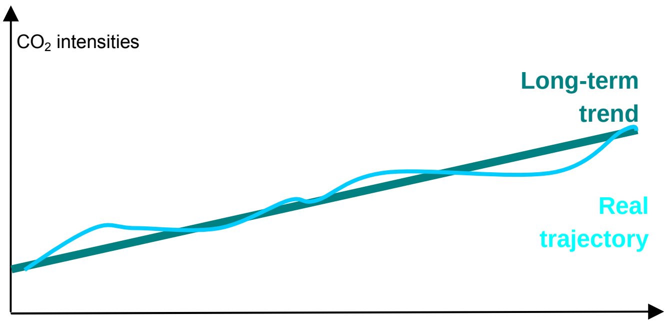
D. Econometric estimates of CO_2 intensity: the impact of GDP and of the percentage of thermal power generation

The preceding remarks brought out a number of observations that can be developed in greater depth by quantitative items. Two types of analysis were thus carried out, based on the estimated elasticity of the CO_2 intensities of the economies, first in relation to growth, and secondly, in relation to the choice of energy.

Elasticity makes it possible to quantify the CO_2 intensity of a country when the GDP or the percentage of thermal power generation goes up. It can be interpreted as follows: if the elasticity of the CO_2 intensity in relation to the GDP is – 0.5, a 1% increase of GDP will be accompanied by a 0.5% decline in CO_2 intensity.

Elasticity can be evaluated both in the long and the short term. In the long term, it gives an indication of the trend towards lower carbon intensity of the economies (the trend of CO_2 in relation to economic growth). In the short term, it evaluates the impact of a variation in GDP or in the percentage of thermal power generation on the real trajectory of CO_2 intensities (variations around the trend), thanks to an error correction model (ECM).

Figure 9 – Diagram of the short- and long-term trends of CO_2 emissions



First of all, only results pertaining to the 15-member European Union, the United States and Japan are presented. The European countries will be discussed in greater detail in Part III.

The econometric results obtained here for the major developed economies are quite convincing for Europe and Japan, whereas they are less reliable for the United States[7] (see Table 7). This suggests that there is a major explanatory dimension missing for this country, which could explain the price of energy. The variations are indeed far less amortized in the United States than in Europe, for example, due to lower taxes.

Table 7 – Short-term and long-term elasticity estimates.

	Long-term elasticity: trend				**Short-term elasticity: effects of deviation from the trend**			
	GDP before 1973	GDP after 1973	Percentage of thermal power generation	DW	GDP	Percentage of thermal power generation	Return to equilibrium	DW
EU-15	-0.34	-0.91	0.35	1.10	0.00*	0.78	-0.27	1.72
Japan	0.07	-0.69	-0.14*	0.79	0.33	4.55	-0.20	2.06
United States	-0.28	-0.53	1.10	0.37	*No correlation*[8]			

** Not significant at the threshold of 10%.*

The return to equilibrium indicates the pace at which the CO_2 of an economy, modified by a crisis, returns to its long-term trend.

The Durbin-Watson statistic indicates the area in which a self-correlation of errors makes the results risky. Here the results are reliable for a DW statistic of between 1.42 and 2.33. In the other cases, the results should be interpreted as Indications of real connections, but not as proofs.

Source: Climate Taskforce.

Over the long term, the results confirm the impact of the energy crises, since the elasticities dropped sharply, especially for Japan, which had not begun to lower the carbon intensity trend of its economy prior to 1973 (the elasticity of CO_2 intensities in relation to the GDP was positive). Europe, which already had a lower CO_2 intensity trend than the United States, saw the elasticity of its CO_2 intensities in relation to the GDP decline even more significantly.

Furthermore, the elasticity of CO_2 intensities in relation to the percentage of thermal power generation was very different from one country to the next: the emissions level in the United States was far more sensitive to the increase in the percentage of power generated by fossil fuels than that observed in Europe. The explanation lies in energy efficiency gains achieved in power plants: over the long term;

[7] This was also the case of the econometric analyses for Australia and Canada.

[8] This result for the United States (no correlation *and* weak Durbin-Watson statistics) indicates the absence of an explanatory variable, probably the price of energy.

those gains resulted in a negative relationship between CO_2 intensity and GDP after 1973. In the short term, this effect was no longer perceptible and reveals, with a highly positive coefficient, the use of higher CO_2 emitting plants to fill the energy gap.

In the short term, it is interesting to note that the GDP had greater impact on CO_2 intensity in the EU-15 and Japan. Here, Japan's CO_2 intensity returned to its initial trajectory more slowly than Europe, requiring 5 years (1/0.20) instead of 3.7 (1/0.27) for Europe.

III. EU-15 seen in perspective

The 15-member European Union has so far manifested special characteristics. This section will specifically examine the characteristics of the European countries compared with the other developed countries and take a more in-depth look at three groups: the European countries *i.e.* those that formed the core of the industrial revolution, the Scandinavian countries and the two countries that enjoyed the highest growth rate over the last ten years, namely Spain and Ireland.

A. "Old" industrial countries where lowering the carbon intensity of the economy is well under way

The first analysis concerns the 6 founding countries of the European Union: France, Germany, Italy, Belgium, Luxembourg and Netherlands. From the standpoint of CO_2 intensities and their causal factors, the econometric relationships obtained are highly significant.

Table 8 – Short- and medium-term elasticity estimates of EU-6.

	Long-term elasticity: trend				**Short-term elasticity: effects of deviation from the trend**			
	GDP before 1973	GDP after 1973	Percentage of thermal power generation	DW	GDP	Percentage of thermal power generation	Return to equilibrium	DW
EU-6	-0.33	-1.04	0.51	1.30	-0.25*	0.81*	-0.39	1.54
EU-15	*-0.34*	*-0.91*	*0.35*	*1.10*	*0.00**	*0.78*	*-0.27*	*1.72*

** Not significant at the threshold of 10%.*

Source: Climate Taskforce.

The results show that these countries have reduced the sensitivity of their CO_2 intensity to economic growth more than the EU-15 as a whole: the development of service sector activities, especially in Luxembourg, has certainly been a major factor. Moreover, the majority of power generation was thermal-based, even though the total percentage of thermal generation has dropped in Denmark and Germany (see Appendix II). Only France and Belgium now ensure more than half their power generation with nuclear power plants. These energy choices explain a higher sensitivity of CO_2 intensities to the percentage of thermal power generation compared with the countries of EU-15 as a whole.

Another important point to emphasize is that short-term elasticity in relation to the GDP is lower than that observed at the European level. This is definitely linked to the Germany's weight in the sample, as well as to the high degree of financial activity in Luxembourg.

This distinctly negative relationship between CO_2 intensity and GDP is furthermore coupled with greater stability compared with the EU-15: the average time required to return to the trend after a disruption of the intensity level is 2.6 years, compared with 3.7 years for the European countries as a whole.

A second, more detailed analysis, focused on the four main industrialized countries in Europe: Germany, France, Italy and the United Kingdom.

Table 9 – Short- and medium-term elasticity estimates for the 4 main European economies.

	Long-term elasticity: trend				Short-term elasticity: effects of deviation from the trend			
	GDP before 1973	GDP after 1973	Percentage of thermal power generation	DW	GDP	Percentage of thermal power generation	Return to equilibrium	DW
Germany	-0,52	-1.12	0.65*	1.12	-0.66	0.90*	-0.38	1.40
United Kingdom	-0.65	-1.15	-0.17	1.52	-0.31	2.58	-0.38	2.04
France	-0.27	-1.11	0.14	0.76	0.58*	0.25	-0.22	2.10
Italy	0.71	-0.49	-0.49*	0.87	0.58	-1.84	-0.07*	1.61
EU- 15	*-0.34*	*-0.91*	*0.35*	*1.10*	*0.00**	*0.78*	*-0.27*	*1.72*

** Not significant at the threshold of 10%.*

Source: Climate Taskforce.

The first observation is that Germany and the United Kingdom have always shown the most negative elasticities in relation to GDP, both before and after 1973. The oil crises even accentuated these elasticities. Thus, after 1973, 1% growth of GDP led to an average decline in CO_2 intensity of 1.12% and 1.15% for Germany and the United Kingdom, respectively. These countries are also the only ones that show negative short-term intensity elasticity in relation to GDP. The fact that CO_2 intensities ceased to be pegged to economic growth reveals that economic development took place at the expense of high-emitting activities. In Germany, the efficiency of the power generation sector improved, together with a profound restructuring of industry following the integration of the 5 Länder of East Germany.

In the United Kingdom, two factors were at work: first, the deregulation of the energy market, which led to switches to natural gas (which emits less CO_2 than coal or oil) and secondly, economic development oriented towards the finance sector, where direct emissions are very limited. Changes in the UK energy supply system resulted in long-term negative elasticity of its CO_2 intensities in relation to the percentage of thermal power generation.

France and Italy experienced more or less the same impact of economic growth on their CO_2 intensities. Italy, in particular, underwent far-reaching structural change after the oil crises, since the elasticity of its CO_2 intensity in relation to GDP was reversed between the two periods studied.

In France, CO_2 emissions became less and less pegged to economic growth after 1973, owing to the development of its nuclear energy program. This political choice was clearly made after the oil shocks, whereas the previous policy was to develop power production from oil.

B. The Scandinavian countries: an energy policy change following the oil crises

Rapid changes in energy policies were also observed in other European countries, like France. Nevertheless it is a major characteristic of Scandinavian countries.

The Scandinavian countries cannot be considered a homogeneous group, because their greenhouse gas intensities vary widely (see Figure 4): Finland is one of the countries with the highest intensities, Denmark has a medium level of intensity and the intensities in Norway and Sweden are among the lowest.

This diversity is also reflected in energy choices. Whereas Norwegian power generation has always been 100% renewable, the energy mix of the other countries during the period 1950-2003 was oriented towards lower thermal power generation (see Appendix II). This partly explains the sharp decline observed in long-term elasticities (- 1.4 on average) compared with the European countries as a whole (- 0.6). While all the Scandinavian countries underwent structural changes after 1973, they were particularly significant in Sweden, both in terms of the impact on prices (as in the other countries) and the change in political and social policy prompted by increased awareness of environmental problems.

Table 10 – Short- and medium-term elasticity estimates for the Scandinavian countries

	Long-term elasticities: trend					**Short-term elasticities: effects of deviation from the trend**			
	GDP before 1973	GDP after 1973	*Variation between elasticities and GDP*	Percentage of thermal power generation	DW	GDP	Percentage of thermal power generation	Return to equilibrium	DW
Scandinavian countries	0.41	-1.02	*-1.4*	0.47*	1.21	-0.39*	2.12	-0.32	1.93
Denmark	0.31	-0.87	*-1.2*	1.09*	1.05	-0.22*	2.20*	-0.24	2.09
Finland	0.90	-0.53	*-1.4*	0.44*	0.85	0.04*	1.93	-0.14	1.73
Norway	0.28	-0.81	*-1.1*	⚐	1.00	-0.99*	⚐	-0.22	2.18
Sweden	0.35	-1.77	*-2.1*	0.18	1.39	0.08*	0.18*	-0.09*	2.26
EU-15	*-0.34*	*-0.91*	*-0.6*	*0.35*	*1.10*	*0.00*	*0.78*	*-0.27*	*1.72*

⚐ As Norway has no thermal power generation, an elasticity estimate is impossible.

** Not significant at the threshold of 10%.*

Source: Climate Taskforce.

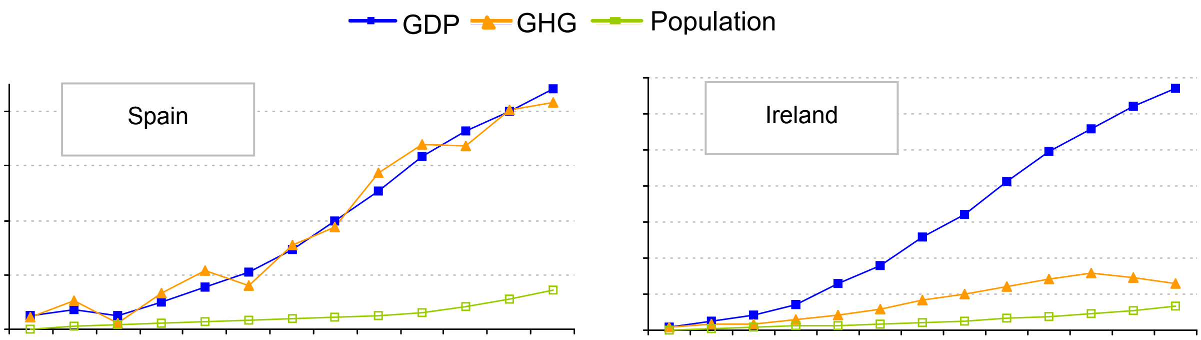
With regard to thermal generation, apart from Norway, the Scandinavian countries oriented their power generation towards nuclear power plants (Sweden, Finland) and renewable energies (Denmark, Finland). The CO_2 intensity of the Finnish economy, and especially of the Danish economy, remained very sensitive, however, to an increase in the percentage of thermal power generation.

C. *Close-up on the European "dragons": Spain and Ireland*

The economies of the developed countries enjoyed an average grow rate of 2.6% between 1990 and 2003. Among the European countries, 4 posted higher growth rates: Ireland (6.8%), Luxembourg (4.8%), Spain (2.9%) and Greece (2.8%). A closer look at Ireland and Spain reveals highly unusual characteristics.

With regard to greenhouse gas emissions, the trajectories of Spain and Ireland were very different. In the former, the increase of emissions paralleled its economic growth. In the second, on the contrary, a dissociation was observable starting in the early 1990s.

Figure 10 – Indices of greenhouse gas emissions, economic growth and population growth for Spain and Ireland from 1990 to 2003.



Source: UNFCCC, OECD.

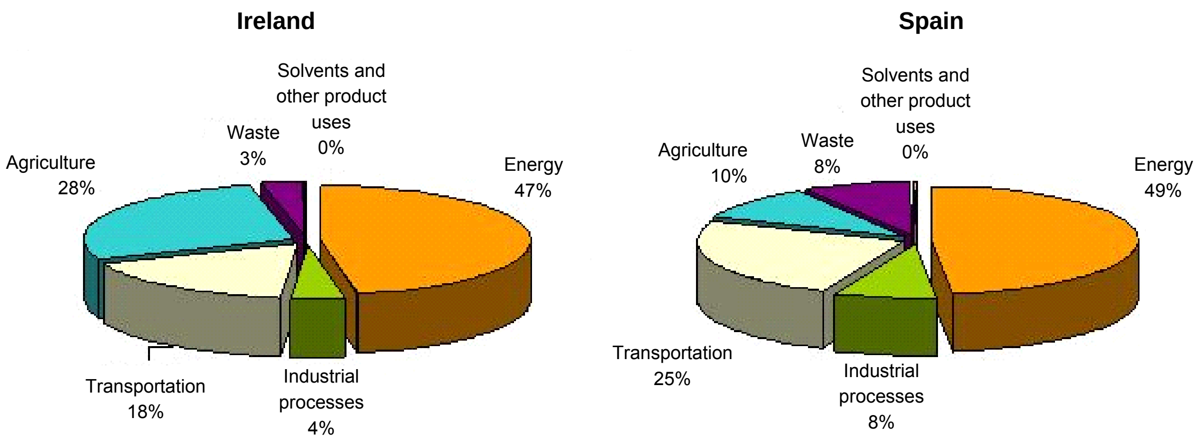
Demographic growth was almost twice as high during the period under consideration in Ireland (+ 13%) as in Spain (+ 7%). At the same time, the GDP more than doubled between 1990 and 2003 in Ireland (+ 134%), whereas the rise was more moderate for Spain (+ 44%). Despite a higher increase in both factors of economic production and demography, the growth of greenhouse gas emissions remained lower than economic growth for Ireland (+ 25%), while that of Spain took off along with economic growth.

However, on close examination, Ireland shows a much higher level of greenhouse gas intensities than Spain: due to the scale of agriculture in Ireland (see Figure 11), which resulted in methane and nitrogen protoxide emissions, production of one unit of GDP in 2003 caused the emission of 0.52 kg CO_2e in Ireland, compared with 0.43 kg CO_2e in Spain.

The fact that Irish emissions were no longer pegged to economic growth can be partly explained by agricultural factors such as the reduction of the amount of livestock, but also by changes in the industrial and energy production sectors. As Figure 11 shows, the latter sector dominated greenhouse gas emissions, but its percentage remained below that observed for the EU-15 (60%). The increase in emissions over the period 1990 - 2003 was high: + 38% for Spain and + 23% for Ireland, in contrast to the EU-15 (- 3%).

These energy needs were also found in the transportation sector, which accounted for nearly one quarter of emissions in Spain, whereas Ireland fell within the European average. In both countries, the increases observed between 1990 and 2003 were far higher than the 25% rise for Europe as a whole: + 130% for Ireland and + 70% for Spain.

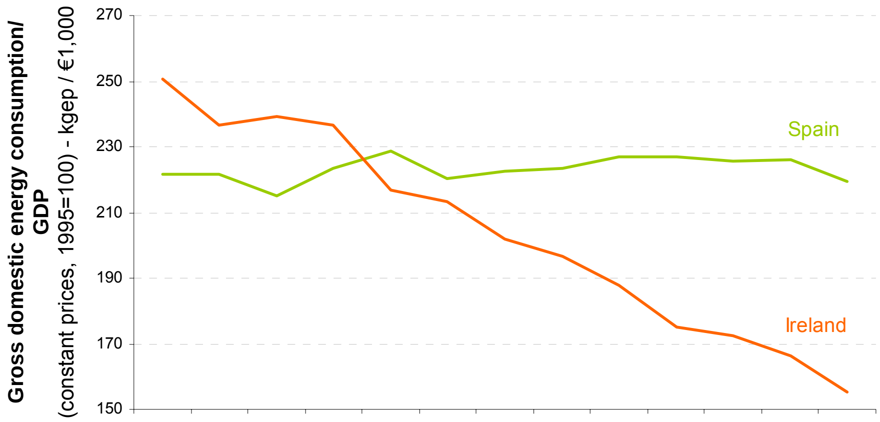
Figure 11 – Greenhouse gas emissions in 2003 by sector in Ireland and in Spain.



Source: UNFCCC.

The sharp rise in the energy requirements of the two European dragons corresponded to an increase in economic activity, corrected by possible improvements in energy efficiency. In this area, Ireland made significant progress, whereas energy intensity stagnated in Spain. This fact may partly explain the growth of emissions linked to industrial processes, which was limited to 0.2% in Ireland, but reached 26% in Spain between 1990 and 2003.

Figure 12 – Energy intensity of the economy, Spain and Ireland, 1991 - 2003.

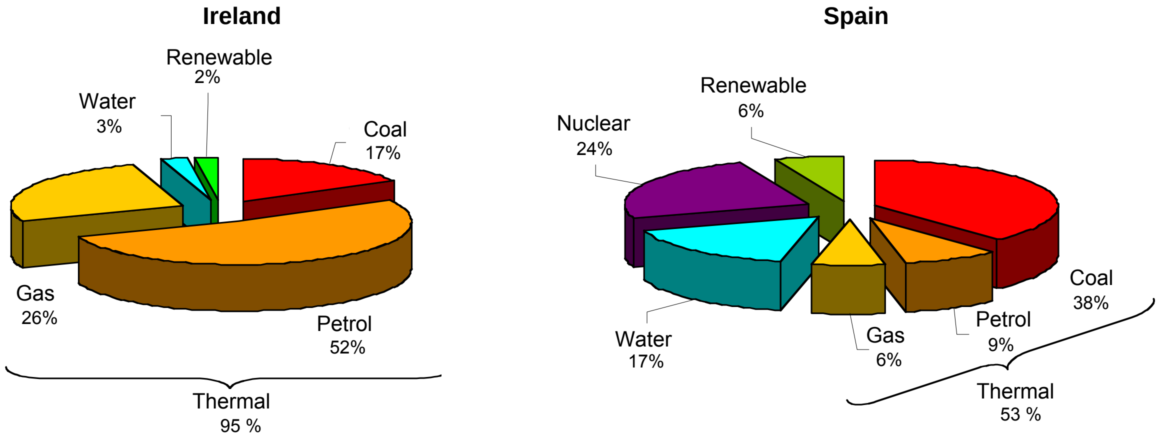


Source: Eurostat.

Indeed, Ireland stepped up its use of natural gas, both for industrial and residential purposes, and closed a number of chemical production plants (ammonia and nitric acid) in the early 2000s. This industrial reorientation towards lower-emission service industries with greater added value also partly explains the difference in the energy intensity level of its economy compared with Spain.

Gains in energy efficiency allowed Ireland to decrease its CO_2 emissions per unit of GDP, even though its energy mix was based on thermal power generation.

Figure 13 – Power generation in Ireland and in Spain en 2003.



Source: Energy Information Agency, IEA.

Given the high percentage of coal in Spain's energy mix, it should be relatively easy to reduce its CO_2 emissions by replacing coal-fired power plants with gas or renewable energies.

This current structure of power generation indeed corresponds to the econometric results concerning the evolution of CO_2 intensities after the oil crises. Thus, in Ireland, the relationship between economic growth and CO_2 intensity was completely reversed, while in Spain, on the contrary, this relationship does not appear to have been seriously disrupted by the oil crisis.

Table 11 – Short- and medium-term elasticity estimates for Spain and Ireland.

	Long-term elasticities: trend					Short-term elasticities: effects of deviation from the trend			
	GDP before 1973	GDP after 1973	*Variation between elasticities and GDP*	Percentage of thermal power generation	DW	GDP	Percentage of thermal power generation	Return to equilibrium	DW
Spain	-0.03*	-0.08*	*-0.1*	0.65	1.11	-0.53	0.50*	-0.47	1.72
Ireland	0.29	-0.54	*-0.8*	1.72	2.11	*No correlation*			
EU-15	*-0.34*	*-0.91*	*-0.6*	*0.35*	*1.10*	*0.00**	*0.78*	*-0.27*	*1.72*

** Not significant at the threshold of 10%.*

Source: Climate Taskforce.

The same analysis, using 1986 as the pivotal date of Spain's entry into the European Union, also shows a decline in the elasticity of CO_2 intensity in relation to GDP, which dropped from 0.05 to 0.03. This elasticity remained positive, however, indicating that CO_2 intensity remained correlated to growth in Spain. This result was also obtained for Portugal: in all likelihood, it corresponded to a "catching-up" effect common to all the Mediterranean countries that have joined the EU.

The difference in Spain's evolution from that of Ireland therefore seems to have resulted from the difference in the initial level of wealth, but it is also probably due to climate factors: increased demand for air-conditioning during the summertime in the Mediterranean countries has delayed the reduction of the CO_2 intensity of their economies.

Conclusion

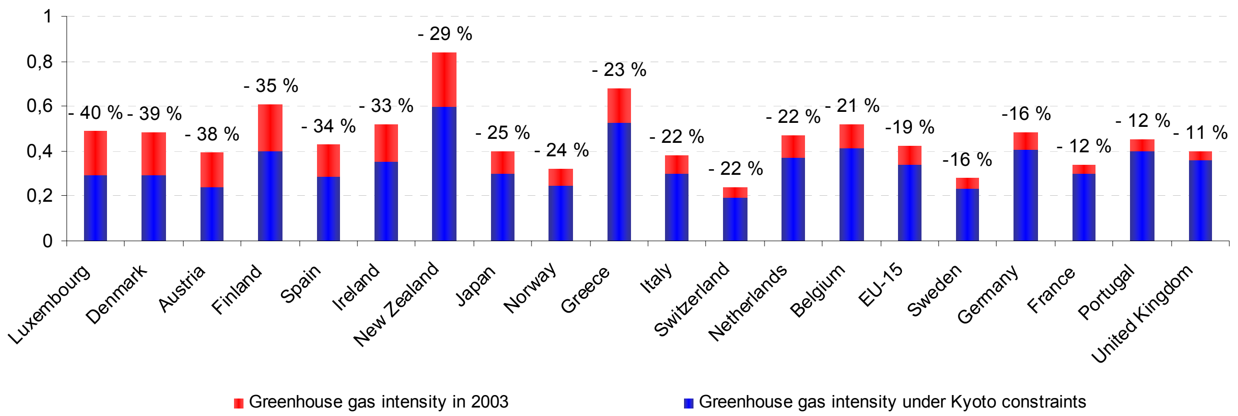
This study of greenhouse gas intensities has brought out the wide diversity existing among the developed countries and the unusual position of the 15-member European Union.

This variability is shown to stem from energy supply choices and to the price signals sent to the actors, as the oil crises of the 1970s demonstrated. The energy crises impacted the structure of energy production and consumption in the developed countries. These changes were especially significant insofar as the energy sector is the cause of more than half of emissions in industrialized countries.

The reduction in the carbon intensity of the economies of the developed countries continues today, but significant disparities remain. In contrast, the convergence observed in Europe underscores the importance of close cultural and political ties. Convergence occurred in Europe before the economic tools of the Kyoto protocol and the European Union Emissions Trading Scheme were introduced. It may therefore accelerate in the coming years.

If the objectives of the Kyoto protocol are to be realised then it is critical that this acceleration in the reduction of carbon intensities be achieved. Figure 14 shows that in comparison to 2003 carbon intensity levels there exists a wide range in the reduction targets (-11% for the UK to -40% for Luxembourg) that countries must achieve if they are to honour their Kyoto commitments. Thus climate change policies should be strengthened to allow developed countries continue to grow while simultaneously respecting the international commitment of Kyoto.

Figure 14 – Greenhouse gas intensities: 2003 and estimate under Kyoto constraints.



The estimate of the greenhouse gas intensity corresponds to the volume of assigned amount units (AAU) requested from the UNFCCC by the countries at the end of 2006 (maximum annual amount of emissions) divided by the 2010 GDP estimated from growth estimates of the OECD. This does not include the United States and Australia, which have not ratified the Kyoto protocol, nor Canada and Iceland which have not yet made their AAU request.

Source: Climate Taskforce.

Appendix I – Data used and methodology

A. Scope of the study

Developed countries are defined by the World Bank as countries with a high standard of living, with per capita gross national income exceeding 10,066 dollars in 2004.

The World Bank excludes from the list of developed countries Hong-Kong (China), Israel, Kuwait, Singapore, and the United Arab Emirates, due to their economic structure or their government. If the very small countries are not included, the majority of the developed countries correspond to the countries in the OECD, which have made commitments concerning their emissions within the scope of the Kyoto protocol. In this study, we will therefore be looking only at those countries, namely[9]:

- the countries of the EU-15: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom,
- Australia,
- Canada,
- United States,
- Iceland,
- Japan,
- Norway,
- New Zealand,
- Switzerland.

B. Sources

Economic data

Most of the economic data used in this study is derived from the OECD. When this proved impossible, the data was obtained from the CIA World Factbook, which compiles the national data provided by the various American government departments, World Bank data and, for long-term GDP data, the Total Economy Database of the University of Groningen[10]. This latter database corresponds to the compilation of data from the OECD (National Accounts), Eurostat and, for much of the data prior to 1990, from the book by Angus Maddison, *The World Economy: Historical Statistics* (OECD Development Centre, 2003).

For GDP comparisons, the data were corrected by purchasing power parities rather than by exchange rates. Indeed, there are two drawbacks to using exchange rates: they continually fluctuate, sometimes for reasons unrelated to the countries' production (i.e. speculation, a change in interest rates, etc.), and they skew price assessments with financial factors and prices of tradable commodities.

Purchasing power parities allow GDP to be assessed according to the monetary valuation of a basket of goods and services covered by the GDP (consumer goods and services such as foods, power supply and leisure facilities, governmental services, plant, etc.). This method is better suited to comparing production levels.

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[9] The Republic of South Korea is part of the OECD, but has not made Kyoto commitments; Slovenia has made Kyoto commitments but does not belong to the OECD.

[10] This database presents GDP expressed in 1990 dollars, converted by Geary-Khamis purchasing power parities.

Greenhouse gas emissions

The changes in land and well use are not taken into account in this study. Indeed, carbon capture is not linked to the problem under discussion, and there is great uncertainty about measurement and methodology.

Most of the data is taken from the inventory drawn up by the United Nations Framework Agreement on Climate Change (UNFCCC). This data covers the period 1990-2003 for the countries in Appendix I. For the others, only a few years are available, the latest being 2000.

UNFCCC inventories

The countries in Appendix I of the Kyoto protocol are required to publish an annual national inventory report (NIR) as well as charts in the Common Reporting Format (CRF). This data is subsequently examined by the UNFCCC secretariat, which points out any observed anomalies to the countries. The countries then submit corrected data to the secretariat.

The NIRs present the methods, emissions coefficients and activity data chosen by the countries. Estimates may be revised regularly, based on the instrument proposed by the IPCC: Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.

The data concerning global greenhouse gas emissions was obtained from the World Research Institute (WRI), through its CAIT database (Climate Analysis Indicators Tool). It reproduces the official data of the UNFCCC, the IEA and the World Bank, particularly the data covering CO_2 emissions related to combustion and cement from 1850 to 2002 and anthropogenic greenhouse gas emissions since 1990. The data therefore has the same levels of uncertainty, especially in the area of changes in land use, which we have not used in this study.

Data pertaining to CO_2 prior to 1990 was obtained from the OECD based on data from the International Energy Agency and does not concern emissions caused by energy. The other set of data used is from the Carbon Dioxide Information Analysis Center (CDIAC), which compiles CO_2 emissions linked to fossil fuels and cement plants by the United States Department of Energy.

One last point should be emphasized in regard to data concerning greenhouse gas emissions: the data refers to emissions directly produced on national territory. Associated production is not intended for the national market. Thus, at a like level of consumption, an exporting country will have a higher level of greenhouse gas emissions than a country that imports more frequently. This bias, even though reduced in the developed countries, must be kept in mind in making comparisons between countries.

Appendix II – Energy mix of the developed countries in 1980, 1990 and 2003

The following table presents the breakdown of power generation in the developed countries according to the energy source used. The data are expressed in percentages.

	1980				1990				2003			
	Thermal	Water	Nuclear	Renewable	Thermal	Water	Nuclear	Renewable	Thermal	Water	Nuclear	Renewable
Group 1: high greenhouse gas intensities												
Australia	85	15	0	0	90	10	0	0	92	7	0	1
New Zealand	9	84	0	7	20	72	0	8	32	59	0	10
Canada	22	68	10	0	22	63	15	1	27	59	12	2
Greece	84	16	0	0	95	5	0	0	89	9	0	2
United States	77	12	11	0	69	10	19	2	71	7	20	2
Finland	57	26	17	0	44	21	35	0	49	12	27	12
Group 2: medium greenhouse gas intensities												
Ireland	91	9	0	0	95	5	0	0	95	3	0	2
Belgium	75	1	23	1	38	0	61	1	41	0	57	2
Luxembourg	87	10	0	3	83	12	0	5	94	3	0	3
Denmark	100	0	0	0	97	0	0	3	81	0	0	19
Germany	83	4	12	1	68	3	28	1	63	3	28	6
Netherlands	92	0	6	2	93	0	5	1	90	0	4	6
Portugal	45	53	0	2	64	33	0	2	60	35	0	5
Group 3: low greenhouse gas intensities												
Spain	68	27	5	0	46	17	36	0	53	17	24	6
EU-15	70	17	13	1	53	13	34	1	52	11	34	4
United Kingdom	86	1	12	0	77	2	21	0	75	1	23	2
Japan	69	16	14	0	64	11	24	2	65	10	23	2
Austria	29	70	0	1	33	65	0	2	36	61	0	4
Italy	71	26	1	2	83	15	0	2	83	12	0	4
Iceland	1	97	0	2	0	93	0	6	0	84	0	16
France	47	27	25	0	11	13	75	1	10	11	78	1
Norway	0	100	0	0	0	100	0	0	0	99	0	1
Sweden	11	62	27	1	2	51	46	1	6	40	49	5
Switzerland	2	70	28	0	1	56	42	1	1	55	41	2

Source: Energy Information Administration, International Energy Annual 2004.

Appendix III – Summary of econometric estimates (1950 – 2003).

The following econometric estimates pertain to CO_2 intensities, expressed in kg per thousand dollars US (PPP 1990).

Country or group of countries	Long-term elasticity (ordinary least squares (OLS) method – with a structural break in 1973)				Short-term elasticity (error-correction model in the presence of co-integration)			
	GDP before 1973	GDP after 1973	Thermal %[11]	DW statistic[12]	GDP	Thermal %[8]	Return to equilibrium	DW statistic[9]
USA	-0.28	-0.53	1.10	0.37	No co-integration			
Japan	0.07	-0.69	-0.14*	0.79	0.33	4.55	-0.20	2.06
EU-15	-0.34	-0.91	0.35	1.09	0.00*	0.78	-0.27	1.72
France	-0.27	-1.11	0.14	0.76	0.58*	0.25	-0.22	2.10
Germany	-0.52	-1.12	0.65*	1.12	-0.66	0.90*	-0.40	1.40
Spain	-0.031	-0.08	0.65	1.11	-0.53	-0.50	-0.47	1.72
Ireland	0.29	-0.54	1.72	2.11	No co-integration			
Italy	0.71	-0.49	-0.49*	0.87	0.58	-1.84	-0.07*	1.62
United Kingdom	-0.65	-1.15	-0.17	1.52	-0.31	2.58	-0.38	2.04
Tigers (Spain, Portugal, Greece, Iceland, Ireland, Japan)	0.09	-0.40	1.09	0.64	0.34	2.63	-0.15	2.08
EU- 6 (France, Germany, Italy, Benelux)	-0.33	-1.04	0.51	1.30	-0.25*	0.81*	-0.39	1.54
Mediterranean countries (France, Italy, Spain, Portugal, Greece)	-0.01	-0.42	0.84	0.64	0.51	1.02	-0.17	1.85
Scandinavia (Norway, Sweden, Finland, Denmark)	0.41	-1.02	0.47*	1.21	-0.39*	2.12	-0.32	1.93

** Not significant at the threshold of 10%.*

Source: Climate Taskforce.

11 Percentage of fossil-based thermal power generation of a country or a group of countries.

12 The Durbin-Watson statistic indicates the area in which errors run the risk of being self-correlated, which leads to deceptive results. Here, with 53 observations per variable and per country and 3 explanatory variables, the DW statistic should be situated between 1.42 and 2.33. This is clearly the case for error correction models, constructed specifically to eliminate self-correlation of errors. Unsurprisingly, that is seldom the case for OLS estimates, for there is at least one relation of correlation between the variables. The OLS results must therefore be interpreted with caution as indications and not proofs of genuine connections, more or less probable according to the DW statistical value.

Lexicon

CO_2 equivalent: unit of mass (usually the gram, kilogram or ton) corresponding to the sum of the masses of various gases weighted by the corresponding values of the potential global warming. This method enables a comparison of gases with varying warming potential and lifespan. The greenhouse gases recognized by the United Nations Framework Agreement for Climate Change are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide, sulfur hexafluoride (SF_6) as well as the families of perfluorocarbons (PFCs) and des hydrofluorocarbons (HFCs).

Coefficient of variation: ratio of typical variation to the mean.

Durbin-Watson statistic: evaluates the risk of self-correlation of the errors in an econometric analysis. It is interpreted according to the size of the sample and the number of variables.

Elasticity: ratio of the variations of two variables. For example, the elasticity of emissions in relation to economic growth is therefore the variation of emissions (in %) observed for 1% growth of the GDP.

GDP: gross domestic product. Aggregate measuring the wealth within a country during a given period. It corresponds roughly to the sum of the added value from the various economic sectors.

Global warming potential: see CO_2 equivalent.

Gross domestic consumption: quantity of energy necessary to satisfy domestic demand. It corresponds to the sum of consumption, distribution losses, transformation losses and statistical variations.

Ppm: parts per million

PPP: purchasing power parity. This coefficient applied to the GDP reflects the difference of purchasing power between countries. It is calculated on a basket of goods representative of the activities covered by the GDP: consumer goods and services (food, healthcare services, transportation, electricity, etc.), governmental services, plant and construction projects. This methodology was used in preference to weighting by exchange rates, which may show variations unrelated to industrial realities (i.e. speculation, interest rate changes, etc.).

Return to equilibrium: this value indicates the pace at which the CO_2 intensity of an economy, modified by a crisis, returns to its long-term trend.

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Publications of the Caisse des Dépôts Climate Taskforce

Research report N°1: "Carbon investment funds: general assessment of the market"

Ariane de Dominicis, January 2005

Research report N°3: "CO_2 emissions exchanges and the functioning of trading systems"

Romain Frémont, June 2005

Research report N°5: " Domestic offset projects "

Ariane de Dominicis, September 2005

Research report N°7: "Carbon investment funds: growing faster"

Ariane de Dominicis, November 2005

Research report N°8: "Overview of European national allocation plans"

Claire Dufour and Alexia Leseur, April 2006

Executive summary of the report: "Expanding the means to combat climate change through domestic offset projects"

Emmanuel Arnaud, Ariane de Dominicis, Benoît Leguet, Alexia Leseur, Christian de Perthuis, November 2005

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The Climate Task Force of Caisse des Dépôts is a resource centre that facilitates and coordinates research and development in favour of action against climate change.

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Ariane de Dominicis	***01 58 50 98 20***
Anaïs Delbosc	***01 58 50 99 28***
Benoît Leguet	***01 58 50 98 18***
Alexia Leseur	***01 58 50 41 30***
Christian de Perthuis	***01 58 50 22 62***
Luke Redmond	***01 58 50 99 77***
Xin Wang	***01 58 50 77 41***

Caisse des dépôts and consignations

Département développement durable

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