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Greenhouse gas reductions in Germany — lucky strike or hard work?

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Abstract

With greenhouse gas (GHG) emissions decreasing by more than 18% in the 1990s, Germany appears to be among the few industrialised countries which are on track to meet the targets they committed themselves to under the Kyoto Protocol. This achievement may appear less remarkable if one takes into account that Germany benefited from so-called "wall-fall profits", i.e. the breakdown and restructuring of the East German economy after reunification in 1990. Nevertheless, various policies at national, regional, and local levels were introduced in the 1990s in Germany, which also resulted in a reduction of CO_2 and other greenhouse gases.

The objective of this paper is to examine the underlying factors for the GHG emission trends in Germany in the 1990s. In particular, it is estimated to what extent the observed reductions are wall-fall profits, and to what extent they are the result of policy measures.

The findings indicate that wall-fall profits account for almost 50% of the reduction of all six greenhouse gases. This share increases to 60% if only energy-related CO_2 emissions are considered. At the same time, a diverse set of policies also had a significant effect on the reduction of greenhouse gases. Environmental policies directed towards non-CO_2 gases were as important as policies addressing CO_2 emissions. Overall, the contribution of all the policies combined was slightly higher than the impact of unification. Although Germany is on a reduction path to meet the Kyoto target, the likelihood of it achieving the more ambitious national target without additional policy efforts appears rather slim. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Greenhouse gas; CO_2 emission; Wall-fall profits; Energy policy; Climate policy

1. Introduction

In the 1990s, emissions of the specified basket of six greenhouse gases in Germany decreased by more than 18%. Thus, unlike most other industrialised countries, where greenhouse gas emissions have

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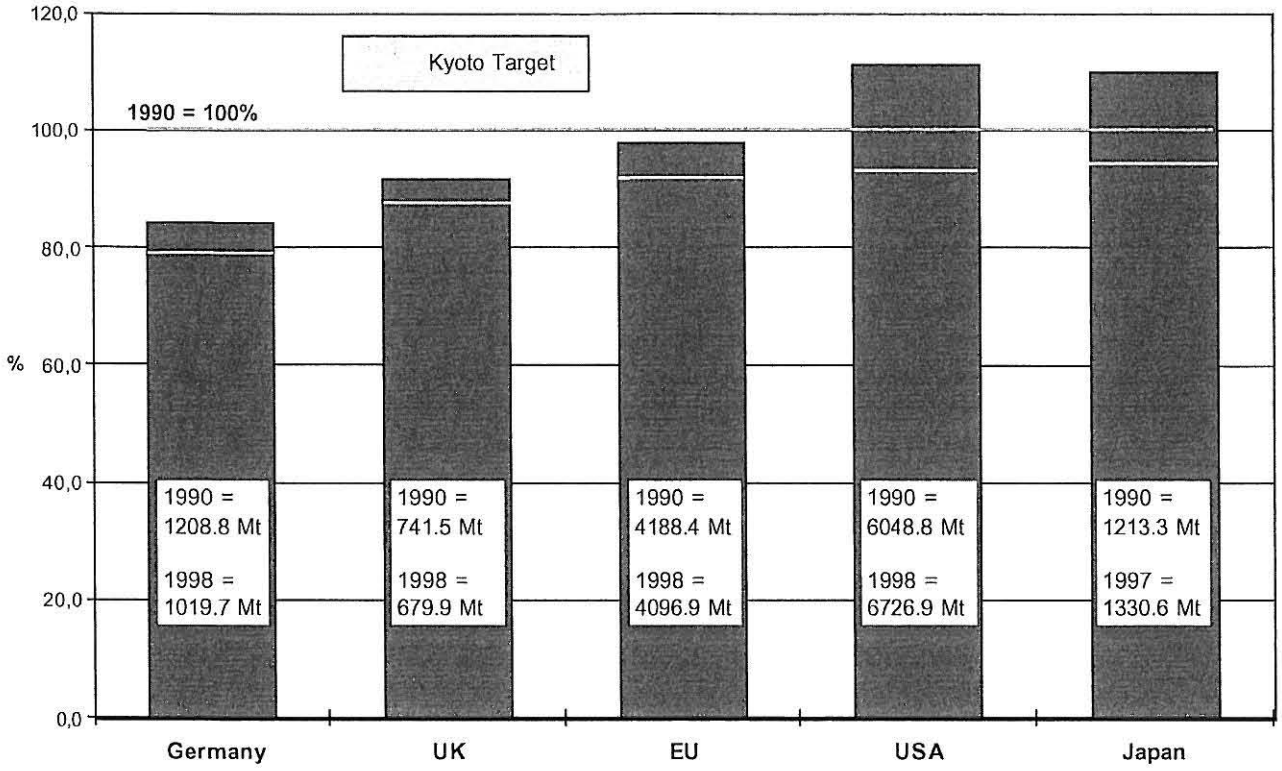


Fig. 1. Total greenhouse gas emissions of selected Annex I parties in CO_2-eq. for 1990 and 1998 (source: UNFCCC (2000)).

increased since 1990, Germany is among the few industrialised countries which are on track to meet the emission reduction targets they are committed to under the terms of the Kyoto Protocol in 1997 and the subsequent European Union's burden-sharing agreement in 1998 (Fig. 1). While the European Union is required to reduce its greenhouse gas emissions by 8% from 1990 to 2008–2012, Germany is required to reduce these emissions by 21%. In terms of CO_2 emissions, Germany has pledged to meet an even stricter domestic policy target: the government has set the goal to reduce CO_2 emissions by 25% between 1990 and 2005. These emission reduction targets, however, may appear less ambitious if it is taken into account that Germany benefited from special circumstances providing extraordinary opportunities for emission reductions: the breakdown and restructuring of the East German economy after reunification in 1990. As a result, CO_2 emissions in the new federal states (Laender) declined by over 40% in the 5 years thereafter (Ziesing and Jochem, 1997). But Germany was not only helped by these "wall-fall profits". Over the last decade, various climate-specific and more general environmental policy measures at the national, regional, and local levels were implemented which have also resulted in emission reductions.

This paper examines the underlying factors for greenhouse gas emission trends in Germany in the 1990s. In particular, the paper explores whether the observed emission reductions are coincidental and should be attributed to special circumstances, or whether they are the result of specific policy measures.

The rest of the paper is organised as follows. In Section 2, an analysis of components is applied to adjust for the effects of population growth, economic development, changes in primary energy intensity, the share of non-fossil fuels, and the CO_2 factor of primary energy consumption on CO_2 emissions in Germany. The impact of German reunification on the development of CO_2 emissions is estimated in

Section 3. In Section 4, the contribution of climate policy at the federal, regional, and local levels to the reduction of CO_2 emissions is assessed. Section 5 contains a brief analysis of the development of non-CO_2 gases. Section 6 offers a summary of the main results and conclusions.

2. Analysis of the components of CO_2 emission reduction Germany

Between 1990 and 2000, total CO_2 emissions in Germany, fell by 15.3% from 1014.3 to 859.3 million tons (Mt). These emissions are mostly energy-related, and only about 3% stem from industrial processes. While non-energy-related CO_2 emissions stayed fairly constant, energy-related CO_2 emissions decreased from 986.6 Mt in 1990 to 834.3 Mt in 2000, i.e. by 15.4% (Ziesing, 2001). The greater part of the emission reduction was achieved up to 1994 (−11.2%). Afterwards, the reduction slowed down.

Since the development of energy-related CO_2 emissions is a function of annual variations in temperature, it is useful to adjust CO_2 emissions for temperature for further analyses. Between 1990 and 2000, the temperature-adjusted CO_2 emissions were above actual emissions in all years except 1996, i.e. all years apart from 1996 were warmer than the long-term average (in terms of degree days) in Germany. For some years, the CO_2 emission changes based on actual and temperature-corrected values differ widely. For the whole period 1990–2000, the difference is less pronounced: the temperature-adjusted change amounts to 14.8% compared to an actual change of 15.3%.

Apart from temperature variations, the development of total CO_2 emissions of an economy (C) can be decomposed using the following identity:

$$C = Pye(1 - \alpha)c_f \tag{1}$$

where P is the population, y the GDP per capita, e the primary energy consumption in relation to GDP (energy intensity), α the share of fossil fuels in primary energy consumption, c_f the CO_2 emission factor of fossil primary energy.

The development of these factors between 1990 and 2000 is shown in Fig. 2. The population grew by 3% from 79.8 to 82.1 million between 1990 and 2000. The real increase of gross domestic product (GDP) amounted to 18 or 1.7% per annum. As a result, per-capita income rose by just under 15% from 40,800 to 46,750 DM (in 1995 prices). [1] The other determinants, however, showed trends which resulted in decreased CO_2 emissions. First of all, Germany experienced a considerable decrease in primary energy intensity (temperature-corrected primary energy consumption related to real GDP) which fell on average by 2.1% per annum during this period. The share of non-fossil fuels in total primary energy consumption increased from 11.9% in 1990 to 14.7% in 1990 which was the result of increasing availability of nuclear energy, but also of a rise in output from renewable energy sources in the second part of the decade. Finally, the CO_2-intensity of fossil primary energy decreased by 8%, mainly due to the extensive substitution of lignite by oil and gas.

To quantify the relevance of these different factors for changes in (energy-related and temperature-corrected) CO_2 emissions between 1990 and 2000, decomposition methods are applied. [2] The variation

[1] 1 DM = 0.51 EURO.

[2] Similar calculations were carried out in Ziesing and Jochem (1997) and Diekmann et al. (1999).

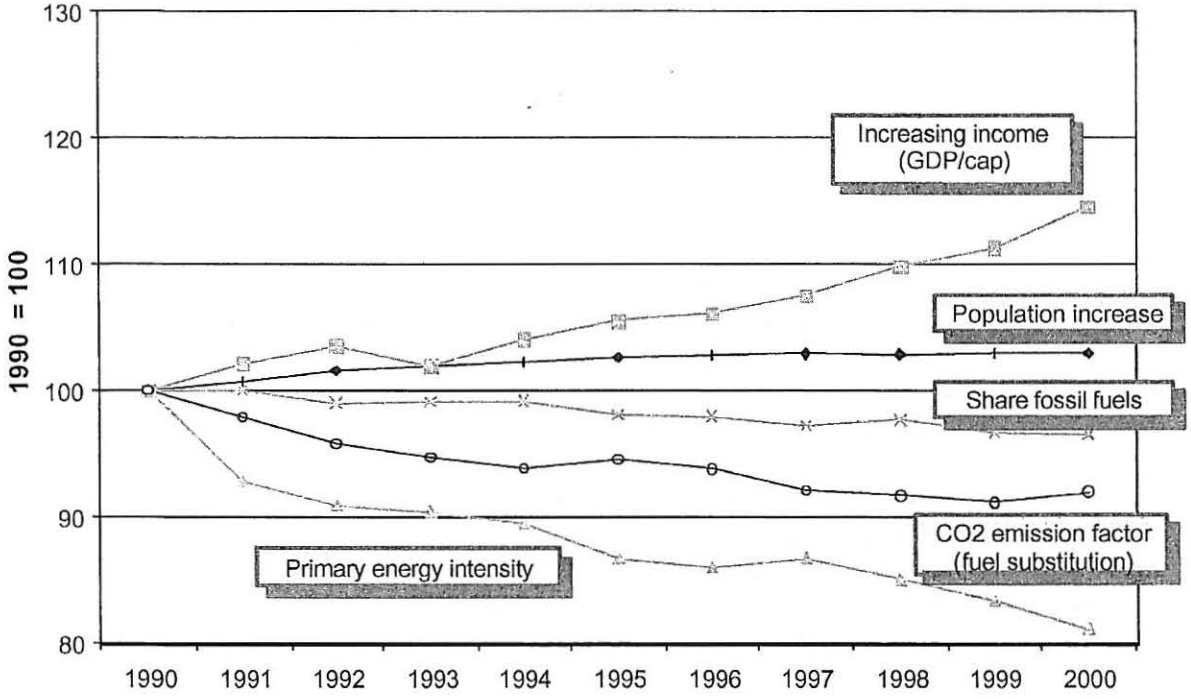


Fig. 2. Trends of various factors of influence on energy-related CO_2 emissions in Germany from 1990 to 2000 (sources: Federal Statistical Office, 2001; Ziesing, 2001).

of CO_2 emissions between 1990 and 2000 can be expressed as

$$
\begin{aligned}
C_{2000} - C_{1990} &= P_{2000}\, y_{2000}\, e_{2000}(1-\alpha_{2000})c_{\mathrm{f}\,2000} - P_{1990}\, y_{1990}\, e_{1990}(1-\alpha_{1990})c_{\mathrm{f}\,1990} \\
&= \underbrace{(P_{2000} - P_{1990})y_{1990}\, e_{1990}(1-\alpha_{1990})c_{\mathrm{f}\,1990}}_{\text{(a)}} \\
&\quad + \underbrace{(y_{2000} - y_{1990})P_{1990}\, e_{1990}(1-\alpha_{1990})c_{\mathrm{f}\,1990}}_{\text{(b)}} \\
&\quad + \underbrace{(e_{2000} - e_{1990})P_{1990}\, y_{1990}(1-\alpha_{1990})c_{\mathrm{f}\,1990}}_{\text{(c)}} \\
&\quad + \underbrace{[(1-\alpha_{2000}) - (1-\alpha_{1990})]P_{1990}\, y_{1990}\, e_{1990}\, c_{\mathrm{f}\,1990}}_{\text{(d)}} \\
&\quad + \underbrace{(c_{\mathrm{f}\,2000} - c_{\mathrm{f}\,1990})P_{1990}\, y_{1990}(1-\alpha_{1990})}_{\text{(e)}} + \text{residual (2000, 1990)}
\end{aligned}
\tag{2}
$$

In this equation, (a) represents the effect of population fluctuations on the changes in CO_2 emissions between 2000 and 1990, (b) the effect of changes in per-capita income, (c) the effect of changes in energy intensity, (d) the effect of changes in the share of fossil fuels, and (e) the effect of changes in the CO_2 emission factor. The method used is a Laspeyres derived index, where the residual term is divided among the other components as proposed by Sun (1998). The result of this analysis is presented in Fig. 3. For example, the increase in population of 2.3 million on its own would result in an increase

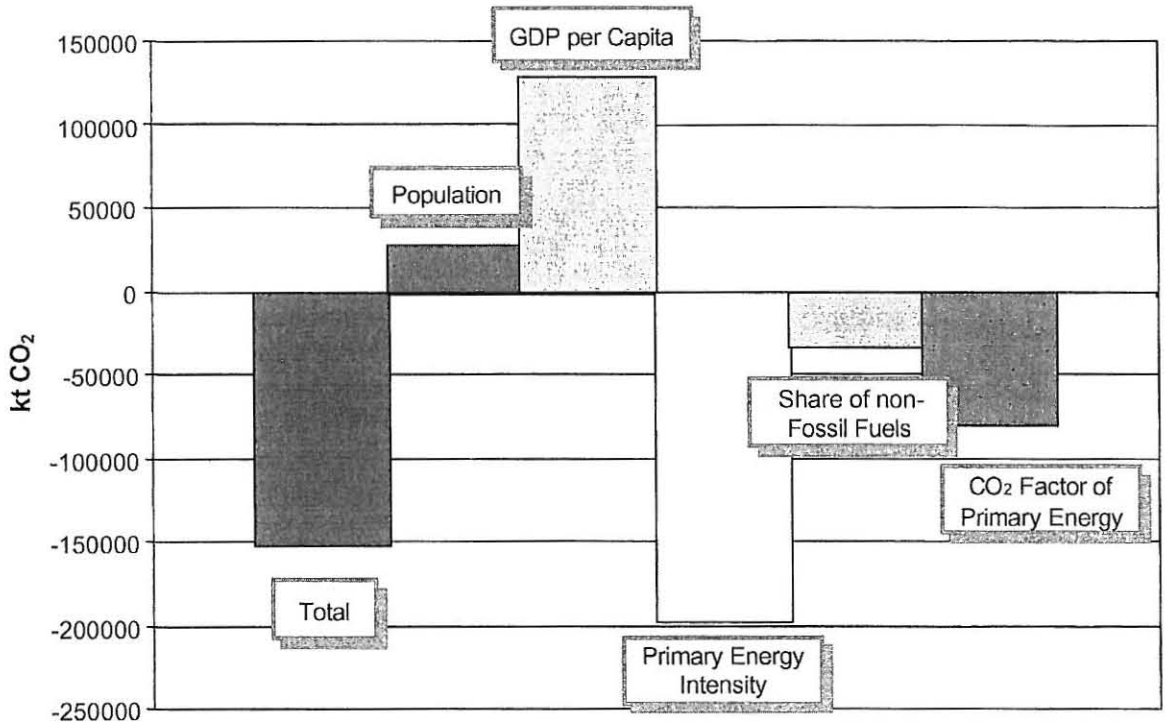


Fig. 3. Contribution of various factors to changes in energy-related CO_2 emissions in Germany 2000–1990 (temperature-corrected).

of CO_2 emissions by almost 28 Mt CO_2, provided that all other components remained constant (ceteris paribus). Effects which led to an increase in emissions, such as population and GDP growth, were more than offset by effects which led to a decrease in emissions such as a higher share of CO_2-free fuels, a lower CO_2 emission factor of primary energy and a lower energy intensity. Looking at the orders of magnitude of the various effects considered, the decisive factor for the observed emission reductions was the decrease in energy intensity, which accounted for a reduction of 200 Mt of CO_2, ceteris paribus.

3. The impact of reunification on CO_2 emissions in Germany

As indicated in Table 1, the most dramatic drop in CO_2 emissions in the 1990s occurred in the new federal states (Laender) between 1990 and 1995, where energy-related (temperature-corrected) CO_2 emissions fell by about 43%, while emissions in the old Laender remained almost constant. For the unified Germany, CO_2 emissions decreased by almost 13% in the first-half of the 1990s but fell by only 2.3% in the second-half. Since CO_2 emissions in 1999 accounted for nearly 85% of the Kyoto-gas basket in Germany, more than half the Kyoto target had already been reached in only a quarter of the period under consideration.

The most dramatic emission reductions in the new Laender occurred in the manufacturing, energy and transformation sectors, i.e. sectors which had been hit the most by the economic downturn following the fall of the Berlin Wall in late 1989 (Ziesing and Jochem, 1997). In the first 2 years thereafter, GDP in the new Laender decreased by about one third and, in the manufacturing sector, gross value added decreased by

Table 1
CO_2 emissions, GDP, and CO_2-intensity in Germany from 1990 to 2000[a]

	1990	1995	2000	Percentage change			Annual average growth rates		
				1990–1995 (%)	1995–2000 (%)	1990–2000 (%)	1990–1995 (%)	1995–2000 (%)	1990–2000 (%)
Germany									
CO_2[b] (in 10^6 t)	1041.9	908.7	887.6	−12.8	−2.3	−14.8	−2.7	−0.5	−1.6
GDP[c] (in 10^9 DM)	3253.6	3523.0	3840.8	8.3	9.0	18.0	1.6	1.7	1.7
CO_2/GDP (in t/10^6 DM)	320.2	257.9	231.1	−19.5	−10.4	−27.8	−4.2	−2.2	−3.2
New Laender									
CO_2 (in 10^6 t)	315.6	180.3	–	−42.9	–	–	−10.6	–	–
GDP (in 10^9 DM)	298.3	317.8	–	6.5	–	–	1.3	–	–
CO_2/GDP (in t/10^6 DM)	1057.9	567.1	–	−46.4	–	–	−11.7	–	–
Old Laender									
CO_2 (in 10^6 t)	726.3	728.4	–	0.3	–	–	0.1	–	–
GDP (in 10^9 DM)	2955.3	3205.2	–	8.5	–	–	1.6	–	–
CO_2/GDP (in t/10^6 DM)	245.8	227.3	–	−7.5	–	–	−1.6	–	–

[a] Source: Ziesing (2000, 2001).
[b] Total CO_2 emissions, energy-related emissions are temperature-corrected.
[c] In 1995 DM.

over 60% (Ziesing and Jochem, 1997; Ziesing and Diekmann, 1999). Thus, at least at first glance, these figures support the view that the observed emission reductions are mainly the result of the economic downturn in Eastern Germany, rather than the result of conscious climate and other environmental policy measures.

However, there is evidence that economic growth in Germany was higher than it would have been without the fall of the Wall. In 1993, the economy in the new Laender started to pick up again, spurred by strong growth primarily in the construction, manufacturing and services sectors, so that, as early as 1994, GDP in the new Laender overtook its 1990 level. Also, the old Laender benefited economically, supplying the vast majority of consumption goods for the new Laender, and exhibiting annual GDP growth rates of over 5% in 1990 and 1991. Thereafter, economic growth slowed down considerably and even became negative in 1993. Nevertheless, economic growth between 1990 and 1995 in the unified Germany exceeded the average growth experienced in the other EU15 countries by more than 2%.

A key factor in the reduction in CO_2 emissions was a significant decrease in the CO_2-intensity of the economy (measured as the ratio of total CO_2 emissions to real GDP), which decreased by about 28% between 1990 and 2000 in the unified Germany. In particular, in the new Laender, where CO_2-intensity was more than four times as high as in the old Laender in 1990, CO_2-intensity dropped by more than 46% up to 1995. This decline was primarily the result of the economic transformation, which was characterised by greater efficiency in the use of all production factors, and significant structural changes towards less carbon-intensive economic development. The latter include, for example, a decrease in the share of energy-intensive industrial sectors, and the decline of carbon-intensive lignite as an input for electricity and heat production. More specifically, the share of lignite in total primary energy consumption in the new Laender decreased from about 69% in 1990 to 38% in 1995 (Ziesing and Jochem, 1997). In addition, several policy measures had been implemented to further improve energy efficiency, such as support for district heating from CHP generation, or for the modernisation of existing buildings and heating systems, and ordinances pursuant to the Federal Emission Control Act. So, CO_2-intensity reduction continued to decrease in Germany after 1995, but at a much lower rate.

The question then arises as to what extent the observed reductions in greenhouse gas (GHG) emissions over the last decade can be attributed to so-called "wall-fall profits", and to what extent they are the result of specific policy measures. Here, wall-fall profits are defined as the reduction in emissions that are due to the special circumstances in Germany in the early 1990s, and not due to policy measures, efficiency gains, or structural change, etc., which would have taken place in any case. Thus, to quantify the wall-fall profits for the year 2000, one has to estimate the quantity of CO_2 that would have been emitted in the year 2000 in the old and new federal states in the absence of the wall-fall effect. Wall-fall profits can then be calculated as the difference between the actual CO_2 emissions and the hypothetical emissions estimated for the year 2000. Our estimate of the wall-fall profits is based on a simpler version of Eq. (1)

$$C_t = Y_t\, c_t \tag{3}$$

where Y_t is the GDP in year t and c_t the CO_2-intensity of GDP in year t.

That is, for any period t, CO_2 emissions can be calculated as the product of GDP and CO_2-intensity. Using this notation, wall-fall profits in 2000 can be expressed as

$$C_{2000}^{\text{actual}} - C_{2000}^{\text{hyp}} = C_{2000}^{\text{actual}} - (C_{2000}^{\text{hyp,O}} + C_{2000}^{\text{hyp,N}}) \tag{4}$$

where $C_{2000}^{\text{hyp,O}}$ and $C_{2000}^{\text{hyp,N}}$ are the hypothetical CO_2 emissions in the year 2000 for the old and new federal states, respectively. Hypothetical values for CO_2 emissions are calculated by substituting Eq. (3) into

Eq. (4) and making assumptions about hypothetical growth rates for GDP and CO_2-intensity in the old and the new federal states during the 1990s. Starting with the actual values for GDP and CO_2-intensities for both the old and the new federal states in 1990, the following assumptions are made to calculate hypothetical emissions of CO_2 in the year 2000.

- For old and new federal states, the annual growth rate of GDP between 1990 and 1995 is equal to the average annual GDP-growth rate of the EU15 during that period.
- For old and new federal states, the annual growth rate of GDP between 1995 and 2000 is equal to the actual average annual growth rate of unified Germany during that period (i.e. wall-fall effects on GDP are assumed to have levelled out by 1995).
- For the old federal states, the annual growth rates of CO_2-intensity between 1990 and 1995 are equal to the actual annual growth rates in the old Laender during that period.
- For the new Laender, the annual growth rates of CO_2-intensity between 1990 and 1995 are equal to the average annual growth rate in former East Germany between 1985 and 1989.
- For the old and the new federal states, the growth rates of CO_2-intensity between 1995 and 2000 are equal to the actual growth rates of unified Germany during that period (i.e. wall-fall effects on CO_2-intensity are assumed to have levelled out by 1995).

Under these assumptions, the hypothetical temperature-corrected CO_2 emissions in the year 2000 are 992.5 Mt, compared to the actual quantity of 887.6 Mt. Thus, the wall-fall profits are estimated to be about 105 Mt of reduced CO_2 emissions.

To analyse the effects of GDP growth and CO_2-intensity separately, the overall effect can be decomposed into an activity effect and an intensity effect. The growth effect which indicates the change in CO_2 emissions that occurs because actual GDP in 2000 is higher than it would have been in the hypothetical case, is estimated to be about 10 Mt of CO_2 (which is actually a "wall-fall deficit"). More importantly, the intensity effect which indicates the change in CO_2 emissions that occurs because CO_2-intensity of GDP is actually lower than it would have been without unification, is estimated to be about 115 Mt of CO_2.

4. The climate policy contribution to CO_2 reduction

To start with, an overview of the most relevant federal policies and their estimated contributions to the reduction of greenhouse gases in Germany in the 1990s is provided. Then, the impact of policies at regional and local levels is evaluated.

Quantitative figures for the effects of all the policies and measures which were initiated before 1997 are based on Ziesing and Diekmann (1997), where emission reductions were estimated against a "without-measures" reference scenario. These estimates were adjusted, if necessary, to account for more recent information. The estimated effects of policies introduced after 1997 are based on Ziesing and Diekmann (1999) and DIW (2001).

4.1. Climate policy measures at the federal level

Policy measures at the federal level include those introduced by the conservative-liberal coalition government prior to the fall elections of 1998, and by the government formed by the coalition of the Social Democratic party and the Green party thereafter. The set of policies considered covers federal policies

that were primarily implemented to reduce CO_2 emissions, such as standards for thermal insulation, or feed-in tariffs for electricity from renewable energy sources, and policies introduced for purposes other than climate change mitigation but which had a direct effect on CO_2 emissions, such as the various increases in fuel taxes. All sectors are typically covered by a mix of policies.

4.1.1. Industrial and services sectors

The most prominent policy measure in the industrial and services sectors are the voluntary agreements between the majority of German industrial associations, organised under the Federation of German Industries (BDI), and the federal government in 1995–1996 and 2000, which include commitments by industry to specific energy reduction. Like most other sectors, the industrial and services sectors are also covered by building regulations — which address installations of heating equipment as well as thermal insulation — and by programmes offering low-interest credits for energy-saving investments. The entire manufacturing sector (as well as the agricultural and forestry sectors) is virtually exempt from the financial burdens of the Ecological Tax Reform, which came into force in April 1999, paying only 20% of the general tax increases for fuel inputs and the new electricity tax. In addition, companies whose additional tax payments exceed the reduction in the social security payment (funded by the tax revenues) by a ratio of more than 1.2 will be reimbursed.

4.1.2. Energy transformation sector

The above mentioned voluntary agreements by German industry also include all major utilities. So far, significant emission reductions on the supply side have been achieved primarily through efficiency improvements and fuel switches.

The medium-term objective of the German government is to double the share of renewable energy sources in power production by the year 2010. The seminal instrument to achieve this goal is the Act on the Sale of Electricity to the Grid, which was enforced in 1991 and prescribed feed-in tariffs for electricity from renewable energy sources not owned by utilities. These feed-in tariffs were linked to the average sales price for electricity and had to be paid for by the preceding grid operator. Because the liberalisation of the electricity market in 1998 resulted in lower electricity prices for end users (approximately −30% for industrial customers and −10% for private customers between 1998 and 2000), feed-in tariffs for electricity from renewable energy sources would have fallen without further intervention. To avoid stranded investments and to increase planning security for new investors, German lawmakers passed the new Renewable Energy Act in February 2000. Under the new law, feed-in tariffs are no longer linked to electricity sales prices, but fixed for 20 years and the costs are evenly distributed among grid operators. Furthermore, utilities are now allowed to participate as producers.

The feed-in tariffs have for a long time been complemented by public funding programs, in which both the federal government and the "Laender" (federal states) played an important role (see Section 4.2). The technology that has benefited the most from the feed-in tariffs is wind energy: with more than 6100 MW of installed capacity, Germany now hosts the largest wind energy capacity in the world.

In the new federal states, an extensive programme of modernisation of District Heating and Combined Heat and Power' (CHP) was implemented in the early 1990s in collaboration with the federal government.

Low electricity prices in the wake of liberalisation had already led to the closure of several CHP plants and are now seriously threatening the existence of this low-cost technology for climate change mitigation. To provide temporary support for cogeneration in the public electricity supply sector, and to avoid stranded investments, lawmakers passed a CHP protection law ("KWK-Vorschaltgesetz") in spring 2000. Similar

to the Renewable Energy Act, municipal power producers can now receive a minimum compensation from the grid operator for electricity generated from cogeneration.

4.1.3. Transport sector

Tax increases on emitting activities occurred especially in the transport sector. The two increases of mineral oil taxes in 1991 (12.5 Euro cents) and 1994 (8 Euro cents), almost doubled the mineral oil taxes in force prior to 1991. The revenues of the 1994 increase were used to support the railway system (BMU, 1996, p. 33). The Ecological Tax Reform, which is scheduled to increase fuel taxes by a total of about 15 Euro cents in five steps from 1999 to 2003, was implemented on environmental grounds, but also to finance the reduction in social security payments.

Two important measures in the German transport sector were initiated at EU level. First, under the terms of the agreement between the European Commission and the European, Japanese and Korean car producers, specific CO_2 emissions of cars in 2008–2009 will be approximately 25% lower than in 1995. As a conservative estimate, considering only the effects of those technical measures identified in the European Commission (2001) — which are slightly lower than the agreement's goals — an interpolation for the year 2000 results in a reduction of 2.4 Mt of CO_2 relative to the reference scenario. Second, the Regionalisation Act for public transport assigns the responsibility for regional public transport to the federal states. This act is expected to boost the efficiency and customer orientation of transport services, which are supposed to favour the modal shift from private cars to public transport systems.

4.1.4. Residential sector

For residential thermal energy consumption, the most important policies are the ordinances on heating installations and on thermal insulation. Both regulations prescribe standards, in particular, for new buildings, but also for refurbishment. Furthermore, especially in the new Laender, funding programmes for the renovation of older houses have been implemented. In recent years, labelling as well as standardisation measures for electrical equipment such as refrigerators, washing machines, etc. have been introduced. Finally, the Ecological Tax Reform has increased prices for heating fuels (oil and gas) as well as for electricity.

4.1.5. Reduction of CO_2 emissions

Fig. 4 illustrates the timing and estimated effects of the most relevant policies and measures on CO_2 emissions. The figure also shows that several measures that had an important impact up to 2000 are now being followed up or substituted by new and often more stringent measures. More specifically, standards have been tightened, such as the new Energy Saving Ordinance for buildings; procedures have been modified, such as subsidies for the renovation of residential buildings, or for electricity from renewable energy sources; or the voluntary commitments made by certain sectors of German industry have become more ambitious (see BMU, 2000).

In Ziesing and Diekmann (1997), federal policies implemented prior to 1997 were estimated to result in a reduction of 66.4 Mt CO_2 in the year 2000 relative to the reference scenario. This figure was adjusted to account for more recent information.

Firstly, the voluntary commitment of parts of the German industry sector turned out to be largely in line with autonomous technical progress and unification effects, which were already included in the reference scenario. Assuming that the commitment induces only an additional 40% of the ex ante estimates, CO_2 emissions are then reduced by just 7.2 Mt instead of 18.2 Mt. This figure includes direct emissions from

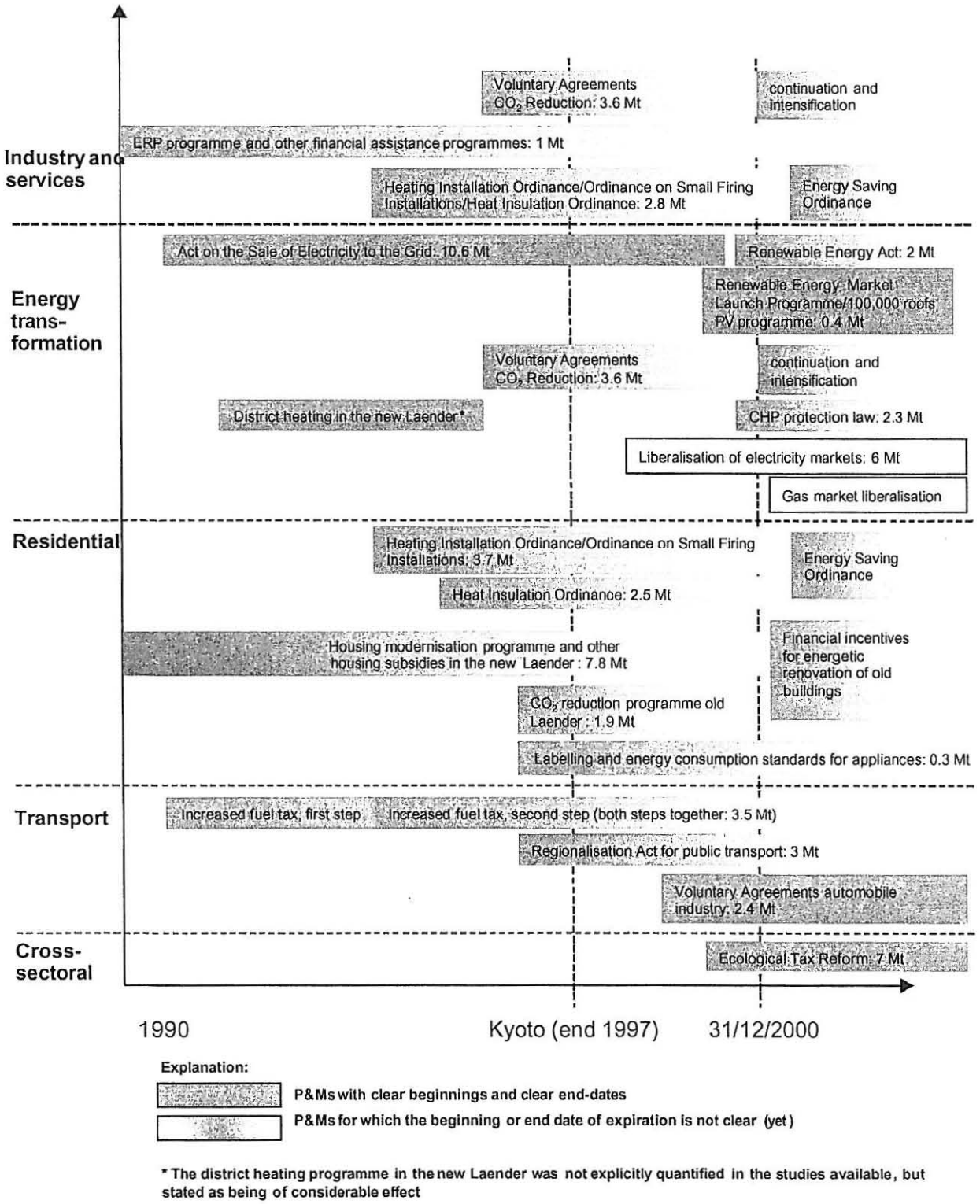


Fig. 4. Policies and measures for the reduction of CO_2 emissions in Germany between 1990 and 2005 (Source: Ziesing and Diekmann, 1997; DIW, 2001; own estimates).

energy transformation, industry and services, as well as indirect emissions from industrial/commercial electricity consumption. In Fig. 4, emission reductions are split equally between energy transformation and industry/services, which implicitly assumes that the share of additional reductions is higher in energy transformation.

Secondly, the building regulations do not appear to be fully implemented yet. Assuming an actual implementation rate of 80%, the reduction effect in the industrial/services and residential sectors combined is 1.8 Mt lower than previously estimated.

Thirdly, the Act on the Sale of Electricity to the Grid for electricity from renewable energy sources has induced a far higher wind energy capacity (4600 MW by the end of 1999, 6100 MW by the end of 2000) than predicted (2000 MW until 2005). Although a large part of the funding for wind energy stems from the budgets of the Laender, to simplify matters, total emission reductions of 10.6 Mt of CO_2 (compared to 4.8 Mt) are attributed to the federal regulation.

Finally, the liberalisation of the electricity market was originally expected to result in a reduction of CO_2 emissions of 3 Mt, mainly through additional combined-cycle gas-turbine power plants. But excess capacities, increased competition, and higher productivity, effectively lowered electricity prices for final users, making energy conservation efforts, CHP and renewable energy sources less attractive. Thus, liberalisation of the electricity market in Germany is estimated to have increased CO_2 emissions by 6 Mt.

Under these assumptions, the total effect of policies implemented prior to 1997, including those at the regional and local levels (see Section 4.2), but excluding liberalisation of the electricity market, is estimated to be a reduction of about 56 Mt CO_2, relative to the reference scenario.

Estimates for policies introduced since 1997 are based on a recent analysis of the effects of the Ecological Tax Reform (DIW, 2001) (a reduction of 7 Mt), and on Ziesing and Diekmann (1999) for other more recent policies by interpolating the effects in 2010 for the year 2000 (a reduction of 7.4 Mt CO_2). Thus, all policies implemented in the 1990s at the federal, regional and local levels are estimated to have resulted

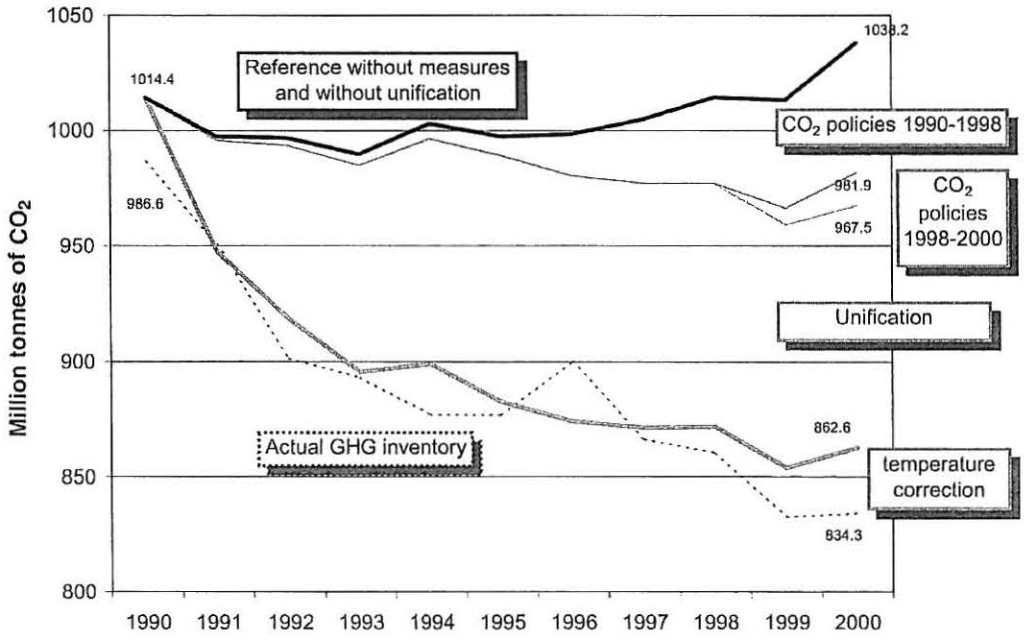


Fig. 5. The role of policies and reunification in the reduction of energy-related CO_2 emissions in Germany.

in a reduction of energy-related CO_2 emissions of 70.7 Mt CO_2. These findings are illustrated in Fig. 5, which also shows the effects of German reunification as estimated in Section 3.

4.2. Climate policy measures at the regional and local levels

Reductions of CO_2 emissions rank highly on the agenda of most German Laender and municipalities. Numerous initiatives aiming at climate protection have been launched in the past decade ranging from local task forces, citizen memberships in international climate organisations up to local energy agencies. Ziesing and Diekmann (1997) estimate these activities to result in a reduction of around 7 Mt CO_2 for the year 2000, mainly in the commercial and services sector (3.3 Mt) and the private household sector (2.4 Mt). Beyond that, only a qualitative assessment of the influence of decentralised activities is possible, since evaluations of the measures in terms of their impact on CO_2 emissions have not usually been carried out.

4.2.1. Public funding for renewable energy sources

In the 1990s, financial support for renewable energy sources, in particular, for wind power and thermal solar energy, came mainly from the Laender. The annual financial support for the installation of all renewable energy sources (wind, hydro, solar collectors, photovoltaic, biogas, biomass, heat pumps and geothermal) in the second-half of the 1990s was around 165 million DM, more than 90% of which was provided by the Laender. However, at the end of the 1990s, the relative contribution of Laender versus federal funding for renewable energy sources started to shift significantly towards the latter. Of particular importance is the federal "*Markteinführungsprogramm Erneuerbare Energien*" (market penetration programme for renewable energy sources), which started in 1999 and focuses on the use of solar thermal and biomass energy. The funds, totalling 200 million DM, originate from the revenues of the Ecological Tax Reform. In addition, in February 1999, the "100,000 *roofs*" *photovoltaics programme* of the Reconstruction Loan Corporation (KFW) was introduced, which aims to support the installation of an additional 300 MW — on top of the existing 50 MW — by providing zero-interest loans for new systems.

4.2.2. Membership in local alliances for climate protection

There is a symbiotic relationship between the membership of a community in an alliance for climate protection and local climate activities: membership is a consequence of commitment and, at the same time, a catalyst for further measures. As early as 1998, one-third of all German communities with more than 10,000 citizens (equivalent to 72% of the German population) participated in a local alliance for climate protection (Boede and Gruber, 2000). Most communities which have joined a climate organisation are members of the Climate-Alliance/Alianza del Clima. Member communities have committed to cut their CO_2 emissions by at least 50% by the year 2010, but various factors such as the lack of common standards, different starting positions, and co-existence of other policies make it difficult to estimate the contribution resulting from being a member of a climate alliance.

4.2.3. Local Agenda 21 (LA21)

The Agenda 21 of Rio 1992, which was reinforced by the "Charter of Alborg", requires communities to initiate sustainable development at a local level. Besides many basic activities such as developing concepts, analysing weaknesses, identifying necessary actions, and setting objectives, communities also

launch practical projects once a "LA21" resolution has been formally passed. For all communities engaged in LA21 processes, climate protection/energy savings measures play an important role. Activities include centres for energy advice, energy round tables, task forces, energy codes for buildings, energy audits for companies, activities in households, information campaigns, or 50/50-projects at schools. After a slow start, the number of communities to have passed an LA21 resolution has steadily increased from about 40 communities in mid 1997 to nearly 2000 in early 2001.

5. Causes for the reduction of non-CO_2 greenhouse gases

In Germany, there were substantial decreases in emissions of CH_4 (−36%) and N_2O (−8%) between 1990 and 1998. Unlike CO_2 emissions, the effects due to German reunification have been quite small and account for only about 10% of the reductions, stemming primarily from the reduction in livestock in the new federal states. Two major political initiatives were responsible for the bulk of emission reductions of non-CO_2 GHG in the 1990s. First, the Technical Instructions on Waste from Human Settlements (TA Siedlungsabfall) from 1993 limited the amount of organic waste which could be dumped at landfill sites and prescribed measures to recover landfill gas. Based on BMU (1997) and UBA (2000), these directives are estimated to account for a reduction of about 26 Mt CO_2-eq. of methane emissions relative to a reference case. Second, the voluntary agreements between the government and the two German adipic acid producers to capture and transform N_2O emissions is estimated to result in a similar reduction of 26 Mt CO_2-eq. compared to a reference scenario (BMU, 1997 and UBA, 2000).

Methane reductions in the waste sector have also been the result of the Closed Substance Cycle and Waste Management Act (Kreislaufwirtschafts und Abfallgesetz), which requires waste avoidance and recycling, and by the Technical Instructions on Waste, Part I (TA Abfall, Teil 1), which sets rules for those wastes that require special supervision.

Furthermore, there have been considerable methane emission reductions in hard coal mining, where both a reduction in production and an intensification of pit gas recovery have lowered emissions by about 7 and 3 Mt CO_2-eq., respectively.

In agriculture, the greater share of emission reductions (CH_4 and N_2O together roughly 10 Mt CO_2-eq.) was due to the reduction of livestock, especially in the new Laender. This effect is mainly regarded to be a unification effect. Further reductions were brought about by compensation payments for abandoning agricultural area, by the Fertiliser Ordinance (Düngemittelverordnung) and by a general reduction in fertiliser use.

For halogenated gases ("F-gases", i.e. HFCs, PFCs and SF_6), there have been two voluntary commitments by industry: the "Declaration of the German primary aluminium industry" for PFCs and the "Declaration on the use of SF_6 in electrical switching equipment and systems in Germany", both of which are estimated to have had an effect of about 0.5 Mt compared to the reference scenario. With regard to HFCs in particular, major steps still have to be undertaken to avoid a considerable rise in emissions.

To sum up, the aggregated effect of climate and other environmental policies on non-CO_2 gases is estimated to be a reduction of 56.7 Mt CO_2-eq. relative to a "without measures" scenario. Other policies have resulted in a reduction of 5.9 Mt CO_2-eq., and reunification is estimated to have resulted in a reduction of 8.0 Mt CO_2-eq.

Table 2 lists the figures in a more detailed form. It shows the projected year 2000 emissions (as estimated in UBA, 2000) — first for the trend scenario, i.e. without policy measures or unification effects, then

Table 2
Reductions of non-CO_2 gases[a]

											non-env. policy with...		
Ml			1990	1995	2000 without measures and without unification	2000 with measures and with unification	Measures	2000 policy impact vs. trend	Climate Policy	Other env. Policy	positive climate impact	negative climate impact	unification effect
CH4	GWP=21		117.0	81.7	110.6	70.1		-33.8					-6.7
	Energy related		37.3	27.4	30.9	23.4		-7.5					
		Fuel combustion	4.5	2.3	2.7	1.8							
		>of which transport					> catalytic converters in cars	-0.9		X			
		Fugitive Fuel Emissions	32.8	25.1	28.2	21.6		-6.6					
		>of which from solid fuels	25.8	17.6	22.1	15.5	> reduction of coal production	-3.7			X		
							> voluntary agreements to increase capture of pit gas	-2.9	X				
		>of which from oil and natural gas	7.0	7.5	6.1	6.1	> increased gas use in the new Laender	net effect roughly zero				X	
							> reduction of distribution losses		X		X		
	Agriculture		38.9	32.7	39.9	39.0		-0.2					-6.7
		>of which enteric fermentation	26.2	21.4	26.2	22.0	> reduced livestock mainly in the new Laender						-4.2
							> better digestion due to food improvement program	small	X				
		>of which manure mangement	13.2	10.8	13.2	10.5	> reduced livestock mainly in the new Laender						-2.5
							> reduction of emissions from anaerobic processes, and increased biogas use	-0.2		X			
	Waste sector		39.8	21.6	39.8	13.7		-26.1					0.0
		>of which disposal on land	38.7	21.6	39.8	13.7	> Technical Instructions on Waste from Human Settlements	main impact		X			
							> Closed Substance Cycle and Waste Management Act	additional		X			
Total enviromental policy effect									-30.1				
N_2O	GWP=310		69.6	67.3	74.0	44.9		-27.8					-1.3
	Industrial processes	>chemical industry (mainly adipic acid production)	25.7	25.4	32.8	6.5	> voluntary commitments by adipic acid producers to capture N_2O	-26.3	X				
	Agriculture		29.8	26.4	29.8	25.0		-3.0					-0.8
		emissions from soils and manure management					> compensation payments for farmers who reduce their cultivated area	-2.2			X		
							> Fertiliser Ordinance	-0.2		X			
							> reduced livestock; autonomous reduction of fertilising	-0.6					-0.8
	Energy related		11.4	12.3	11.4	12.4		1.5					-0.5
		>of which transport	3.2	5.4	3.6	5.6	> catalytic converters in cars	2.0		X			
		>of which other sectors	8.2	6.9	7.8	6.8	> reduction of energy consumption in the old Laender	-0.5	X				
							> reduction of energy consumption in the new Laender						-0.5
Total enviromental policy effect									-25.6				
F-Gases	(base value for 1995)		8.9	11.1	11.0	10.0		-1.0					0.0
	industrial processes and other sources		8.9	11.1	11.0	10.0		ca. - 1,0					
	PFCs						>voluntary commitment by aluminium industry	ca. -0,5	X				
	SF6						>voluntary commitment by switching equipment industry	ca. -0,5	X				
Total enviromental policy effect									-1.0				
Total Non-CO2 effects			195.5	160.1	195.6	125.0			-56.7		-5.9		-8.0

[a]Source: BMU (1997), UBA (2000), and own calculations.

including both these effects. It then identifies specific policies and measures undertaken, and states their estimated individual and aggregated effects. The last column shows the estimated effects of unification.

6. Summary and conclusions

This paper examines the underlying factors for greenhouse gas emission trends in Germany in the 1990s. In particular, an analysis was made to what extent the observed reductions of greenhouse gases of more than 18% between 1990 and 2000 have to be attributed to reunification, and to what extent these emissions reductions are the result of specific policy measures. A summary of the main findings is shown in Table 3.

On the one hand, reunification had an important impact on the observed reduction of greenhouse gases, especially in the first-half of the 1990s. More specifically, wall-fall profits are estimated to have contributed almost 50% of the reduction of all greenhouse gases. This share increases to 60% if only energy-related CO_2 emissions are considered. Compared to the 1990 level of all greenhouse gases, the 2000 emissions are 225 Mt CO_2-eq. lower, of which 105 Mt CO_2-eq. are estimated to be wall-fall profits.

On the other hand, a diverse set of environmental policies, which were introduced over the previous decade, also had a significant impact on the reduction of greenhouse gases. Policies affecting energy-related CO_2 emissions accounted for about 40% of the reduction of these emissions. Likewise, environmental policies directed towards non-CO_2 gases (in particular, waste management and the reduction of N_2O from adipic acid production) had an equally important impact as policies addressing CO_2 emissions. The contribution of all the environmental policies together was slightly higher than the impact of unification. Not only policies at the federal level, but also local and regional activities have contributed significantly to the reduction of greenhouse gas emissions (Fig. 6). In 2000, the contribution of such activities was estimated to be around 7 Mt CO_2-eq., though the real impact is likely to be larger since these activities are generally not systematically monitored.

Table 3
Comparison of environmental policy and unification effects on greenhouse gas emissions between 1990 and 2000 in Germany

	Energy-related CO_2		All Kyoto gases	
	Policy effect	Unification effect	Policy effect	Unification effect
Reduction compared to "BAU" for 2000 (Mt) (percentage of 1990 emissions)[a]	175.6 (17.3)	175.6 (17.3)	240.3 (19.4)	240.3 (19.4)
Single effects, compared to "BAU" (Mt) (percentage of total reduction)[a]	70.7 (40.3)	104.9 (59.7)	127.4 (53.0)	112.9 (47.0)
Actual reduction compared to 1990 emissions (Mt) (percentage of 1990 emissions)	151.6 (14.9)	151.6 (14.9)	224.8 (18.2)	224.8 (18.2)
Single effects[b] (Mt) (percentage of 1990 emissions)	61.0 (6.0)	90.6 (8.9)	119.2 (9.6)	105.6 (8.5)

[a] Temperature-corrected emissions.

[b] The actual emission reduction was distributed in proportion to the shares of the single effects vs. business-as-usual development.

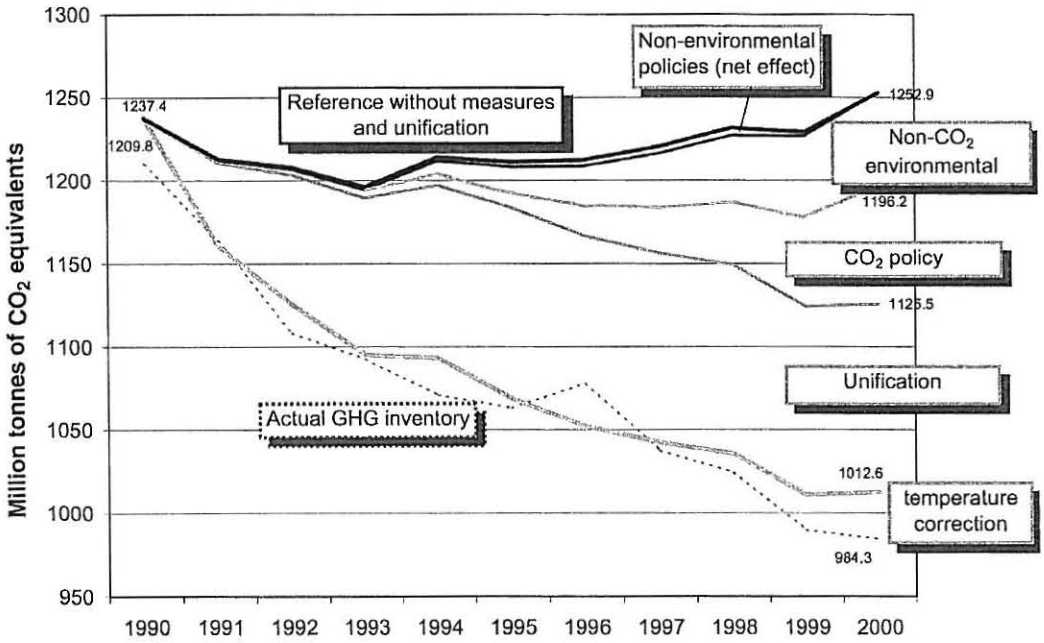


Fig. 6. The role of policies and special developments (unification) in the reduction of greenhouse gas emissions in Germany.

The analyses further imply that, excluding unification effects, the reduction of greenhouse gases observed would have been about 9% in 2000 compared to 1990 levels. Extrapolating this figure, Germany would achieve a reduction of 18% by the year 2010, even without benefiting from wall-fall profits. Wall-fall profits, however, were the main reason behind Germany's stringent emission reduction target of −21% under the terms of the EU Burden Sharing Agreement. Thus, it may be argued that, once the unification effects are excluded, Germany should have a similar reduction target as the European Union, i.e. about −8%. Under these premises, the progress occurring in Germany halfway through the first commitment period under the Kyoto Protocol, is quite significant. At this point in time, Germany is clearly on a reduction path to meet the Kyoto target. However, the likelihood of reaching the more ambitious national target of −25% CO_2 emissions by 2005 appears rather slim. To meet this target, further and immediate policy efforts appear necessary. Areas where such policies are likely to be effective include the transport sector, combined heat and power generation, and extending the Ecological Tax Reform and modifying the tax schemes to provide stronger incentives to save energy, in particular, in the manufacturing sector.

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