Dynamic Cost Estimates of Carbon Dioxide Emissions Reduction in Eastern Europe and The Former Soviet Union:

An Evaluation

February 1992

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DYNAMIC COST ESTIMATES OF CARBON DIOXIDE EMISSIONS REDUCTION IN EASTERN EUROPE AND THE FORMER SOVIET UNION:

AN EVALUATION

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FOREWORD

This paper provides a dynamic cost analysis of the potential to reduce energy and carbon dioxide emissions intensities in the post-planned economies of the former Soviet Union, Poland, and Czechoslovakia. Drawing on previous research by experts from each of those countries, Richard Baron develops for the first time marginal cost estimates of emissions reduction to the year 2005. Previous country studies had reported only the average costs of carbon dioxide emissions reduction.

This paper is one of a series of climate policy studies sponsored by the Climate Change Division of the U.S. Environmental Protection Agency (EPA), directed by Dennis Tirpak. The work was performed at the Advanced International Studies Unit (AISU), part of the Global Studies Program at Battelle, Pacific Northwest Laboratory in Washington, D.C.

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In 1992, Baron is a visiting fellow at the Washington D.C. office of the Pacific Northwest Laboratory where he works on modeling long-term global greenhouse gas emissions. I am grateful to the International Research Center on Environment and Development (CIRED) in Paris for making his visit and this work possible.

William U. Chandler
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by Richard Baron

ABSTRACT

Planned and post-planned economies, including those of Eastern Europe and the former Soviet Union, are currently more energy and carbon intensive than their western counterparts. However, economic restructuring and cost-effective investment in energy conservation should bring about major carbon dioxide emissions reductions in these countries. Cost-effective energy-saving technologies alone, if substituted for current capital-intensive supply technologies, represent an emissions reduction potential of one-sixth to one-fifth of today's level by the year 2005. For the former Soviet Union, Poland, and Czechoslovakia, this implies an annual levelized investment in energy efficiency equivalent to 0.2 percent of each country's gross domestic product (GDP) between now and the year 2005. This figure does not reflect the potential macroeconomic impact of investment re-allocation.

Please note that in some instances we continue to refer to the newly independent nations of the former Soviet Union as the Soviet Union. The calculations in this study were based on the former Soviet Union, thus it is sometimes necessary to continue to use this terminology in order to include the entire area.

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DYNAMIC COST ESTIMATES OF CARBON DIOXIDE EMISSIONS REDUCTION IN EASTERN EUROPE AND THE FORMER SOVIET UNION:

AN EVALUATION

We studied future rates of carbon emissions and the emissions reduction potential for three key countries among formerly planned economies: 1) the former Soviet Union, the largest energy consumer and carbon dioxide-emitting country among these economies; 2) Poland, an important coal producer and consumer; and 3) Czechoslovakia, a heavily industrialized country in Eastern Europe. This study is based on the work of local energy and energy conservation experts.[1] All of these experts consider energy conservation as the primary means to curtail carbon dioxide emissions while avoiding increasing costs of energy supply in the future.

THE CURRENT ENERGY SYSTEM: THE SIGNIFICANCE OF ENERGY EFFICIENCY

The existing patterns of energy supply and demand in Eastern Europe and the former Soviet Union explain the high energy and carbon dioxide intensities of gross domestic product (GDP) in these countries (Figure 1 and Table 1). On the supply side, the countries of the former Council of Mutual Economic Assistance (CMEA) have large reserves of fossil fuels. The territory of the former Soviet Union holds 41 percent of the world's natural gas, seven percent of the oil, and 25 percent of the solid fuel reserves. The former Soviet Union exports natural gas and oil to Eastern European countries; for example, Soviet fuels supply half of Hungary's primary energy needs, including electricity.

Current shares of primary energy resources show a relatively balanced distribution of fossil fuels in the former Soviet Union, with natural gas being the largest energy source (Table 2). The former Soviet Union, however, is facing increasing costs of fossil fuel production due to the depletion of cheaper resources in its western region and the need for costly exploitation of Siberian reserves. Capital outlays for prospecting, producing, and transporting oil are expected to grow by more than 100 percent by the year 2010. As for primary electricity, important potential for hydropower generation remains, whereas the potential for expanding the use of nuclear energy has suffered from the Chernobyl accident in 1986. Public reactions to the accident have created serious obstacles for developing nuclear energy in neighboring Eastern Europe.

Poland is the world's fourth largest producer and a net exporter of coal, providing a major source of hard currency. But coal mining is absorbing an increasing share of Poland's investment in industry (10 percent in 1970 and 19 percent in 1980), reflecting deteriorating mining conditions, and a reported 20 percent decrease in labor productivity since 1978. In 1988, coal accounted for 74 percent of all energy use in Poland.

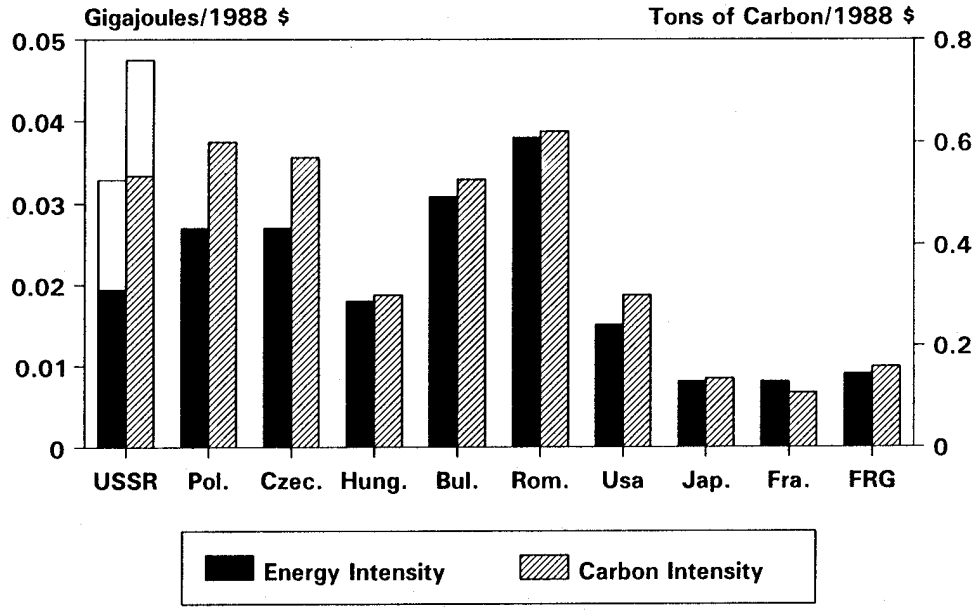
Table 1. Population, GDP, Energy, and Carbon Dioxide Emissions in Eastern Europe and the Former Soviet Union

	Population (Millions)	GDP*/ Capita (1988 $)	Energy Consumption/ Capita (GJ)**	Total CO_2 Emissions (MtC)
Bulgaria (1989)	9	3920	189	26
Czechoslovakia (1989)	15.7	7100	197	65
Hungary (1989)	10.6	6800	132	21
Poland (1989)	38.4	5260	164	120
Romania (1989)	23.3	3650	124	52
Soviet Union (1989)	288.0	6470-10960***	212	1020

* Calculated from Paul Marer's 1980 GNP figures[2] (adjusted purchasing power parity) using CIA's estimated 1980 to 1989 growth rates and implicit price deflator.[3]

** GJ = Gigajoules

*** In the case of the former Soviet Union, the lower figure was calculated according to Marer's methodology; the higher estimate was provided by Bashmakov et al. (1990) and computed by Soviet methodology, with a different purchasing power parity.[4]



Note: Soviet intensities are given for two values of GDP (see Table 1).

Figure 1. Energy and CO_2 Intensities of GDP (Source: Marer 1985; Makarov and Bashmakov 1990)

Czechoslovakia has followed a comparable path of energy use, with coal accounting for 61 percent of total energy demand. Both Poland and Czechoslovakia have been steadily increasing their reliance on low-quality domestic fuels, lignite in Poland and brown coal in Czechoslovakia, creating strong environmental repercussions, including high rates of sulfur dioxide deposition. Another feature of energy supply in Poland and Czechoslovakia is the small share of primary electricity (hydro and nuclear) in total energy production. These countries rely mostly on coal for electricity and heat generation, contributing to higher carbon dioxide emissions. Ninety-five and 60 percent of all power and heat are generated from solid fossil fuels in Poland and Czechoslovakia, respectively.

In addition to supply system factors, the break-down of energy demand also explains the high energy and carbon intensities of GDP in these countries. Industry (from mining to manufacturing) accounted for 40 percent of the total GDP of Eastern Europe in 1985, whereas in the countries of the Organization for Economic Cooperation and Development (OECD), industry was 28 percent of GDP. Today, industrial energy demand is 59 percent of total energy demand in Eastern Europe and 37 percent in OECD countries. Industry accounts for 42 percent of the total carbon dioxide released from energy use in Poland, more than 50 percent in the former Soviet Union, and 68 percent in Czechoslovakia.

Table 2. Primary Energy Consumption in Eastern Europe and the Former Soviet Union

	Total	Oil	Natural Gas	Coal	Electricity
	Exajoules (EJ)		Percent		
Bulgaria (1989)	1.7	34	14	39	13
Czechoslovakia (1990)	3.1	22	11	61	6
Hungary (1989)	1.4	31	33	24	12
Poland (1989)	6.3	12	8	78	2
Romania (1989)	2.9	21	48	27	4
Soviet Union (1990)	61.1	31	38	24	7
Compared with:					
West Germany (1989)	12.8	39	18	28	15
France (1989)	9.0	45	12	9	34
United States (1989)	85.6	42	24	23	11

Source: EIA 1991;[5] Makarov and Bashmakov 1990.

The residential and commercial sectors in these countries are also less energy-efficient than those in the West. In Eastern Europe, price subsidization of heating and hot water, and the absence of individual meters and controls on consumption make these sectors 25 to 50 percent more energy-intensive per square meter of living area than the residential and commercial sectors in the United States. This is the case even though Eastern European countries and the former Soviet Union rely largely on district heating, which in theory is more efficient than individual heating.

Subsidization of energy prices has contributed to the low energy efficiency of Eastern European countries. Coal prices were subsidized by 49 percent in Poland in 1989, gas prices by 83 percent, and the price of electricity by 27 percent. Since then, the process of de-subsidization has begun: on January, 1, 1992, the price of one kilowatt-hour was raised again by 20 percent, up to 570 zlotys or five cents, which is closer to western electricity prices. Heating and natural gas prices were increased by 70 percent and 100 percent, respectively.

The government recently eased similar price controls in Czechoslovakia on heating in order to restore equilibrium prices. This led to a fourfold price increase for heating in 1991. Households are still not equipped with meters and thermostats, however, which would enable them to monitor and control their consumption. Equilibrium pricing of energy therefore may not have the expected impact on energy consumption. Major investments in energy conservation are also required.

Total energy consumption in the transportation sectors of the countries studied has been relatively low due to the lower number of cars and the widespread use of public transportation. Today, the car-per-person ratio is 0.2 in Czechoslovakia and 0.05 in the former Soviet Union, whereas it is more than 0.5 in the United States. The transportation sector accounted for four percent of final energy use in Czechoslovakia in 1985, 13 percent in the former Soviet Union, and 13.5 percent in Poland, compared with 26 percent in France, and 22 percent in West Germany. These relatively low figures hide some of the inefficiencies in the transportation sector, such as the low fuel economy of Eastern European vehicles (about 8.7 liters/100 km, or 27 miles per gallon, which sounds efficient by western standards but is actually inefficient given the small size of the vehicles).

Reliance on fossil fuels and the large share of energy consumption in heavy industry help explain the high level of carbon dioxide emissions in these countries. It is interesting to note that in 1988, Poland (population 38 million) released 22 percent more carbon dioxide than Italy (population 57 million). Energy conservation measures can be emphasized in the future as a means for limiting these emissions.

THE FUTURE OF CARBON DIOXIDE EMISSIONS

In this section we analyze future carbon dioxide emissions in the former Soviet Union, Poland, and Czechoslovakia under two alternative scenarios. The Reference Scenarios incorporate structural change without emphasis on energy-efficiency improvements. The Low Emissions Scenario includes the implementation of cost-effective energy-efficiency measures.

We limit ourselves to a 15-year period in order to estimate energy conservation costs more accurately by using data on available technologies rather than attempting to determine the costs of new technologies that may be developed in the future.

Reference Scenarios for 2005

We could use two different scenarios for the high-emissions case as references of carbon dioxide emissions projections. These scenarios were outlined by regional experts in recent studies developed for the Battelle Advanced International Studies Unit. The first is a base case scenario[6] which extends past energy trends without factoring in ongoing political and economic changes in Eastern Europe and the former Soviet Union.[7]

The second scenario incorporates structural and political changes. It is preferable to use the latter scenario as a reference to analyze energy-saving and carbon dioxide reduction measures, because it captures improvements in energy use which are not related to energy-efficiency measures. For example, major changes in the production structure, away from heavy industry towards a more consumer-oriented market, would result in a 34 percent decrease in Poland's energy demand by the year 2005 compared to the base case scenario. This change would also allow a reduction of 45 million tons of carbon dioxide emissions.[8] Structural change would likely entail either costs or benefits for the whole economy, that is, an increase or decrease of GDP when compared to current trends, resulting from shutting down major heavy industries and accelerated development of manufacturing sectors; but the macroeconomic costs or benefits of these changes cannot be used as a

proxy for the cost of carbon dioxide emissions reduction, since these would be a "free" by-product of economic restructuring.

The reference scenarios[9] used here assume that political changes and economic restructuring in Eastern Europe and the former Soviet Union will come into effect between 1992 and 2005. From an economic point of view, this does not mean optimum economic development, since no appropriate modeling tools were used for that purpose in this study, but rather a change in the economic structure that results in improved living standards. The projections are the result of two offsetting trends accounted for in the scenarios: on one hand, a decrease in energy consumption in the heavy industry and defense sectors and the transfer of capital to the manufacturing of consumer goods; and on the other hand, an increase in energy demand from the household and service sectors, such as buildings and transportation, brought about by higher standards of living.

Figure 2 shows the impact of structural changes on the carbon content of GDP for the former Soviet Union, Poland, and Czechoslovakia, a direct outcome of the decrease in overall energy intensity of GDP. Under the reference scenario, these countries would experience decreases in their energy-GDP ratio of 25 percent, 27 percent, and 40 percent by the year 2005, respectively.

Czechoslovakia, however, is the only country in which restructuring the economy would result in a net reduction of energy demand, from the 1990 level of 3.1 EJ to 2.8 EJ in 2005 (Table 4). In the 1980s, Czechoslovakia was one of the most industrialized among the former CMEA countries. During that period, the country produced 27 percent of the crude steel, 25 percent of the tractors, and 60 percent of the diesel locomotives in all of Eastern Europe, although its population represented only 13 percent of the region.[10] Structural change of Czechoslovakia's heavily industrialized economy would lead to a larger reduction in energy demand, compared to other Eastern European countries.

Table 3. Major Assumptions for 2005 Energy Projections, Reference Case: Average Annual Growth Rate, 1990-2005

	GDP	Pop.	Energy Prices: Oil	Gas	Coal	Elec.
	Percent					
Soviet Union	3.25	0.7	5.4	0.5	1.1	NA
Poland	2.5	0.36	2.5	1.0	2.5	1.0
Czechoslovakia	2.5	0.3	2.5	1.0	2.5	1.0

Source: Makarov and Bashmakov 1990; Sitnicki et al. 1990; Kostalova et al. 1991.

Table 4. Primary Energy Demand and Carbon Dioxide Emissions, 1990-2005

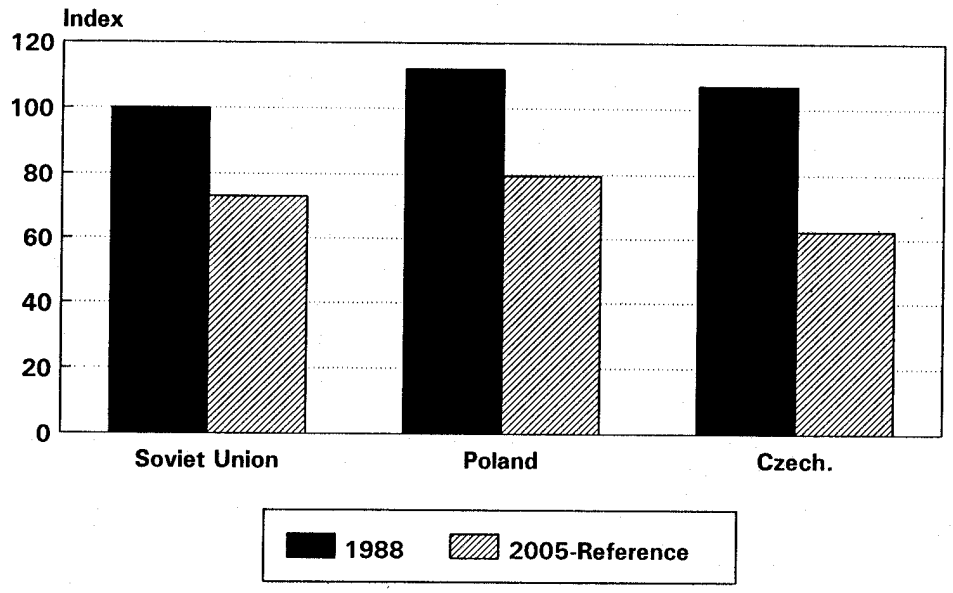
	1990	Reference	Low-Emissions
	Energy Demand (EJ)		
Soviet Union	61	79	66
Poland	5.4	6.0	5.1
Czechoslovakia	3.1	2.84	2.3
	Carbon Dioxide Emissions (MtC)		
Soviet Union	990	1256 (+23%)	1033 (+1.3%)
Poland	120	129 (+7.5%)	109.7 (-10%)
Czechoslovakia	61	55 (-10%)	42.4 (-30%)

Source: Makarov and Bashmakov 1990; Sitnicki et al. 1990; Kostalova et al. 1991; Author.

These reference scenarios show that overall energy efficiency in Eastern Europe and the former Soviet Union will increase with the transition to a market economy, because satisfying consumer needs will become a priority. However, Table 4 shows carbon dioxide emissions in the former Soviet Union and Poland increasing between 1990 and 2005. Implementing specific energy-efficiency measures in Poland, Czechoslovakia, and the former Soviet Union can curtail anticipated carbon dioxide emissions.

Low-Emissions Scenarios: the Impact of Energy Conservation Measures

Studies of the three countries provided us with the background to determine an energy-saving potential of



Note: Index=100 for the Soviet Union in 1990.

Figure 2. Carbon Content of GDP, 1988-2005 (Source: Makarov and Bashmakov 1990; Sitnicki et al. 1990; Kostalova et al. 1991)

cost-effective conservation measures for the year 2005. Cost-effective energy-conservation measures are defined as those which are less expensive than current energy supply technologies (see next section for more details on methodology). The low-emissions scenarios assume that all of these measures are carried out along with the changes in the structure of the economy described in the reference scenario.

Poland, Czechoslovakia, and the former Soviet Union could achieve major reductions in carbon dioxide emissions under this scenario, without additional capital outlays, if the original investment devoted to energy supply is used to save energy. The case of Czechoslovakia is striking: it could achieve a 30 percent reduction of emissions from the 1990 level by the year 2005 without additional costs (cost-effective scenario, Figure 3). This is well beyond the reduction level recommended at the Toronto conference[11] of 20 percent by the year 2005, an objective most industrialized countries believe will be difficult to meet.

The former Soviet Union could almost stabilize its emissions at the current level by exploiting its 13 EJ cost-effective energy-efficiency potential (cost-effective scenario, Figure 4). Yuri Kononov,[12] who is currently leading another research effort on the same topic, finds that implementing all cost-effective energy conservation measures could reduce emissions to a similar level (Table 5).

As for Poland, structural changes in the economy and implementation of energy-efficiency measures make it possible to achieve a 10 percent decrease in carbon dioxide emissions by 2005 (see Table 4 and Figure 5 for carbon dioxide and energy projections).

We reiterate that all of these reductions are cost-effective and assume that current pricing systems in these countries will remain intact. In each case, however, price increases resulting from exhaustion of the cheapest energy reserves were taken into account, especially for

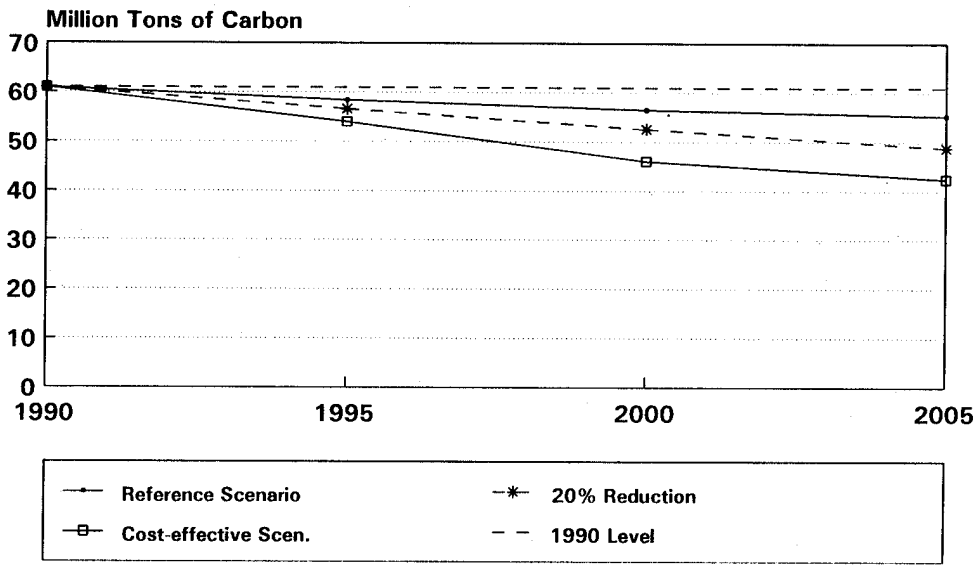


Figure 3. Carbon Dioxide Emissions and Energy Efficiency in Czechoslovakia (Source: Kostalova et al. 1990; Author)

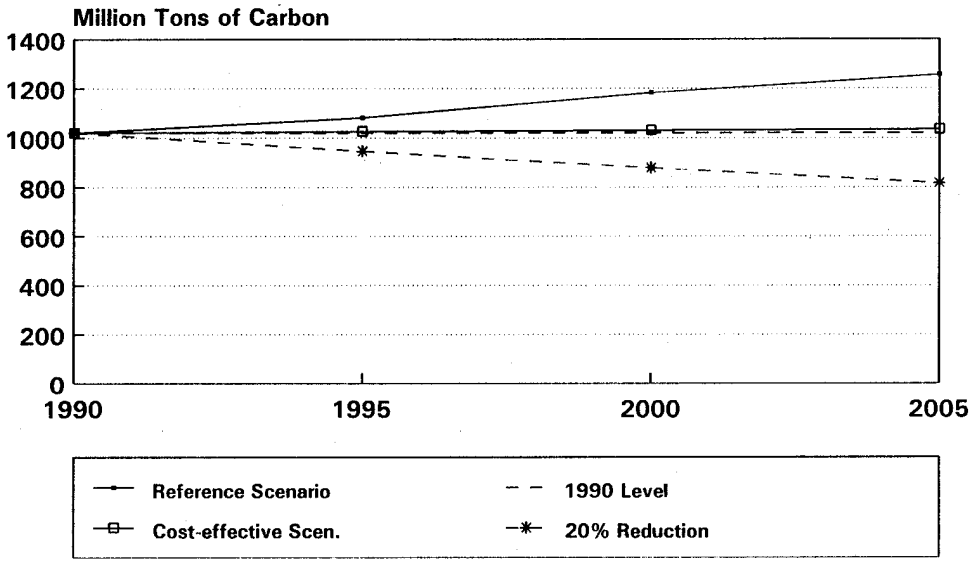


Figure 4. Carbon Dioxide Emissions and Energy Efficiency in the Former Soviet Union (Source: Makarov and Bashmakov 1990; Author)

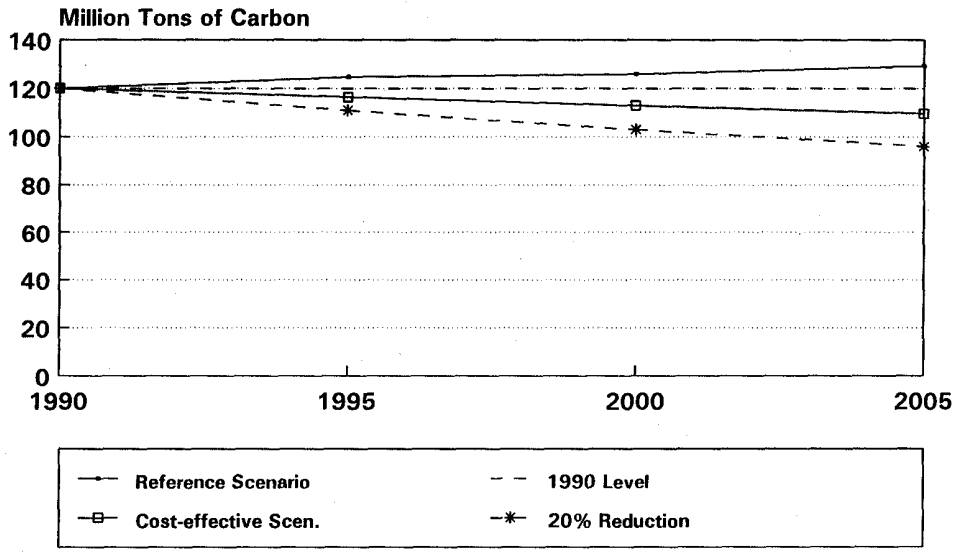


Figure 5. Carbon Dioxide Emissions and Energy Efficiency in Poland
(Source: Sitnicki et al. 1990; Author)

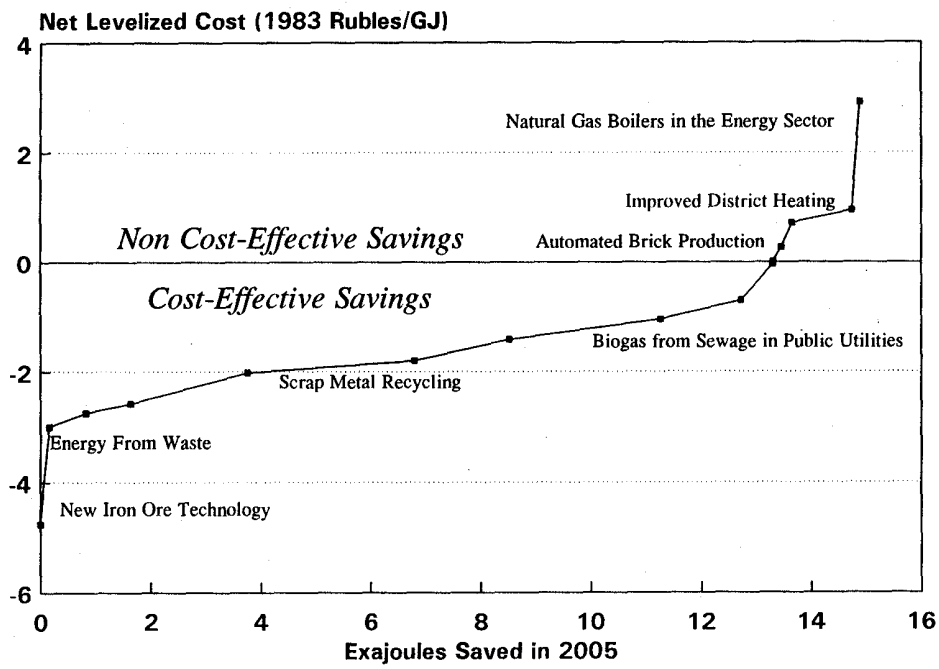


Figure 6. Energy-Savings Potential in the Former Soviet Union
(Source: Bashmakov and Chupyatov 1991[13]; Author)

Table 5. Carbon Dioxide Emissions Reduction Through Cost-Effective Energy Conservation in the Former Soviet Union by the Year 2005

	Energy Demand (EJ)	CO_2 Emissions (MtC)
Kononov's Study	61.1-66.3	967-1055
This Study	66	1018-1050

Source: Kononov 1991;[14] Author.

the former Soviet Union, where gas and oil production will take place increasingly in remote, permafrost areas, considerably augmenting the cost of exploitation and transportation. Evolution toward a market economy, implying a sharp decline in energy subsidization, will most likely allow additional opportunities to save energy using cost-effective measures.

ENERGY-EFFICIENCY POTENTIAL AND ASSOCIATED COSTS IN POLAND, CZECHOSLOVAKIA, AND THE FORMER SOVIET UNION

Industry, especially heavy industry, offers the largest cost-effective potential to limit energy demand and carbon dioxide emissions in our low-emissions scenarios. Industry as a whole, not including the energy production sector, would account for 40 percent of all carbon dioxide emissions reduction in the former Soviet Union, 43 percent in Poland, and 31 percent in Czechoslovakia. Energy-saving measures that do not entail additional costs include:

- adopting continuous casting in the steel sector and scrap recycling in the metallurgy industry
- shifting from wet cement to dry cement technologies and reducing the content of steel in reinforced concrete
- using efficient gas and fuel boilers instead of coal boilers
- installing heat shields, thermostats, automated electric drives, and efficient lighting systems
- using cogeneration and energy production from waste.

Soviet experts emphasize the need for measures, in the energy sector in particular, to reduce losses during transport and to adopt combined-cycle technologies for producing electricity and heat. This single shift would save 2.2 EJ by the year 2005, or 3.6 percent of current energy demand in the former Soviet Union. This would result in a net savings in capital costs of 4.3 billion rubles,[15] and would reduce carbon dioxide emissions by 37.5 million tons.

The residential sectors of all of the countries studied also offer a large potential for energy savings by improving insulation and renovating district heating grids. For example, building insulation could help Czechoslovakia reduce 3.8 percent of its current energy demand by the year 2005.

It is feasible to evaluate the cost of shifting from fuel to electric railways in the transportation sector, but it is more complicated to assess the cost of reducing fuel economy and improving management of public transportation. Research and development of energy-efficient motors would not entail additional costs if applied to the next generation of cars. This kind of technological progress, however, is not considered in this study.

Tables 6, 7, and 8 summarize the energy-saving potential of efficiency measures in each country by the year 2005, including cost-effective measures, with a negative net levelized cost, as well as some additional energy-conservation measures which require net expenses.

Figures 6, 7, and 8 depict the cost curves of energy efficiency in the former Soviet Union, Poland, and Czechoslovakia. Figures 9, 10, 11 show the corresponding costs of carbon dioxide emissions reduction.

Table 6. Energy-Efficiency Potential in the Former Soviet Union by the Year 2005

Measures	Potential (EJ) (% of 1990)	Net Average Levelized Cost (R/GJ)*	Capital Cost** (Billion R)	CO_2 Reduction (MtC)
Cost-Effective	13.0 (21%)	1.76	36.2	207-238
Additional:				
-Net-Cost	0.3 (0.5%)	1.41	4.5	6.0
-Net Capital Cost	1.2 (2.0%)	0.96	16.9	20-33
Other	2.1 (3.5%)	NA	NA	11-15
TOTAL	16.6 (27%)			278-325

* R = 1983 rubles.
** Capital cost refers to total cost over the period considered.
Source: Bashmakov and Chupyatov 1991.

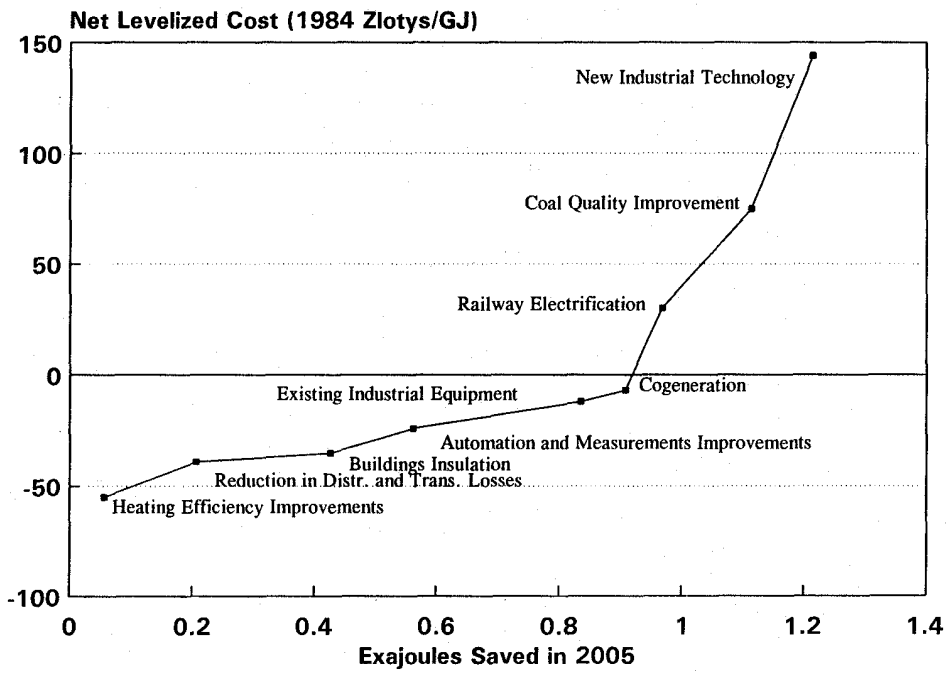
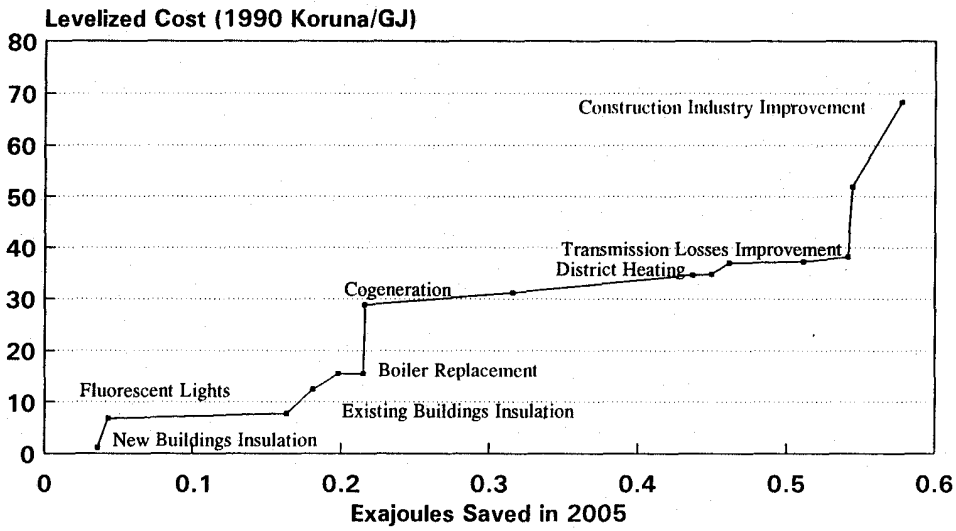


Figure 7. Energy-Savings Potential in Poland (Source: Sitnicki et al. 1990; Author)



Note: Assumed marginal cost of energy supply is 70 koruna per GJ.[16]

Figure 8. Energy-Savings Potential in Czechoslovakia (Source: Kostalova et al. 1991)

Implementing cost-effective energy-efficiency measures would make it possible to shift from the level of emissions in the reference scenario to a less carbon-intensive growth path, namely the low-emissions scenario, without diverting capital resources from the rest of the economy. We can estimate further emissions reduction, assuming that these countries consider global warming important enough to invest specifically in reducing carbon dioxide emissions through additional, non-cost effective, energy-efficiency measures (see Table 9 for carbon dioxide reduction potentials and associated costs).

Bashmakov and Chupyatov (1991) report that emission of an additional 26 million tons of carbon could be avoided by 2005 for a net cost of 21.4 billion rubles (2.7 percent of 1988 GDP). However, 80 percent of this additional potential (1.2 EJ), referred to as net capital cost measures, would bring about negative costs through the reduced need for labor and other investments. These potential benefits have not been estimated since they are not related to energy. We therefore present these measures as non-cost effective. Those measures for which capital costs are difficult to assess are referred to as "other measures" (Table 6).

A total reduction of 254 million tons of carbon emissions by 2005 in the former Soviet Union is impressive, but even with structural economic change and the implementation of costly energy conservation measures, it is not sufficient to achieve the 20 percent reduction from current levels recommended at the Toronto conference.[17]

Emissions reduction beyond the 10 percent decrease in Poland, could save 9 million tons of carbon at an average levelized cost of 7,400 zlotys,[18] the marginal cost of carbon supply being 5,700 zlotys.[19] Poland could almost obtain a 20 percent reduction of its carbon emissions by the year 2005, with supplementary investment outlays amounting to 361 billion zlotys (2.9 percent of 1988 GDP).

We have shown here that cost-effective energy conservation could bring about considerable carbon dioxide emissions reduction in these countries by the year 2005. This would lead to a stabilization or a decrease of emissions from current levels without requiring additional capital outlays, where the marginal levelized cost of saving one ton of carbon is lower than the marginal cost of supply (Table 9). This would require an important re-allocation of investment expenses from traditional energy supply to energy conservation. The reader is reminded that the total capital outlays for implementing all cost-effective energy-efficiency measures amounts to five percent, four percent, and four percent of 1988 GDP for the former Soviet Union, Poland, and Czechoslovakia, respectively.

Table 7. Energy-Efficiency Potential in Poland by the Year 2005

Measures	Potential (EJ) (% of 1990)	Net Average Levelized Cost (Z/GJ)*	Capital Cost** (Billion Z)	CO_2 Reduction (MtC)
Cost-Effective	0.908 (17%)	-26.7	456	19.6
Additional	0.307 (5.7%)	89.0	361	8.7

* Z = 1984 zlotys; net average levelized cost was computed using a 17% discount rate.
** Capital cost refers to total cost over the entire period considered.
Source: Sitnicki et al. 1990; Author.

Table 8. Energy-Efficiency Potential in Czechoslovakia by the Year 2005

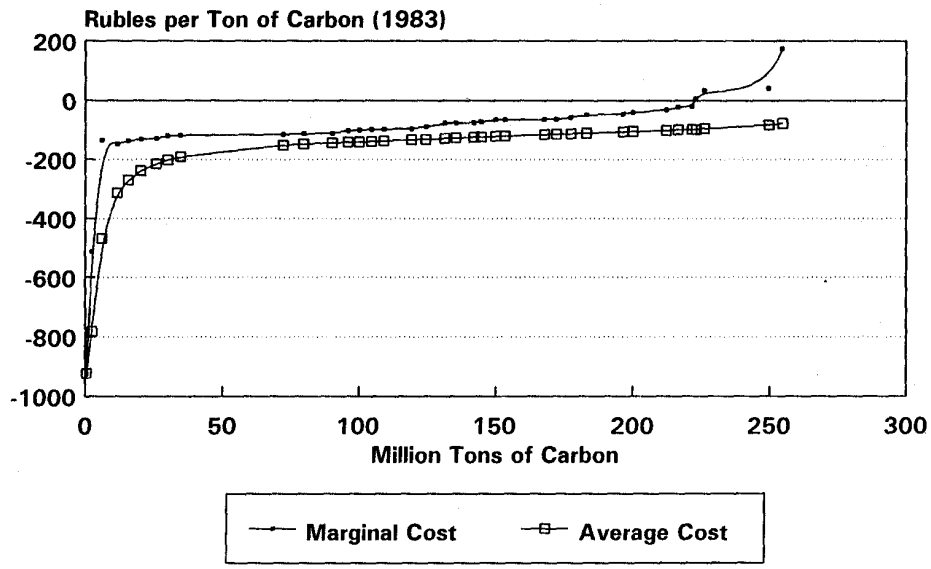
Measures	Potential (EJ) (% of 1990)	Average* Levelized Cost (K/GJ)**	Capital Cost*** (Billion K)	CO_2 Reduction (MtC)
Cost-Effective	0.578 (18%)	26.7	26.5	12.9

* The average levelized cost of energy supply is 70 koruna. This price is likely to increase as energy is de-subsidized. At the current cost level, the *net* average levelized cost would be -43.3 koruna, meaning that all measures are cost-effective. Since cost of energy supply is subject to change, we do not report the net cost in this table.
** K = 1990 koruna.
*** Capital cost refers to total cost over the entire period considered.
Source: Kostalova et al. 1991.

FURTHER CARBON DIOXIDE EMISSIONS REDUCTIONS THROUGH FUEL SUBSTITUTION AND MORE EXPENSIVE ENERGY CONSERVATION

The above scenarios presented the potential for limiting carbon dioxide emissions by reducing primary energy demand. In an attempt to estimate the cost of reducing carbon dioxide emissions, substitution of less carbon-intensive or non-fossil energy sources for coal, oil, and gas had to be assessed.

Czechoslovakia and Poland rely mostly on hard coal, brown coal, and lignite as primary energy sources. Natural gas could be used efficiently in electricity and heat production at lower capital costs than those required for coal-burning facilities. An end to coal mining



Note: Interfuel substitution not included.

Figure 9. Cost Function for CO_2 Emissions Reduction in the Former Soviet Union: Net Levelized Costs (Source: Bashmakov and Chupyatov 1991)

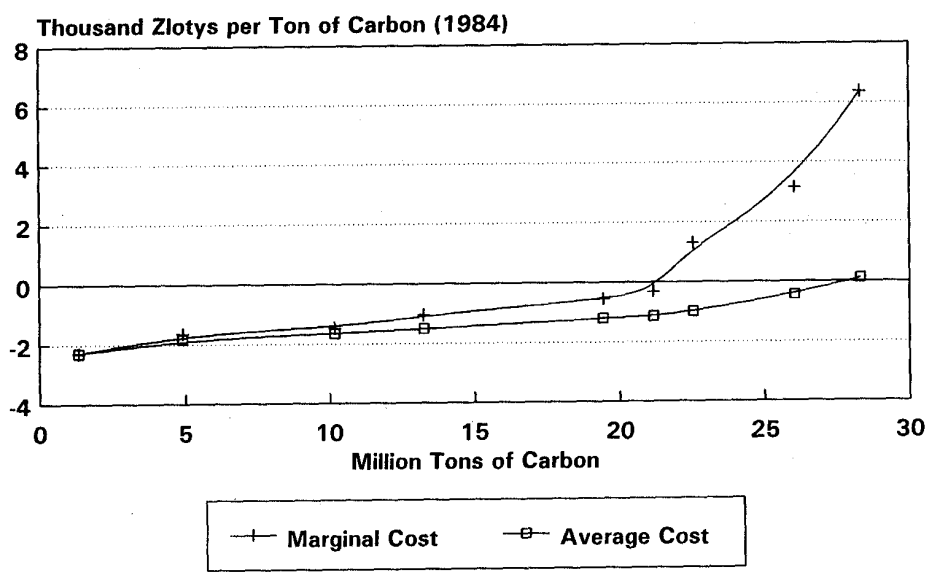
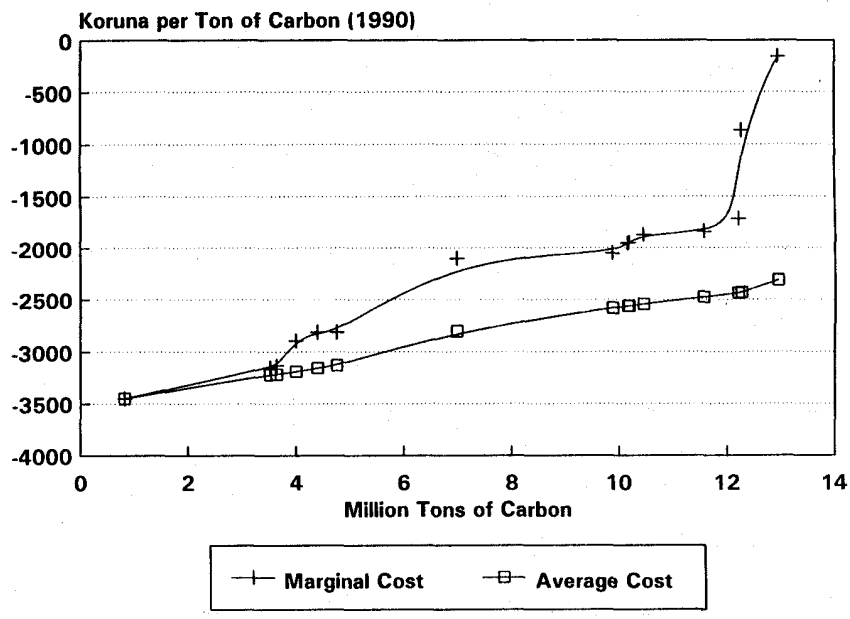


Figure 10. Cost Function for CO_2 Emissions Reduction in Poland: Net Levelized Costs (Source: Sitnicki et al. 1990)



Note: Assumed marginal cost of supply is 70 koruna.

Figure 11. Cost Function of CO_2 Emissions Reduction in Czechoslovakia: Net Levelized Costs (Source: Kostalova et al. 1991)

subsidization in these two countries, where more expensive, lower quality coal reserves are being exploited, should make natural gas a more competitive energy resource. However, this would require increased imports of natural gas. Kostalova et al.[20] report that if Czechoslovakia replaces all coal-fired facilities at the end of their lifetime with gas-burning power and heat-generation facilities, required gas imports would exceed 20 billion cubic meters. This would be a 20 percent increase from current gas supply agreements with the former Soviet Union, which total 16.6 billion cubic meters annually until 1995.

It is beyond the aim of this paper to assess macroeconomic costs of these measures by the year 2005. A comparison of costs and benefits should also take into account the environmental costs of coal exploitation and burning. Sitnicki et al.[21] report that these costs amounted to 10 percent of Poland's GDP in 1986. It is plausible that a decrease of two million tons of carbon dioxide emissions from the levels in the low-emissions scenario to 107 million tons carbon in 2005 could be obtained without entailing additional costs.

Kostalova et al.[22] studied more stringent energy-saving measures for Czechoslovakia. These measures include: 1) completely halting electricity exports; and 2) utilizing nuclear power plants currently under construction, which eliminates the need for new fossil-fuel facilities until the year 2030. If the shift from coal to natural gas were applied to the low-emissions scenario, emissions could be reduced to 40.4 million tons of carbon dioxide, a 37 percent decrease from the 1990 level.

The Soviet case is very different: under to the reference scenario, in 2005 the country will produce 40 percent of its electricity and heat from natural gas; nuclear and hydropower sources will account for 22 percent. Makarov and Bashmakov[23] estimate the net capital cost of averting the emission of one ton of carbon by nuclear power to be 400 rubles, which is below the net marginal capital requirement for non-cost-effective measures of 800 rubles per ton of carbon.[24] One should nevertheless consider potential environmental costs and the social acceptability of the two carbon dioxide-saving measures in this nuclear/energy-efficiency tradeoff.

Alternative energy resources, such as solar, geothermal, and wind power, are also available in the former Soviet Union, but at a relatively high cost for most areas of the country. Makarov and Rudenko[25] conclude that by the year 2005, these technologies could be competitive

Table 9. The Cost of Carbon Dioxide Emissions Reduction through Energy Efficiency by the Year 2005

	Average Capital Cost	Average Levelized Cost	Marginal Levelized Cost	Marginal Cost of Supply/tC*	CO_2 (MtC) Emissions Reduction
Soviet Union (1983 Rubles/tC)					
Cost-Effective Measures	139	27	88.6	150	222
Additional Measures	824	197	290	150	32
Poland (Thousand 1984 Zlotys/tC)					
Cost-Effective Measures	23.2	4.1	5.7	5.7	19.6
Additional Measures	41.5	7.4	13	5.7	8.7
Czechoslovakia (1990 Koruna/tC)					
Cost-Effective Measures	14,609	1190	3340	NA*	12.9

MtC = Million Tons of Carbon; tC = Tons of Carbon

* We computed the cost of supply of one ton of carbon using the estimated amount of energy supply by the year 2005 and the corresponding carbon content.

** Kostalova et al. (1991) report that the average cost of energy supply is about 70 koruna per gigajoule (about 3000 koruna per ton of carbon); the marginal cost should be higher, but here we assume that they are equal. The 12.9 million tons of carbon dioxide emissions reduction would come with cost-effective energy conservation measures.

with traditional energy sources only in remote areas where decentralized energy supply would be necessary. By 2005, a decrease in carbon dioxide emissions in these particular zones could be achieved with a levelized cost between 500 and 700 rubles per ton; the marginal cost of non-cost effective measures of energy efficiency would be lower at 290 rubles per ton of carbon.

Interfuel substitution could further reduce carbon dioxide emissions in the three countries. Poland could achieve a 20 percent emissions reduction through energy-efficiency and a shift to natural gas for electricity and heat production. In this latter case, such a shift should be cost-effective if coal mining were thoroughly de-subsidized.

Our study and the study by Kononov[26] suggest similar conclusions for the former Soviet Union: cost-effective energy efficiency can limit the increase of carbon emissions to less than three percent over the next 15 years. Going beyond stabilization is achievable through further conservation and some interfuel substitution, the choice between the two being more political than economic since energy efficiency and nuclear energy are available for equivalent capital costs once a certain energy-efficiency potential is exhausted.

The former Soviet Union might encounter some financial and economic problems in its attempt to substantially curb emissions according to the study by Kononov. Limiting carbon emissions to 80 percent of the current level by the year 2010, through an optimal energy-efficiency strategy involving less carbon-intensive production technologies, should bring about a four to seven percent decrease of GDP, compared with a reference case that maximizes consumption over the 1990 to 2010 period. Financial assistance would be necessary in order to cover at least the non-cost-effective measures that could be implemented in the former Soviet Union as well as in other Eastern European countries.

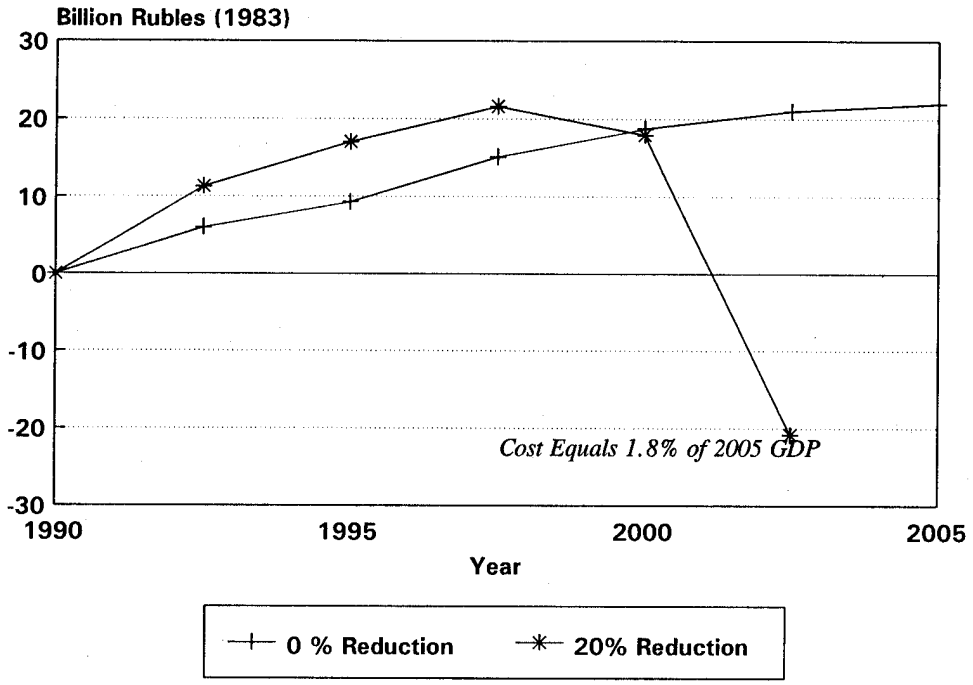


Figure 12. Net Benefits and Costs of CO_2 Emissions Reduction in the Former Soviet Union (Source: Bashmakov and Chupyatov 1991; Author)

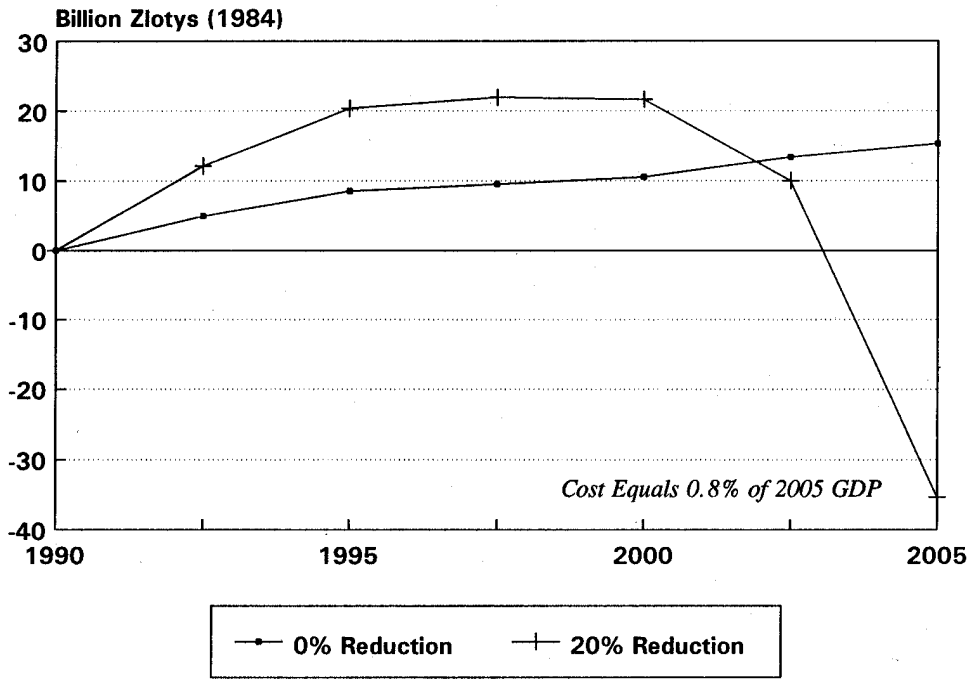


Figure 13. Net Benefits and Costs of CO_2 Emissions Reduction in Poland (Source: Sitnicki et al. 1990; Author)

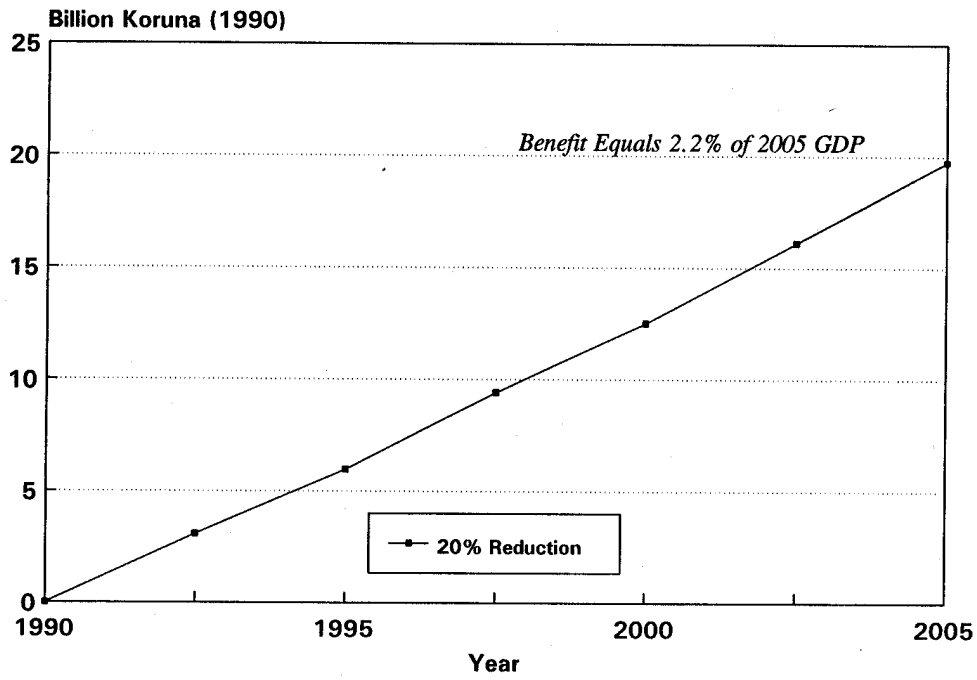


Figure 14. Net Benefits and Costs of CO_2 Emissions Reduction in Czechoslovakia (Source: Kostalova et al. 1991)

In Figures 12, 13, and 14, we estimate the evolution of economic benefits and costs that could result from carbon dioxide emission reduction strategies in the former Soviet Union, Poland, and Czechoslovakia.[27] The percentage of GDP in these figures reflects only the financial savings for the given year; GDP is used as a scale, and potential macro-economic impacts are not included.

The following is a summary of potential carbon dioxide emissions reduction and the associated costs and benefits for the three countries in this study:

- The former Soviet Union could receive important benefits through stabilizing its emissions by 2005, because this could be achieved through cost-effective energy efficiency. Going beyond stabilization (a 20 percent decrease by 2005) should bring higher benefits during the first 10 years but would entail significant costs after the year 2000, because the country would then have to rely on nuclear and renewable technologies to further curtail its emissions.

- Poland could follow a similar path to abate carbon dioxide emissions by 20 percent. The country could then start investing additional funds towards this goal after the year 2000.

- Czechoslovakia should be able to save both capital investment and energy through efficiency measures, bringing about a carbon dioxide emission reduction of 30 percent compared to current levels.

POLICIES AND CONSTRAINTS

Poland, Czechoslovakia, and the former Soviet Union are now undergoing major economic changes that may assist in curbing their carbon dioxide emissions. Reduction of emissions will come as an indirect by-product of ongoing economic restructuring. But these countries can also avoid substantial carbon dioxide emissions through energy conservation. Energy conservation appears to be the most efficient way to curtail carbon dioxide emissions by about one-fifth of current emissions.

We have found that Eastern European countries, using Poland and Czechoslovakia as examples, unlike some western countries, could almost comply with the Toronto recommendation[28] by the year 2005 by re-allocating

investment from energy supply to cost-effective energy conservation.

The former Soviet Union, however, is not likely to achieve the 20 percent reduction without making the choice between lowering its contribution to carbon dioxide build-up or achieving higher economic growth. The Soviet potential for cost-effective energy efficiency could at best lead to a stabilization of carbon dioxide emissions at today's level by 2005.

It is important to consider existing and potential barriers to the integration of energy efficiency in formerly centrally-planned economies. First, the potential for energy efficiency described in this paper is an optimal potential and all of the conditions required to achieve this level, or a satisfactory state close to it, are not currently present in these countries. We should therefore identify the economic and market potentials of energy efficiency since the social discount rate may differ greatly from the implicit discount rate used by individuals. Bashmakov and Chupyatov (1991) use a discount rate equivalent to a pay-back period of five years for any capital outlay in the industrial sector and two years in the residential sector. We calculated the cost-effective energy-efficiency potential in this study using this assumption in order to guarantee its acceptability.

Second, the dynamics of relative energy prices are also essential in this process. As mentioned earlier, Eastern European countries and the former Soviet Union are currently putting an end to price subsidization and energy is one of the primary targets of this evolution toward equilibrium pricing.. This might have counterproductive effects on energy conservation if the relative price of energy compared to other goods decreases, while simultaneously increasing in nominal terms, as is the case in the former Soviet Union according to Bashmakov and Chupyatov (1991). This could delay decisions to invest in energy efficiency.

Third, the capital costs we present here do not incorporate any implementation costs. Additional research is required to estimate these costs. Given western experience in energy markets, it is unlikely that the evolution toward marginal cost pricing of energy supply will alone lead to the optimal economic investments in conservation described in this paper, at least not without additional policy measures.

Fourth, a regulatory mechanism, fiscal policies, and information to final energy consumers are all necessary to accelerate replacement of obsolete equipment and to create a complete energy market in which supply technologies and energy conservation could be in competition. Administrative costs, however, might alter the energy-efficiency potential.

Fifth, the success of implementing energy efficiency hinges on the ability of these economies to produce appropriate energy conservation technologies; this is mostly dependent on the capacity of an economy to reallocate capital resources from heavy industries to the energy-conservation technology manufacturing sector. International cooperation and technological transfers are crucial in helping these countries build an energy-efficiency market base using the best available technologies.

It is possible that the marginal cost of avoiding the emission of one ton of carbon would be lower in Eastern Europe and the former Soviet Union than in most OECD countries. There might therefore be an opportunity for western conservation equipment manufacturers and Eastern European countries to mutually benefit from a carbon emissions reduction strategy. The former would realize great economic prospects while the latter would reduce its investment in the energy sector and benefit from technology transfers.

Eventually, one can argue that investing scarce capital resources in reduction of carbon dioxide emissions might affect overall economic growth. Capital cost estimates, however, may not be sufficient to determine this mechanism, therefore the macroeconomic cost of limiting carbon dioxide emissions should be assessed. But macroeconomic modeling might not be very helpful in this case because it implies the following drawbacks:

- Long-term projections would have to be made on the basis of past observations. Eastern European economies and the former Soviet Union, however, are undergoing dramatic economic changes making past periods obsolete for econometric regression analysis.

- Macroeconomic models usually assume that current markets (including the energy market) behave optimally, and create a reference scenario under this assumption. Introducing a carbon emissions constraint on the reference case therefore results in a decrease in GDP. Here, the considerable potential of cost-effective energy efficiency demonstrates that energy markets are not close to the optimum. Unless the model incorporates energy efficiency as

a separate energy source in competition with traditional supply technologies, we can predict a negative macroeconomic impact of limiting carbon dioxide emissions in these economies. It is unclear, however, to what extent we can rely on this conclusion.

SUMMARY

Planned and post-planned economies, including Bulgaria, Czechoslovakia, Hungary, Poland, and the former Soviet Union, represent eight percent of the world's population and account for 22 percent of global carbon dioxide emissions from fossil fuel burning. Energy and carbon dioxide intensities in these countries, measured in terms of energy and carbon per unit of GDP, are above most western levels. The purpose of this paper is to estimate the capital costs of reducing carbon dioxide emissions by applying available technologies.

This analysis is based on long-term studies made by regional experts on energy and environmental issues in three key countries which were formerly centrally planned economies: the former Soviet Union, Poland, and Czechoslovakia. We used economic restructuring projections as our reference scenario in order to show that ongoing structural change, where production is shifted away from heavy industry toward manufacturing consumer goods, is likely to bring about a major reduction in the energy (and carbon dioxide) intensity of the GDP. However, the macroeconomic cost or benefit of this transition cannot be used as a proxy for determining the cost of carbon dioxide emissions reductions since these are indirect effects of economic change.

Starting from a reference scenario which incorporates structural changes, we evaluated the potential for carbon dioxide savings by the year 2005 through the implementation of cost-effective energy-conservation measures. Our data suggest that the former Soviet Union, Poland, and Czechoslovakia could either stabilize or reduce emissions compared to current levels while saving capital and domestic energy resources: in the low-emissions scenario, Soviet emissions will grow by only 1.3 percent between now and 2005, Polish emissions will decrease by 10 percent, and Czechoslovak emissions will fall by 30 percent, assuming that all cost-effective energy-efficiency measures are implemented.

If the former Soviet Union and Poland commit themselves to reducing emissions by 20 percent by the year 2005, they will encounter supplementary capital expenditures from the year 2000 amounting to two percent of 2005 GDP for the former Soviet Union and one percent of 2005 GDP for Poland.[29] Until 2000, both countries could use the capital saved by conserving energy for other purposes in their economies.

Czechoslovakia should have no problem complying with the 20 percent reduction recommended at the Toronto Conference, assuming the envisioned economic changes take place and energy-efficiency measures are implemented, allowing benefits through major capital savings.

Although most of the energy-efficiency potential is cost-effective, several barriers still hamper investment in energy efficiency. First, re-allocating more than three percent of GDP from energy supply to energy efficiency will require more than just marginal cost pricing of energy. The outcome of energy prices in the de-subsidization process is an important policy issue: the risk is that prices will remain constant or even decrease in relative terms while increasing in nominal terms. This could delay energy-efficiency investments in individual households, and in the industry and service sectors.

Administrative costs were not accounted for in this study. More research is required to estimate the costs of programs to create a regulatory mechanism, promoting technical education, and launching public information campaigns.

The technological progress of these countries has also been addressed to estimate the potential to curtail carbon dioxide emissions. We recognize that investment in carbon emissions reduction appears much more cost-effective in these countries than in their western counterparts. Both formerly centrally-planned economies and western market economies could benefit from the transfer of energy-efficient technology to limit emissions.

Finally, this study does not try to estimate the macroeconomic costs and effects of limiting carbon dioxide emissions through energy-efficiency measures. This is mainly because most macroeconomic models have to base reference projections on past observations which are now irrelevant to the countries studied due to ongoing economic and political changes.

ACKNOWLEDGMENTS

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NOTES ON SELECTED FIGURES

Figures 3-5 Carbon Dioxide Emissions 1990 to 2005. The 20 percent reduction and the stabilization cases are displayed for reference purposes only.

Figures 6-8 Energy-Savings Potential. Here we indicate the cost of energy savings and the corresponding potentials (cost- and non-cost-effective) given 1990 price levels. These cost-effective potentials could be implemented without incurring additional costs, if cost-effectiveness was the criterion for energy investments over the 1990-2005 period. The cost-effective potential is bound to grow if the energy production sector is de-subsidized in Eastern Europe and the former Soviet Union.

Figures 9-10 Cost Function of Carbon Dioxide Emissions Reduction. These figures show the net average and marginal costs of limiting carbon dioxide emissions through energy efficiency and fuel substitution.

Figures 12-14 Net benefits (or costs) resulting from the implementation of energy-efficiency measures over time. Costs and benefits are expressed in the corresponding currency and as a percentage of GDP for the last year. The latter are not to be confused with so-called macro-economic costs (welfare cost, loss or gain of consumption...), which were not computed in this study. Percentages are simply the ratio of total costs over GDP for that year.

ENDNOTES

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6. The base case scenario incorporates only those measures without additional financing specifically devoted to energy conservation, but considers steps taken under the former Soviet system of decision-making to improve overall efficiency.

7. Makarov and Bashmakov, 1990; Sitnicki et al., 1990; Kostalova et al., 1991.

8. Sitnicki et al., 1990.

9. These scenarios have been computed using the EPA End-Use Model for Poland and Czechoslovakia and the Octopus model, a non-linear optimization model developed by the Energy Research Institute, for the Soviet Union.

10. Kostalova et al., 1991.

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14. Kononov, 1991.

15. Rubles are for 1983.

16. Koruna are for 1990.

17. The Toronto Conference on the Changing Atmosphere, 1989.

18. Polish zlotys are for 1984.

19. The cost of carbon supply is the cost of energy supply resulting in the emission of one ton of carbon.

20. Kostalova et al., 1991.

21. Sitnicki et al., 1990.

22. Kostalova et al., 1991.

23. Makarov and Bashmakov, 1990.

24. Kononov (1991) gives a different cost range: between 140 and 370 rubles per ton of carbon saved through nuclear energy.

25. Makarov, A., and Y. Rudenko. 1990. Possible Scenarios for Energy Development in the USSR: Estimates on the Eve of the Transition to the Market Economy. USSR Academy of Sciences, Commission for Determining Alternative Scenarios on Energy Development, Moscow.

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27. Net benefits = (levelized cost of carbon dioxide-saving measure) - (levelized marginal cost of traditional energy supply technology).

28. The Toronto Conference on the Changing Atmosphere, 1989.

29. These figures are net capital costs, they do not mean a loss of GDP. GDP is used only to illustrate the magnitude of capital outlays.