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ENERGY CONSERVATION: THE MAIN FACTOR FOR REDUCING GREENHOUSE GAS EMISSIONS IN THE FORMER SOVIET UNION

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I. A. Bashmakov
V. P. Chupyatov

December 1991

Work supported by
the U.S. Environmental Protection Agency
under a Related Services Agreement with
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

MASTER

FOREWORD

In this paper, Valery Chupyatov and Igor Bashmakov present important new research on the potential for greenhouse gas emissions reduction in the former Soviet Union. The authors describe relative costs of energy efficiency and energy supply. Their methodology thus elegantly overcomes obstacles to understanding a planned economy, and remains valid and useful as the newly independent republics begin programs of economic reform. Their work deepens our understanding of the emissions reduction potential in the region formed by the former union.

This paper forms part of a series of country studies sponsored by the Global Climate Division of the Office of Policy, Planning, and Evaluation, U.S. Environmental Protection Agency (EPA).

Dennis Tirpak, director of EPA's Global Climate Division, initiated this work in mid-1988. Since that time, we have completed studies of Canada, Czechoslovakia, France, Hungary, Italy, Japan, Poland, the United Kingdom, and the United States, and research is underway or planned in Bulgaria, Romania, and Ukraine.

Our approach to each country study has been to find the best indigenous analysts to perform the work. This method enables us to benefit from a wealth of experience and knowledge. Bashmakov and Chupyatov define that standard, and we are very grateful for their cooperation. For the spirit and quality of this collaboration, Alexei Makarov, director of the Energy Research Institute, deserves our special thanks.

William U. Chandler
Director, Advanced International Studies

DISCLAIMER

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ABSTRACT

The energy intensity of the former Soviet Union[(b)] is more than twice that of other market economics in similar stages of economic development. Low energy efficiency in the Soviet Union has contributed significantly to global carbon and other greenhouse gas emissions. The technological potential for energy conservation in the former Soviet Union is the largest in the world. The inefficiencies of the previously command-system economy, however, have provided little incentive for conserving energy. The present transition to a market-based economy should encourage the incorporation of energy-efficiency improvements in order for the former Soviet Union to successfully lower its energy intensity. There are several obstacles that limit implementing energy conservation: for example, energy prices and discount rates influence the volume of investment in energy efficiency. Nevertheless, cost-effective measures for energy conservation do exist even in the most energy-intensive sectors of the Soviet economy and should form the core of any energy conservation program. The overall cost-effective potential for carbon savings in the former Soviet Union is estimated to be 280 to 367 million tons of carbon per year by the year 2005, or 23 to 29 percent of 1988 energy-related emissions.

(b) This study includes calculations taken over the entire territory of the former Soviet Union, thus it is necessary to use terminology which incorporates the whole area considered. For the sake of simplicity we will continue to use the previous names: Soviet Union and USSR.

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THE EVOLUTION OF ENERGY INTENSITY IN THE FORMER SOVIET UNION AND OTHER COUNTRIES

I. Bashmakov
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Theoretical and empirical analysis has shown that energy conservation is a major factor in reducing greenhouse gas emissions. The potential to reduce harmful emissions through energy conservation exceeds that of fuel switching by a factor of two, according to recent studies analyzing carbon emissions in various countries.[1] The former Soviet Union is one of the most energy-intensive countries in the world. The energy intensity of its economy in 1985 was twice that of Western Europe and 30% more than the United States[2]. The energy intensity of an economy is an important indicator of its potential to reduce energy use, averting emissions of millions of tons of carbon.

To conserve energy, it is necessary to reduce energy intensity. Economic output, however, need not be compromised. Energy intensity can be reduced over time through a process of structural and technological change. Installing new energy-efficient technologies and recycling waste are just two of the measures which can be implemented in most economic sectors to reduce energy use. We determined the potential for the former Soviet Union to reduce carbon emissions and energy use by the year 2005 for over 120 energy-saving measures in the industrial, residential and commercial, electric power, transportation, and energy sectors.

This paper assesses the total cost and capital investment required to implement the identified measures and achieve the potential for energy savings. There are many limits, however, to implementing measures which reduce energy intensity. We attempt to assess some of these limitations, as well as the variables that affect the pace of transition to energy efficiency in the Soviet economy.

Before focusing on the Soviet Union, however, it is necessary to compare Soviet energy performance to energy trends of industrialized countries. One recent study compares the differences in the dynamics of energy intensity in the Soviet Union, the United States, and Western Europe.[3] The efficiency of energy use in a country relative to other countries can be determined by comparing the gross domestic product (GDP).

Table 1 depicts the change in energy intensity in several industrialized countries since 1960, and gives projections for energy intensity reduction until the year 2000 ranging between 0.2 and 2 percent per year. This table indicates that there is a tendency for energy intensity to decline over time.[4] The main reason for this trend is that as economies develop, inputs of labor- and capital-intensive goods tend to increase relative to those of energy intensive primary materials. In other words, the demand for energy per unit of useful economic output is reduced. This process of energy-intensity reduction is the fundamental component of energy conservation.

Two interrelated variables influence the energy intensity of an economy: structural and technological change. Structural change is an important contributor to energy conservation and the reduction of energy intensity. Structural change is defined as a change in the production mix of an economy. Structural enhancement is tied to rates of economic growth and causes fluctuations in the energy-intensity trend. During a recession, for example, structural change may account for 20 to 40 percent of the changes in the energy-intensity index (GDP).[5] During periods of rapid growth, such change diminishes in relative importance and may even increase energy intensity.

Changes in production technology can bring about structural change in the economy, varying the energy intensity of the GDP. The rate of technological change is in turn affected by energy prices. Inexpensive energy reduces the incentive to introduce energy-saving technologies. For example, low prices in the second half of the eighties greatly slowed energy-efficiency improvements in some western industrialized countries.

ENERGY INTENSITY IN VARIOUS SECTORS OF THE SOVIET ECONOMY

Energy conservation practices have been slow to develop in the Soviet Union as compared to the relatively rapid pace of conservation in the West. Although official Soviet statistics reported that the energy intensity of the Soviet GDP dropped by 10 percent between 1975 and

Table 1. The Dynamics of GDP Energy Intensity in Industrialized Countries (%/Year)

COUNTRY	1951-60	1961-73	1973-79	1980-85	1986-88	1990-2000
USA	0.4	-0.3	1.1	3.0	0.4	1.1-1.6
CANADA	0.5	-0.6	0.6	1.3	1.2	0.2-0.8
JAPAN	-0.4	-0.9	2.0	3.9	1.0	1.7-2.0
W.GERMANY	2.6	-0.4	1.0	2.4	1.9	2.2-2.8
FRANCE	1.7	-0.4	1.8	0.9	1.5	1.5-2.0
GR. BRITAIN	1.6	0.8	1.5	2.6	3.7	0.3-1.9
ITALY	-5.1	-3.0	1.1	1.9	0.5	1.1-1.4

Source: Bashmakov et al. 1990.

1985, when this figure is adjusted for inflation energy intensity actually increases by 14 percent for the same period.[6]

In light of the current transformation facing the former Soviet Union, energy conservation will likely become a critical factor in reducing the country's energy intensity, while allowing simultaneous expansion of economic development. Below we discuss energy intensity in five sectors of the Soviet economy and compare them with energy use in the West.

One important reason why the Soviet-style economy is so energy intensive is that the ratio of extracted energy to GDP is higher than in other countries, signifying a high level of economic expenditure in the energy sector. Inefficient resource extraction, processing, and distribution technologies contribute to high energy intensity in this sector. Other economic sectors also augment the level of energy intensity.

The industrial sector[7] also accounts for a large percentage of energy use in the former Soviet Union. One international comparison[8] of energy intensity excluded the energy sector from industry and found that industrial energy used in the Soviet Union, the United States, and Western Europe was equal to 8.5, 6.4, and 5.3 megajoules per dollar of GDP, respectively.[9] Another analysis was able to explain 62 percent of the difference in industrial energy intensity between the United States and the Soviet Union as a result of dissimilarities in technological factors in production. There are three main differences in the countries' production systems: 1) product structure, that is, the combination of goods produced; 2) technological structure; and 3) the efficiency of technologies, for example the quality of maintenance and management of machinery. The contribution of these three elements in explaining the 62 percent difference is 45 percent, 35 percent, and 20 percent, respectively.

The gap in the efficiency of energy use in the industrial sector can be reduced mainly by implementing advanced technologies and changing the product structure of the economy. This approach, however, requires major capital outlays and a long period of time.

The transportation sector accounts for a relatively large portion of energy use in the former Soviet Union, especially considering the low ratio of cars per person. This is due not only to the large distances within the country, but also to the higher consumption of primary materials and the energy inefficiency of the transport systems. One of the main ways to improve the efficiency of energy use in the transportation sector is to reduce freight turnover, that is the amount of materials transported combined with the distance traveled. Freight turnover per dollar of national income in the Soviet Union is 1.6 times greater than Japan, 2.5 times greater than United States, and 4 times greater than Western Europe. Material and energy-resource transportation accounts for 70 to 80 percent of total freight turnover in the Soviet economy. Apparently, ineffective freight traffic and false entries in freight handling records also affect these numbers.

Energy consumption per dollar of national income (net material product) in the commercial and residential sectors does not differ significantly among the countries studied. The fact that per capita energy use in the United States in 1985 was twice that of the Soviet Union is due to two proven factors: 1) discrepancies in the indexes of the commercial and residential sectors, and 2) differences in technical efficiency at the point of end use. The disparity in per capita energy consumption between the Soviet Union and the United States is partly due to the gap in residential and commercial space available per capita. Americans enjoy three times more living space per person than Soviets, a ratio which is compatible with per capita energy consumption between the two nations. In other words, the gap in energy consumption is mainly due to the gap in the standard of living.

Analysis of energy use in space and water heating, adjusted for climate and the residential building structure, suggests excessive energy expenditures in this sector in the Soviet Union as compared to the United States. This is true even in light of the widespread use of electric heating in the United States. Heat-energy use in the Soviet Union exceeds use in the United States by 1.1 exajoules.[10]

METHODS OF ASSESSING LIMITS TO ENERGY CONSERVATION

The rate at which economic energy intensity can decrease is limited by many factors. Three variables are paramount in determining the time required for the former Soviet Union to make the transition from energy-intensive growth to energy efficiency compatible with economic growth:

- the time required to replace the resource-intensive economic mechanism
- the rate at which obsolete fixed capital stock can be replaced
- various other factors influencing the improvement and substitution of materials.

It is necessary to understand these factors in order to devise measures for projecting future energy use and implementing these measures to reduce greenhouse gas emissions. Useful analysis combines macro- and microeconomic analytical approaches, the integration of which is a difficult scientific problem. This section discusses proposals for solving this problem.

The analytical process begins by accumulating and organizing a vast amount of information on energy-conservation opportunities in the various spheres of energy consumption. We first compiled an energy-conservation database for the former Soviet Union. This database contains economic and technical parameters for 120 energy conservation-measures listed in the attached tables. The criterion for including a measure is that it results in a minimum annual energy savings of 5 petajoules (PJ).[11] Measures are considered for the most energy-intensive processes and equipment in the industrial, transportation, and buildings sectors. The technological potential for energy conservation is based on the hypothesis that any given measure is applicable over the entire stock of energy-consuming equipment using the most efficient technology.

Energy-conservation measures were combined in some cases based on similarity of technological functions and processes. For example, one measure assesses the energy savings achieved by replacing inefficient lightbulbs with both compact sodium and mercury vapor lamps. In other measures, it was necessary to evaluate the savings achieved by listing them individually, such as the impact of installing natural gas-burning furnaces as opposed to electric steel-melting furnaces.

Tables 2 through 5 in the Appendix list these measures and others for the electricity, energy, industrial, and residential and commercial sectors. Implementing efficient lighting in the electric power generation sector, for example, can save 26 PJ or 0.4 to 0.6 million tons of carbon by the year 2005. Meters measuring energy consumption in this sector can result in a similar amount of savings. The tables also specify the amount of capital investment required for each measure and two discount rates (for more detailed explanation see pages 7 and 8).

Larger scale aggregation of measures can also be performed, for example, improvement of entire energy systems, such as heating, electricity, and air compression at metallurgical plants. The aggregates are influenced by the statistics on energy savings, total capital expenditures, and the total savings of any specific measure. In addition, results are affected by the interaction of the components included in the measure.

Energy-conservation measures almost always effect additional benefits in technological change, such as higher equipment productivity, improved product quality, and reduced environmental pollution along with other negative social impacts. For example, the extensive application of continuous steel casting and construction of quality highways are mainly justified by non-energy considerations. These measures can be classified either as dedicated or accompanying measures, according to the objective by which energy conservation is achieved.

Accompanying measures are those for which investments are not solely prescribed on the basis of energy savings. Dedicated measures, on the other hand, are those for which the main effect is to save energy or include a payback through saved energy over a specified time period. Economic estimates in the tables were calculated for dedicated measures only, which contribute 60 to 70 percent of the total identified savings. The resulting energy savings in this analysis do not include contributions by measures amounting to savings less than 5 PJ per year, savings achieved through accompanying measures, or by structural changes.

It is obvious that energy-savings potential alone is an insufficient criterion for determining the effectiveness of potential measures. Nevertheless, it is possible to evaluate whether it is economically preferable to invest in new energy supply or in energy savings.

Different approaches were used to calculate the amount of savings achieved depending on the characteristics of the measure. We compared the actual and predicted energy consumption when a given technology is applied, using an assumed level of improved efficiency. We predicted these values by evaluating the potential reduction of energy losses, the decrease of expenditures resulting from technological changes, and by reviewing compatible estimates of foreign achievements.

The technological potential for energy conservation gives only hypothetical values without considering the limits to its realization. Obstacles and limitations do exist in implementing technological measures, however, and greatly curtail initial estimates of potential. Below we focus our analysis on a few of these constraints.

The first group of limiting factors is called <u>economic limitations</u>. We consider two economic limits on potential. The first is that the machine manufacturing industry can only produce a certain quantity of energy conservation equipment, and this may require renovating or replacing equipment. Economic considerations, in particular, determine the length of the overhaul period. If plant equipment needs to be taken out of service ahead of time, substantial economic losses may be incurred to the user. Where the energy-resource prices are exceptionally high, on the other hand, replacing old energy-intensive equipment ahead of time may be economically justified. This option, however, is usually accompanied by a lower output of products. Our calculations are based on the average lifetime of equipment and length of overhaul periods (Figure 1).

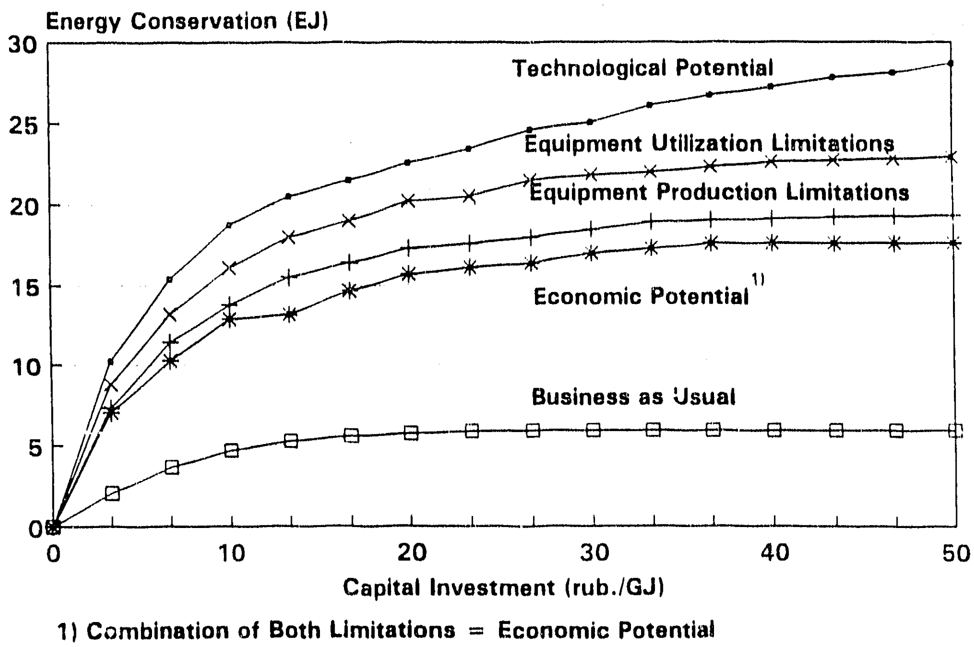


Figure 1. Energy Conservation Potentials by 2005 Compared to 1990 (Source: Authors)

The amount of energy savings achieved by each measure is determined by taking these limitations into account. Neither of these limitations is absolute or inflexible. The first limitation, at the manufacturing level, depends on the amount of investment made to produce energy conservation equipment. Some assumptions can be made regarding the development of the machinery industry to assess the impact of this limitation on realizing potential energy conservation. The rate of energy-efficiency improvement could vary significantly for equal rates of economic growth depending on the availability of machinery.

Government policy could also have a marked effect on the rate of transition. Government agencies could provide direct capital investment, financial credits, tax exemptions, as well as subsidies for purchasing conservation equipment.

The second set of limitations, which we will designate market limitations, includes budgetary constraints and prices for energy resources and energy conservation equipment. We also address the effects of required capital outlay, discount rates, and the rate of equipment depreciation on energy-conservation potential.

Application of energy-saving measures does not lead to substantial added expenses in labor and materials, although, there are some exceptions--for example, in recycling energy waste. Therefore, we can only estimate the depreciation from the additional capital investment when calculating operating expenses. The depreciation rates (the sum of deductions for renovation and overhauling) were adopted in accordance with official regulations, where the levelized costs (LC) are calculated with the following simplified formula:

$$LC = (E_n + a) * K$$

where:

E_n = discount rate

a = equipment depreciation rate

K = capital outlay for energy savings

Capital outlay is estimated using 1983 prices obtained from design offices and research institutes. Where this data is unavailable, prices of similar equipment are substituted. The capital outlay for implemented equipment was calculated as the difference between the cost of the energy-saving and the base equipment. Capital outlay includes the costs of construction and installation, in addition to the equipment purchase cost.

The levelized cost of energy-efficiency equipment depends significantly on the discount rate. This coefficient differs for each investor according to budgetary limitations. Household energy consumers, for example, place stricter demands on payback periods. Several studies from other countries show that household consumers prefer investments with a one- to three-year guaranteed payback period, or capital outlay efficiency coefficients of 0.5 and 0.33, respectively. The decline of real income for the average citizen of the former Soviet Union decreases willingness to pay for energy conservation.

Energy consumers in the services sector usually impose less stringent requirements on capital investment payback. Industry has perhaps the greatest ability to make investments with long payback periods. Two conclusions follow from these observations. First, we should consider in our calculations the fact that consumers in different energy sectors make actual decisions using different discount rates. Second, it is important to understand that different results are obtained if the discount rate used is optimum for the economy as a whole or is taken for a group of consumers in various energy-consumption sectors.

Many assessments of energy-conservation potential do not account for these differences between national economic interests and the interests of individual enterprises and households. As a result, energy-conservation potential is sometimes overestimated. Some government measures can also affect consumer choices. Policy options include altering depreciation allowances, offering subsidies for the purchase and production of energy conservation equipment, and successfully implementing structural reform.

We determined the economic effect of implementing energy-efficiency measures by taking the difference between the avoided costs of additional energy production and the levelized costs of the measures (Figure 2).

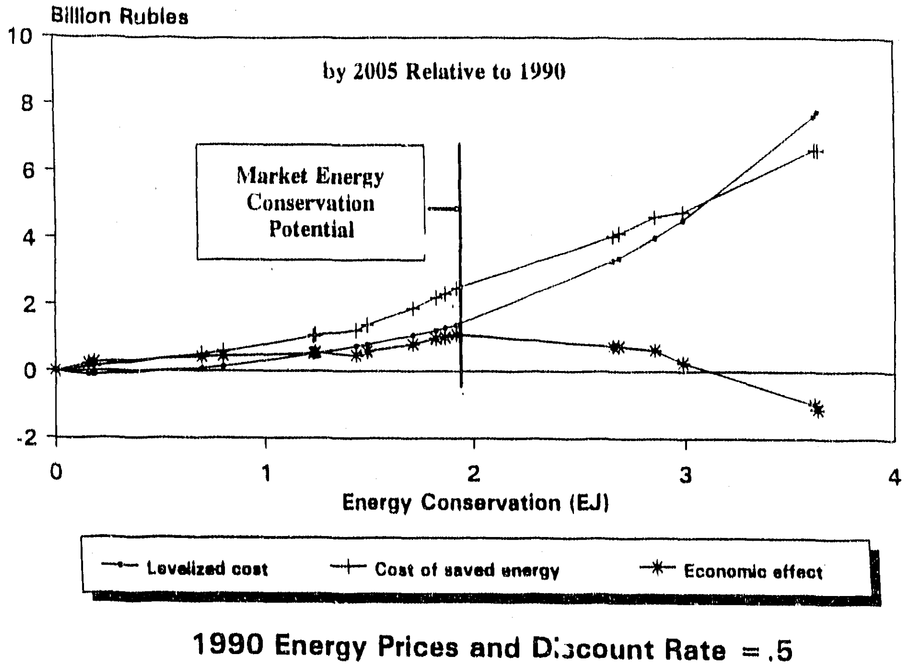


Figure 2. General Concept of Market Energy Conservation Potential (Source: Authors)

We calculated avoided costs in accordance with marginal costs or prices of energy resources. This result directly depends on the anticipated price level.

Several issues relate to evaluations using marginal costs. First, marginal costs reflect the level of costs, while the consumer in a market economy takes into account other variables when making price decisions, such as taxes and profits. The estimate of market potential differs from that based on marginal costs.

Second, marginal costs vary as a function of energy demand. However, if the pricing mechanism is based on estimates of marginal costs, the amount of energy demand at these prices differs substantially from the initial value. Therefore, the values of these marginal costs should be determined from an interactive calculation.

An important point is that price elasticities of energy demand should be estimated for various sectors. As far as we know, no estimates have ever been made for price elasticity of energy demand in the Soviet Union. It is often assumed that with stable energy prices and an administrative-command system of management, meaningful estimates are impossible to obtain. Nevertheless, we believe that these variables can be estimated for two reasons. First, even under the old economic mechanism many production decisions were made by evaluating the relationships between prices of energy, labor, capital, and materials.

Second, energy price indices do in fact change despite stable nominal prices for energy carriers. Real energy prices vary as a result of the following:

- Changes in the structure of fuel type composing in the aggregate energy carrier; that is, the mix of coal or petroleum products changes and therefore so do the prices
- changes in the regional mix of fuels at the point of final consumption--prices do not conform from region to region
- changes in the structure of energy carriers within sectors
- price changes for various goods and services, resulting in a relative reduction of energy prices during periods between energy price hikes (price increases for energy were made only in 1967, 1982, and 1991).

Retrospective analysis of elasticity coefficients gives some basis for conducting prospective estimates. This analysis, however, cannot automatically be applied to an economy which aspires to be market-oriented. We use an alternative approach which determines the market potential of energy conservation at various assumed energy price levels. We can establish an interval of values by comparing the differences of potential values in any sector to the difference between the average price levels for this sector. Thus, we can assess the impact of a measure or producers as well as consumers.

Figures 3 through 6 illustrate the economic effects of energy conservation in the electricity generation, energy, industrial, and residential and commercial sectors. The following conclusions can also be demonstrated:

- Higher energy prices bring greater market potential for energy efficiency.
- More stringent investment requirements (higher discount rates) reduce energy-efficiency potential.
- A nucleus of measures can be cost-effective at any reasonable forecasted price level or investment constraint and should form the core of any energy conservation program.

Three final considerations play a role in determining the market potential for energy efficiency. First, an entire group of additional limitations have not been examined because of the difficulties involved in defining them. These limitations include the lack of information for energy conservation decision-making, and factors such as prestige, customs, and habit.

Second, inflation shifts the function of energy conservation expenditures upwards, reducing the market potential for efficiency. Consequently, it is reasonable to deal only with relative price changes for energy resources. Finally, not all aspects of energy conservation potential fall within the scope of this study.

An evaluation of the possible impacts of these three factors must be carried out in the final assessment of market potential for energy conservation. As we begin to understand these issues more clearly, these estimates will need to be re-evaluated.

QUANTITATIVE ANALYSIS OF THE LIMITS OF ENERGY CONSERVATION

This section assesses the limits of energy conservation in the former Soviet Union through the year 2005. We estimate the impact of assumed energy prices and discount rates on the conservation potential, using the methodology described above. This assessment is the first attempt of its type in the Soviet Union to our knowledge. We calculated the economic efficiency of energy conservation for efficiency measures in the buildings, industrial, fuel supply, and electric power generation sectors.

In each sector, we first calculated the cost of energy saved for two price levels. We used 1990 price levels, in addition to an assumed two-fold price increase, which is close to the marginal cost of supply. The latter is a hypothetical price level, showing the dependence of market potential on price increases.

We then estimated the levelized costs for carrying out energy conservation measures with the normative discount rate and a higher value to reflect consumer discount rates. The normative rate is equal to 0.12 for all sectors. The measures that take into account the consumer discount rate use a value of 0.5 for the buildings sector, and 0.22 for all other sectors. Finally, we calculated both the energy and carbon savings by the year 2005 compared to 1990.

We evaluated the effectiveness of industrial energy-efficiency measures for two capital recovery rates, 0.12 and 0.22. The lower rate is normative while the latter corresponds to a five-year payback period requirement. Between 90 and 95 percent of the energy-saving measures, as a percent of total energy-savings potential, are cost-effective. As for the remaining measures, such as the installation of large methanol production units or improved structure for machine equipment--the technological effect is quite large. Although industrial measures with a total savings potential of 1.5 exajoules (EJ) are considered uneconomical if 1990 prices are assumed, this sum drops to 0.6 EJ when new energy prices are applied.[12]

The tables in the Appendix list the energy savings obtained when a wide range of measures are implemented in each of these sectors. Required capital investments are also listed per gigajoule (GJ) and ton of carbon. In addition, we evaluated levelized costs for the two discount rates.

Table 2 lists energy conservation measures in electric power generation. The total amount of energy saved by implementing the ten specified measures in this sector is equal to 4 EJ, averting emissions of 63 to 66 million tons of carbon. The main way to reduce fuel consumption in electricity production is to employ combined-cycle gas-turbine and steam-gas facilities. The capital investments required for this strategy will not exceed the expenditures for equivalent steam-electric capacity. Thus, additional capital expenditures are equal to zero. These measures are economic for both sets of energy prices, and a capital recovery factor of 0.12. A few measures, however, do not pay back with lower fuel prices and with the capital recovery factor equal to 0.22.

Tables 3a and 3b list measures in the energy sector. By simply reducing coal losses during railway transport, over 0.2 EJ could be saved. Investment would require less than 0.02 rubles per GJ. In the energy sector, however, fuel savings cannot in any case pay back expenditures for reconstructing entire district heating networks, improving thermal insulation and water proofing, or constructing heat exchangers, as these measures are too capital intensive. With the higher discount rate, that is, a shorter payback period, additional measures become uneconomic, including new technologies for oil refining. Moreover, the level of cost-effective energy conservation drops by 0.5 EJ.

Tables 4a through 4f outline measures for conservation in the industrial sector for a total energy savings of over 6.7 EJ, or 111 to 150 million tons of carbon. Measures include improving steel-making infrastructure, installing energy-efficient lighting, and recycling waste paper in production.

Finally, Tables 5a and 5b identify energy-saving measures in the residential and commercial sectors. For example, over 0.5 EJ can be saved by insulating pipelines in district heating systems. New designs for kitchen appliances can save over 0.11 EJ with an investment of only 2.39 rubles/GJ. The total energy savings obtained by implementing all measures in this sector is 3.7 EJ.

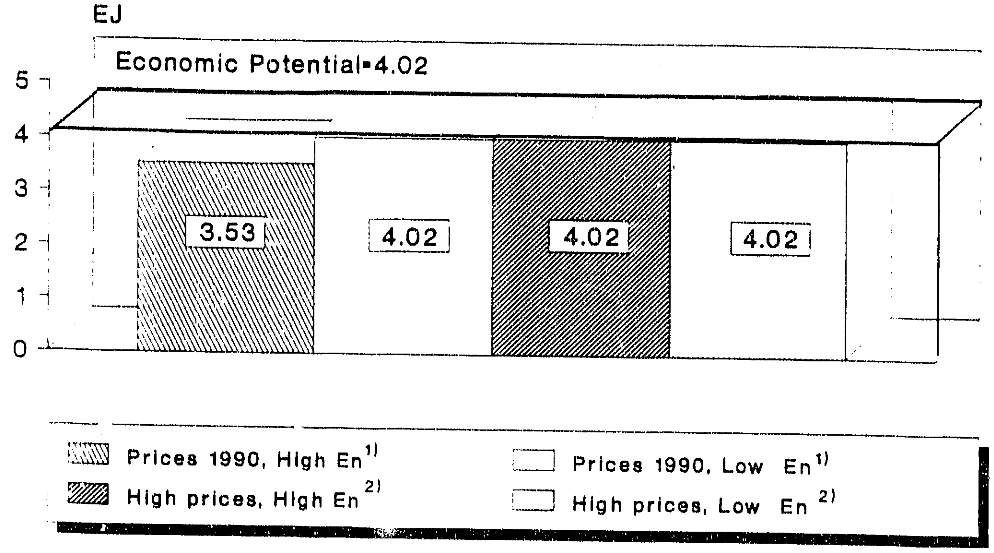
The assumed energy price levels greatly influence the value of energy saved in all sectors, although they have a smaller influence on the level of cost-efficient energy conservation.

All measures in the database are cost-effective in the residential and commercial sectors, assuming the normative discount rate. Individuals may finance a large part of these measures when housing is privatized. An interesting economic experiment would be to observe the number of cost-effective measures undertaken after privatization, assuming the required payback period becomes shorter, corresponding to the psychology of individual investors constrained by budgetary concerns. With a discount rate of 0.5, only half the aforementioned measures would remain cost-effective. The market potential of energy conservation thus may differ greatly depending on the dynamics of energy prices and the assumed discount rate.

We estimated the long-term price elasticity of energy demand in the industrial sector at about -0.1, while in the commercial and residential sectors it is equal to -0.15. These indexes are two to three times lower than in the West. However, if we consider the fact that taxes in western countries constitute a large percentage of the price for energy end-users, the rate of change for these prices will be lower than price changes for primary energy resources. If the elasticity of energy demand is measured on the basis of the latter, the resulting estimates are close to price elasticity coefficients of the Organization for Economic Cooperation and Development (OECD) member countries.[13]

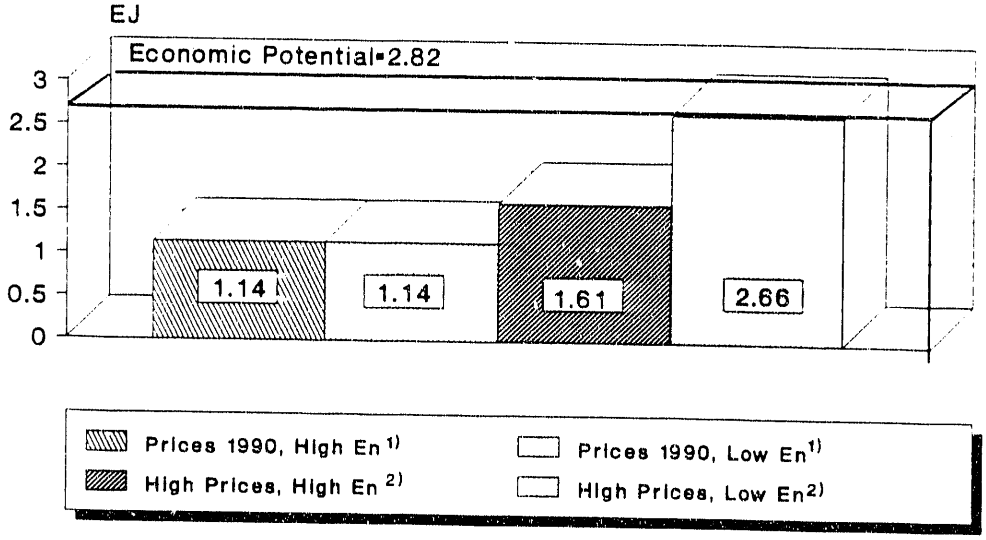
This study indicates that market factors do limit the potential for energy conservation. Additional calculations are needed, however, to obtain more precise estimates of these limitations. Initial estimates show that in several cases in the residential and commercial sectors, for example, market potential is only half the economic potential (defined by the social discount rate). But both economic and market potential could be much greater by implementing government policy measures to stimulate energy efficiency.

The figures in this paper do not depict accompanying measures--measures that save energy but are adopted for other reasons. These measures have a high capital investment per unit of energy saved. The total savings resulting from accompanying measures is 2.1 EJ. Some 59 percent of these accompanying measures are currently available for use in the transportation sector,



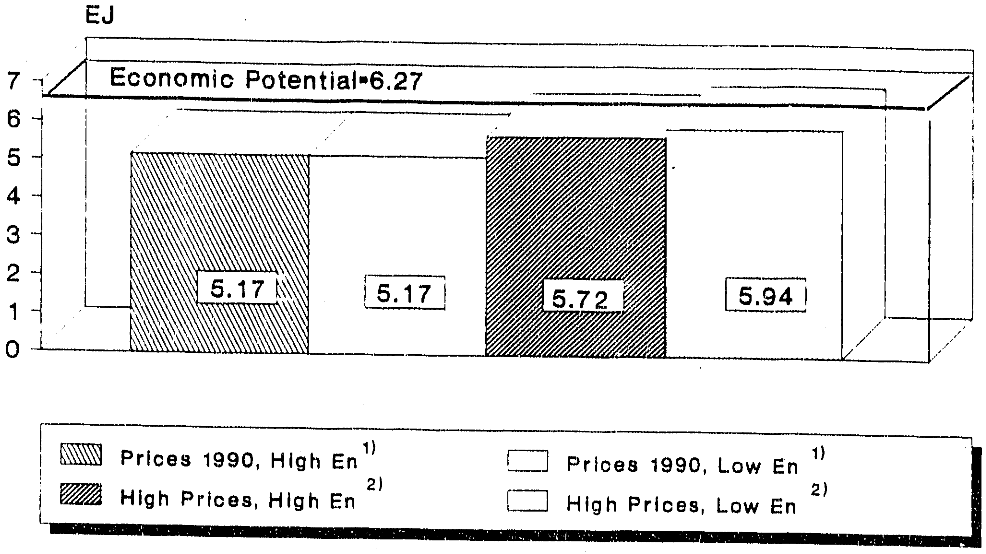
1) En is the discount rate: high=0.5, low=0.12
2) Two-fold increase of 1990 energy prices

Figure 3. Market Energy Conservation Potential in the Electricity Generation Sector by 2005 Compared to 1990



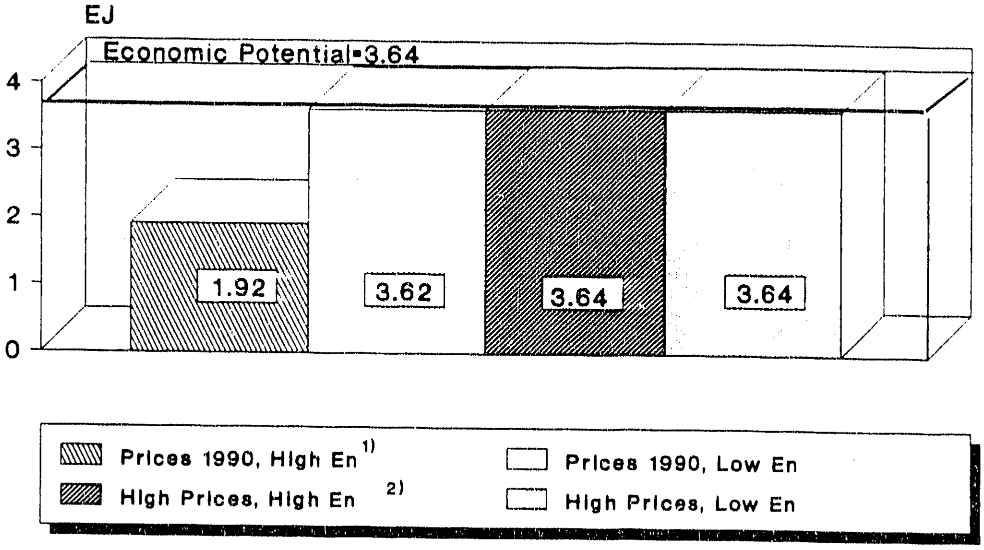
1) En is the discount rate: high=0.5, low=0.12
2) Two-fold increase of 1990 energy prices

Figure 4. Market Energy Conservation Potential in the Energy Sector by 2005 Compared to 1990 (Source: Authors)



1) En is the discount rate: high=0.5, low=0.12
2) Two-fold increase of 1990 energy prices

Figure 5. Market Energy Conservation Potential in the Industrial Sector by 2005 Compared to 1990



1) En is the discount rate: high=0.5, low=0.12
2) Two-fold increase of 1990 energy prices

Figure 6. Market Energy Conservation Potential in the Residential and Commercial Sectors by 2005 Compared to 1990 (Source: Authors)

while 12 and 29 percent are available in the energy and the industrial sectors, respectively.

Estimates of the potential and economically justified levels of energy savings for the national economy are summarized as a function of specific capital investments. Energy savings have also been determined with independent limitations on applying measures. We also present savings due to the same group of measures in the business-as-usual option. The business-as-usual option includes measures without additional financing specifically devoted to energy conservation, but considers steps taken under the old system of decision-making to improve energy efficiency (see Figure 1).

The market potential for energy conservation, depending on the price of energy resources, lies between the economically justified and the business-as-usual options. The difference between these options is the extent to which the measures are applied depending on the given limitations. Therefore, the figures presented here may differ from those published in other energy conservation studies.

Dedicated measures can produce savings of 22 EJ, out of the expected potential of 29 EJ (compared to 1990). Accompanying measures, where energy conservation is an indirect outcome, result in a potential savings of 7.4 EJ.[14]

In conclusion, the economically justified option results in a savings of about 14.7 EJ by the year 2005. The contribution of structural change to energy conservation is assumed to equal 4.5 to 5.9 EJ in order to estimate the overall level of energy conservation in the former Soviet Union. In addition, it is necessary to search for other ways to curtail greenhouse gas emissions. Energy conservation can contribute substantially to this process, but is incapable of stabilizing emissions in the long run.

ENERGY CONSERVATION AND CARBON EMISSIONS REDUCTION

We can calculate the effect of energy-saving measures on atmospheric carbon emissions with some precision using data on the amount of fuel conserved for each measure, and the carbon-to-energy ratios for each type of fuel. We summarized the potential for carbon emissions reduction as savings of millions of tons of carbon (see the last column in Tables 2 through 5b).

Accelerating the use of nuclear power would further reduce emissions at an additional investment of about 400 rubles per ton of carbon. If the nuclear option is pursued, only measures with investment requirements of less than 400 rubles per ton of carbon can be justified in any strong greenhouse gas emissions reduction policy. Only part of the energy-conservation potential identified falls with this limit.

The potentials for carbon emissions reduction for each sector by the year 2005 are summarized as follows:

- 63 to 66 million tons of carbon emissions can be saved in electricity generation by implementing the specified measures.
- 48 to 67 million tons of carbon emissions can be avoided in the energy sector.
- 111 to 150 million tons of carbon can be reduced in the industrial sector.
- 58 to 84 million tons can be saved in the residential and commercial sectors.

Total emissions reduction comes to 280 to 367 million tons of carbon per year by 2005, or 23 to 29 percent of 1988 energy-related carbon emissions in the former Soviet Union.

We estimated the potential for reducing carbon according to the economic potential for energy conservation based on previous calculations. Full implementation of the wide range of measures listed herein in the former Soviet Union can bring about carbon savings equal to the total amount of energy-related carbon emissions in France, Italy, Spain, the Netherlands, Sweden, Norway, and Finland put together (Figure 7).

The importance of environmental interdependence is now accepted around the world. In the process of negotiating international environmental treaties, governments should take action locally, as well as internationally to achieve globally desired results of reducing greenhouse gas emissions with minimal global costs.

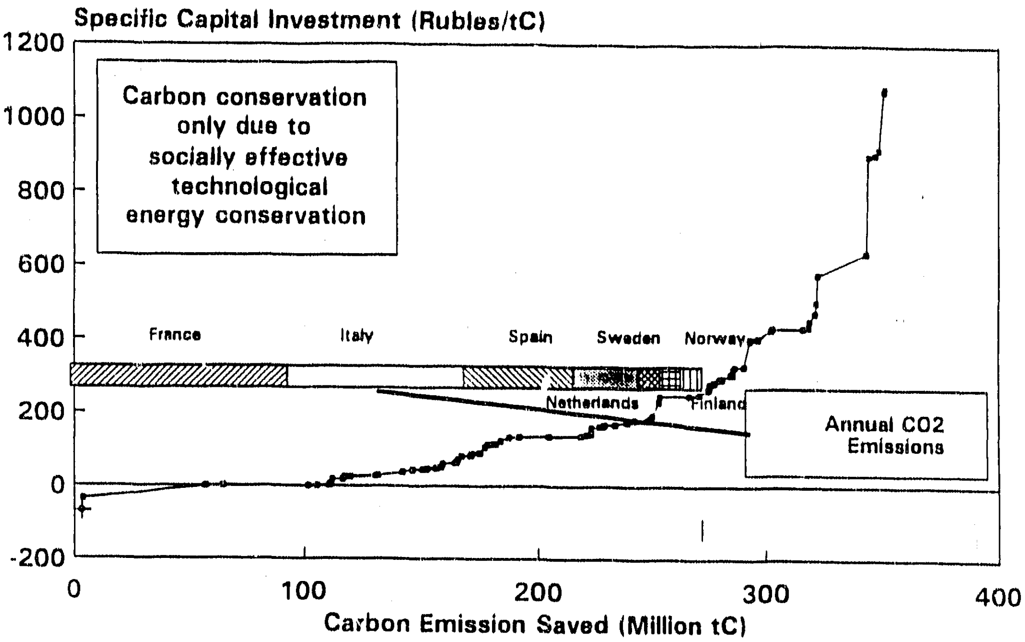


Figure 7. Carbon Conservation Curve for the Former Soviet Union: 1990 to 2005 (Source: Authors)

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5. This result is obtained when singling out 7 to 10 basic sectors of the national economy.

6. Bashmakov, I., et al. 1990.

7. The industrial sector is defined as industry, agriculture, and construction.

8. Bashmakov, I., et al. 1990.

9. Converted at 29.3 gigajoules per ton of coal equivalent from 680, 220, and 180 grams of coal equivalent for the Soviet Union, United States, and Western Europe, respectively.

10. Converted at 29.3 GJ per ton of coal equivalent.

11. A petajoule is 1 X 10^{15} joules, or 1,000 gigajoules. The value cited was converted at 29.3 GJ per ton of coal equivalent.

12. Estimated at 29.3 GJ per TCE.

13. Bashmakov, I., A. Beschinsky, and A. Vigdorchil. 1989. Current Problems of Energy Conservation. VINITI, Moscow, Russia.

14. Again, these values calculated at 29.3 GJ per TCE.

APPENDIX

SUPPLEMENTARY DATA ON ENERGY CONSERVATION MEASURES IN THE ELECTRICITY, ENERGY, INDUSTRIAL, AND RESIDENTIAL AND COMMERCIAL SECTORS

Table 2. Energy Conservation Measures in the Electricity Generation Sector

MEASURE (Install / Manufacture)	Capital Investment		Levelized Cost	Savings by 2005 with respect to 1990	
	Rubles/GJ	Rubles/t C	En=0.22* En=0.12 (Rubles/GJ)	Energy (PJ)	Carbon Million Tons (Mt C)
Steam and gas turbine plants	0.00	0.02	0 0	2475.8	37.5
Heat recovery in congeneration	2.46	168	0.75 0.50	49.81	0.73
Energy efficient technologies	2.56	137.4	0.79 0.53	767.7	14.3
Efficient steam-power stations	2.73	180	0.84 0.57	184.6	2.8
Controlled electric drives in production processes	2.56	102-178	0.88 0.63	55.7	0.8-1.4
Cogeneration at central heating stations	3.75	250	1.16 0.79	293	4.4
Meters measuring energy consumption	3.75	147-220	1.23 0.85	23.4	0.4-0.6
Power factor correction devices	5.63	239-399	1.60 1.04	17.6	0.2-0.4
Cross-section conductors (35-330 kV transmission lines)	7.68	295-497	1.96 1.19	123	1.9-3.2
Efficient lighting	8.19	344-516	2.60 1.78	26	0.4-0.6
TOTAL				4016.61	63-66

* En is the discount rate.

Table 3a. **Energy Conservation Measures in the Energy Sector**

MEASURE	Capital Investment		Levelized Cost	Savings by 2005 with respect to 1990	
	Rubles/GJ	Rubles/t C	En=0.22* En=0.12 (Rubles/GJ)	Energy (PJ)	Carbon Million Tons (Mt C)
Reduction of coal loss in railway transport	0.02	0.7	0.0035 0.0035	205.1	5.3
Improved efficiency of oil refinery furnaces by 22-28%	1.22	63	0.43 0.31	41.02	0.8
Optimization of oil heating temperatures	1.37	63	0.54 0.34	32.2	0.7
Improvement of gas pumping units	2.73	181	0.87 0.60	410	6.2
Controlled electric drives in industrial processes	2.55	100-168	0.89 0.63	222.7	3.4-5.7
Methane for producing electricity and heat	3.11	120-207	0.99 0.68	73.25	1.1-1.9
Meters measuring energy consumption	3.75	220-367	1.22 0.85	87.9	.9-1.5
Power factor correction devices	5.63	213-348	1.60 1.04	67.4	1.1-1.8
Installation of fluidized-bed boilers	6.82	263	2.08 1.40	146.5	3.8
New technologies in oil refining processes	6.49	300-355	2.29 1.64	208.3	3.8-4.5

* En is the discount rate.

Table 3b. Energy Conservation Measures in the Energy Sector

MEASURE (Install, Manufacture)	Capital Investment		Levelized Cost	Savings by 2005 with respect to 1990	
	Rubles/GJ	Rubles/t C	En=0.22* En=0.12 (Rubles/GJ)	Energy (PJ)	Carbon Million Tons (Mt C)
Efficient lighting	8.19	318-550	2.60 1.78	99.6	1.5-2.6
35-330 kV transformers	10.60	378-775	3.00 1.94	20.5	.3-.6
Boilers utilized under pressure	8.50	500	3.15 2.30	23.4	0.4
Improved design of district heating to reduce losses	12.00	468-802	4.45 3.25	1025	15.4-26.4
Natural gas boilers with cooling systems	16.00	1077.1	5.93 4.33	161	2.4
Improved mine and shaft facilities	—	—	—	2.93	0.7
Increased volume of open coal mining	—	—	—	79.11	1.2-2.0
TOTAL				2905.91	48-67

* En is the discount rate.

Table 4a. Energy Conservation Measures in the Industrial Sector

MEASURE	Capital Investment		Levelized Cost	Savings by 2005 with respect to 1990	
	Rubles/GJ	Rubles/t C	En=0.22* En=0.12 (Rubles/GJ)	Energy (PJ)	Carbon Million Tons (Mt C)
Recycling scrap metal in steel making	0	0.01	0.00	386	7.3-7.8
Meters to measure energy energy consumption	1.98	124-213	1.22 0.85	181	3.2-5.5
Continous furnaces for rolling metal	0	0	0.00	8.8	0.1
Improved industrial building insulation	0	0	0.00	129	1.9-3.3
Standards for energy efficient buildings	0	0	0.00	205	3.1-5.3
Local energy autonomy; use of nontraditional energy sources	4.9	8.85	0.04 1.00	140	3
Recycling waste in ferrous merallurgy	0	0	0.00	20.5	0.3
Production of aluminum from scrap metal	0	0	0.00	123	1.9-3.0
Replacement of electric furnaces with gas fired ones	0	0.02-.05	0.00	152	2.2-5.3
Controlled electric drives in production mechanism	2.56	101-169	0.88	546	9.3-15.6
Monitoring of energy use in concrete production	0	0	0.00	11.7	.2-.3
Increased production of cellular concrete blocks	0	0	0.00	108	1.9

* En is the discount rate.

Table 4b. Energy Conservation Measures in the Industrial Sector

MEASURE	Capital Investment		Levelized Cost	Savings by 2005 with respect to 1990	
	Rubles/GJ	Rubles/t C	En=0.22* En=0.12 (Rubles/GJ)	Energy (PJ)	Carbon Million Tons (Mt C)
Production of mixed concrete with plasticizing agents	0.07	2.8-5.7	0.03 0.03	23.4	0.3-0.6
Lubrication technology in sheet and strip mills	0.17	5.0-10	0.04 0.02	5.9	0.1
Utilization of heat distillery liquid to produce soda ash	0.11	6.5	0.04 0.04	11.7	1.9-3.3
Recycling heat of waste gases in chemical production	2.73	160	1.10 0.82	5.8	0.1
Increased clinker calcination	0.22	6	0.08 0.06	2.9	3.1-5.3
Autogenic smelting of copper sulfide concentrate	0.34	20	0.12 0.09	17.6	0.3
Improved iron ore production technology	0.34	13-23	0.13 0.09	26.4	1.9-3.0
Coordination to manufacture & sell efficient furnaces	2.73	175	1.10 0.84	334	5.2
Power factor correction devices	5.63	230	1.60 1.04	96.7	1.5-2.5
Use of sulfides , sulfates, bark, and timber as fuel	0.34	13.0-23	0.13 1.02	225	2.2-5.3
M-400 high capacity methanol production units	0.48	16-33	0.14 0.09	20.5	.2-.3
Reconstruction of air heaters	0.46	29	0.15 0.10	38	1.9

* En is the discount rate.

Table 4c. Energy Conservation Measures in the Industrial Sector

MEASURE	Capital Investment		Levelized Cost	Savings by 2005 with respect to 1990	
	Rubles/GJ	Rubles/t C	En=0.22* En=0.12 (Rubles/GJ)	Energy (PJ)	Carbon Million Tons (Mt C)
Recycling resources for light-weight concrete	0.40	25	0.19 0.15	152	2.5
Increased efficiency of heat-treating furnaces	1.36	59-100	0.30 0.16	73	1.0-1.7
Switching from combine to stationary grain thrashing	0.92	48	0.36 0.26	205	3.9
Membrane method for caustic soda production	1.19	49-82	0.35 0.23	20.5	.3-.5
Clinker production using dry technology	8.19	377-426	2.86 2.13	161	3.1-3.5
Automized brick production with coal enriched waste	5.25	246	2.48 1.96	23.4	0.5
Introduction of automization in pellet producing factories	6.82	400	2.82 2.15	17.6	0.3
Recycling waste for brick and cement production	1.70	113	0.37 0.20	105	1.6
Hot metal setting for heat furnaces	1.02	60	0.39 0.29	35	0.6
Reducing amount of steel in concrete by 3.4 kg/m3	0.85	42-50	0.40 0.32	93	1.6-1.9
Improved technology for concrete structures	0.85	33-57	0.40 0.32	225	3.4-5.8
Use of light -weight machines and tractors	1.20	63	0.46 0.34	205	3.9

* En is the discount rate.

Table 4d. Energy Conservation Measures in the Industrial Sector

MEASURE	Capital Investment		Levelized Cost	Savings by 2005 with respect to 1990	
	Rubles/GJ	Rubles/t C	En=0.22* En=0.12 (Rubles/GJ)	Energy (PJ)	Carbon Million Tons (Mt C)
Production of less energy intensive concrete	1.31	66-77	0.47 0.34	35.2	2.5
Improved insulation for farm structures	1.77	88-91	0.47 0.29	164	1.0-1.7
Improved technology for melting in blast furnaces	1.70	44	0.54 0.38	105.5	3.9
Technologies for regulating gas flow in gas furnaces	7.50	283	2.40 1.66	26.4	0.7
Recycling waste energy in ferrous metallurgy	1.84	77-133	0.56 0.38	108.4	.3-.5
Use of gas turbines without compressors	1.77	69-104	0.39 0.57	23.4	1.6
New techologies in electric steel melting	3.34	131-236	1.19 0.85	35.2	0.5-0.9
New technologies in ferrous alloy production	4.20	185-369	1.67 1.25	8.8	0.1-0.2
Improved heat treatment furnaces in ferrous metal.	1.70	105-122	0.69 0.52	128.9	0.6
Improved technological efficiency	2.45	143	0.50 0.74	117	1.6-1.9
Controlled use of energy & recycling in metallurgy		144-181	0.52 0.79	205	3.4-5.8
Improved sintering technology	2.55	150	0.82 0.56	17.6	3.9

* En is the discount rate.

Table 4e. ***Energy Conservation Measures in the Industrial Sector***

MEASURE	Capital Investment		Levelized Cost	Savings by 2005 with respect to 1990	
	Rubles/GJ	Rubles/t C	En=0.22* En=0.12 (Rubles/CJ)	Energy (PJ)	Carbon Million Tons (Mt C)
Improved rolled stock furnaces	4.78	300-350	1.84 0.34	43.4	0.6-0.7
Electrolitic H boilers in caustic soda production	2.99	175	2.05 1.75	5.9	0.1
Oxidize butene to produce butadiene	7.44	374-523	2.21 1.47	35.20	0.5-0.7
Advanced technologies in ethylene production	7.50	440-500	2.23 1.48	146.50	2.2-2.5
Bricks 50% more hollow (for 75million bricks/year)	8.08	899	3.22 2.41	111.30	1
Type AM-85 & AM 90 large ammonium units	17.07	682-1125	5.09 3.38	131.30	2.0-3.3
Improved machine building technologies	—	0	—	272.50	4.1-5.7
Bleaching sulfate with oxygen additives	—	0	—	5.90	—
Thermo-chemical mechanical (TM,CTM) paper production	—	0	—	2.93	.04-.07
Recycling waste paper in paper production	—	0	—	35.20	0.6
Shifting to production of thinner paper	—	—	—	5.90	2.8-3.7

* En is the discount rate.

Table 4f. Energy Conservation Measures in the Industrial Sector

MEASURES	Capital Investment		Levelized Cost	Savings by 2005 with respect to 1990	
	Rubles/GJ	Rubles/t C	En=0.22* En=0.12 (Rubles/GJ)	Energy (PJ)	Carbon Million Tons (Mt C)
Upgrading machinery (eg.,more buffing equipment)	17.06	667-1167	5.83 4.12	82.4	1.2-2.1
Modern technology for bauxite press.-leach. batteries	3.41	133-240	1.06 0.72	35.2	0.5-0.9
Continuous steel casting	—	0	—	175	2.8-3.7
Automized electrolyzers with 175 & 225 kV	6.14	225-386	3.04 2.43	44	0.7-1.2
Improved infrastructure of steel-making	—	0	—	137.7	1.5-2.4
Energy efficient lighting	8.16	317-536	2.6 1.78	275.4	4.2-7.1
TOTAL				6656.03	111-150

* En is the discount rate.

Table 5a. Energy Conservation in the Commercial and Residential Sectors

MEASURE	Capital Investment		Levelized Cost	Savings by 2005 with respect to 1990	
	Rubles/GJ	Rubles/t C	En=0.5* En=0.12 (Rubles/GJ)	Energy (PJ)	Carbon Million Tons (Mt C)
Insulated panels in new apartments & public bldgs.	-1.32	-89-52	-0.69 -0.18	161.00	2.4-4.1
Exterior insulating shields	-0.68	-4.5-26	-0.36 -0.10	26.40	0.4-0.7
Insulated pipelines in district heating system	0.72	29-47	0.39 0.12	509.80	7.7-13.1
Improved glass door and window designs	0.96	38-65	0.52 0.16	102.55	1.5-2.6
Switching from low to high grade coal in boilers, etc.	1.53	27	0.88 0.29	433.64	11.1
New technologies in heating private homes	0.88	35-52	0.51 0.17	11.72	0.2-0.3
Energy efficient electric ranges	2.04	81-143	1.17 0.39	55.67	0.8-1.4
Automatic central and individual heating controls	1.19	46-119	0.86 0.40	193.40	2.9-5.0
Concentrate heat production at large boilers, shut down others	2.21	132	1.26 0.43	219.75	3.7-94.1
New designs for freezers and refrigerators	2.39	93-152	1.37 0.46	108.41	1.7-2.8
Biogas from sewage and refuse for public utilities	3.07	193	1.66 0.49	43.95	0.7-21.7

* En is the discount rate.

Table 5b. Energy Conservation in the Commercial and Residential Sectors

MEASURE	Capital Investment		Levelized Cost	Savings by 2005 with respect to 1990	
	Rubles/GJ	Rubles/t C	En=0.5* En=0.12 (Rubles/GJ)	Energy (PJ)	Carbon Million Tons (Mt C)
Controlled electric drives in production processes	2.56	102-178	1.60 0.62	55.70	0.8-1.4
Accumulation of electric water heaters with heat pumps	4.60	193-338	2.64 0.89	29.30	0.4-0.7
Production and installation automized boilers	4.50	249	2.63 0.92	732.50	13.3
Introduction of effective heat generators	6.82	—	3.91 1.32	134.80	—
Controlled electric drives for household appliances	5.80	229-379	3.63 1.42	169.90	2.6-4.3
Efficient lighting	8.20	320-540	4.89 1.78	632.90	9.6-16.2
Improved insulation in existing buildings	19.72	722-1445	10.50 2.98	14.65	0.2-0.4
New VCR & TV technologies	—	0	—	64.50	1.0-1.7
TOTAL				3700.54	58-84

* En is the discount rate.

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