UNITED
NATIONS

E

Economic and Social Council

Distr.
GENERAL

ENERGY/2002/11
5 July 2002

Original: ENGLISH

ECONOMIC COMMISSION FOR EUROPE

COMMITTEE ON SUSTAINABLE ENERGY
(Twelfth session, 20-22 November 2002)
Agenda item 6

ENERGY EFFICIENCY AND CARBON TRADING IN THE ECE REGION
- Status and review of selected issues –
-

Note by the secretariat

Introduction

1. The efficient use of energy has been the focus of policy-makers in the ECE region since the mid-1970s. A complex set of reasons has maintained this issue on their agendas for one decade or so: purely economic, financial, broader political and also environmental. It is closely linked to economic growth, energy market structure and quality of environment in such a way that almost all segments of modern society claim to have a right to participate in the related decision making process. The Economic Commission for Europe has been an active party in the process and provided numerous inputs in various forms. Those reasons coupled with an increasing interest in the Kyoto Protocol and its instruments have persuaded the ECE secretariat that a focused and brief paper on the status of energy efficiency and selected policy implications for the region would foster the ongoing discussion among governments, non-governmental organizations and the private sector.[1] In particular, a move from purely descriptive approach towards the use of more sophisticated techniques of analysis was deemed desirable.

2. For the purposes of this paper we define energy efficiency in two steps. In the first and rather narrow framework, energy efficiency is seen as a minimization of specific private energy cost or energy consumption that allows a national economy to operate on its production possibility frontier. A broader and more complex definition of energy efficiency is the minimization of specific private and social energy cost or energy consumption that allows a national economy to operate on its production possibility frontier. While the first definition is almost free from environmental considerations, the second one takes into account an explicit environmental constraint. In the main body of the note we use national energy efficiency and national GDP

energy (emission) intensity interchangeably. Although not synonymous in a literal sense, many of the differences between the two, such as in weather, structure of economy, population density and distances from sources of energy to end-users, seem to be reflected at least partially in relative energy prices, which in turn are a key determinant of energy intensity on a cross-country basis.[2] If for example an economy (i.e. industry) is composed predominantly of activities that rely on intensive use of energy all year long, then the average load factor would be comparatively higher. Everything else being constant, it could translate into relatively lower energy prices. In addition, if a country has a higher population density, then unit costs of serving consumers would be relatively lower resulting in lower end-user energy prices.

3. This note is divided into four parts. The first section deals with the status of energy efficiency in the ECE region in the narrow and the broad sense. Main data on specific energy consumption are presented and analysed for individual ECE countries as well as for three main groups of countries: market economies, economies in transition in central, eastern and southeast Europe, and economies of the Commonwealth of Independent States. The second section focuses on establishing key determinants of changes in energy and emission intensity of gross domestic product. Both cross-country and time-series analysis are used. A relatively large amount of economic, energy and population data was used. The third section deals with selected implications of the analysis on this aspect of energy policy on the domestic and international scene. The last section deals briefly with the analysis implications on targeted reduction of CO_2 emissions under the Kyoto Protocol in the ECE region. The Protocol requires an absolute reduction of greenhouse gas emissions by Annex I countries through the 2008-2012 period. Market economies collectively are supposed to achieve a reduction of emissions of six key greenhouse gases by at least 5 per cent when compared to the emission level in 1990. Thus, in the face of an expected continuation of economic growth, success in the implementation of the Kyoto Protocol depends on the ability of those countries to reduce GHG emissions per unit of gross domestic product (GDP). As this note will demonstrate, it also supposes a simultaneous reduction of energy consumption per unit of GDP. The paper provides certain insights on how the probability of success in the Kyoto Protocol could be enhanced.

I. Status of energy efficiency in the ECE region

4. Energy efficiency in the ECE region varies greatly not only among major groups of countries, but also within each group (Tables 1 and 2), regardless of what measure of gross domestic product is used: based on actual exchange rates or purchasing power parity. The differences between market economies and countries with economies in transition are, however, considerably smaller if the purchasing power parity concept is used. As shown later, the choice of concept would also influence the potential for meeting the Kyoto Protocol emission targets through cooperation between market economies and countries with economies in transition, in particular through often advocated emission trading schemes.

5. If the actual exchange rate base is used for calculation of GDP in the ECE region, the energy intensity of GDP as well as the emission intensity of GDP are highest by far in CIS countries. Ukraine, Azerbaijan, Turkmenistan, Uzbekistan and Kazakhstan, with TS/GDP from 1.74 toe/000 95 US$ to 3.55 toe/000 95 US$ and CO_2/GDP from 5.63 kg /95 US$ to 9.06 kg /95 US$ are certainly the most energy and emission intensive economies in the ECE region. Energy efficiency of E&C European countries also lags behind that of market economies with, in particular, low efficiency in Bulgaria, Romania, The former Yugoslav Republic of Macedonia and

Yugoslavia. They are characterised by high GDP energy intensity of 0.97 toe/000 95 US$ to 1.57 toe/000 95 US$ and high GDP emission intensity of 3.03 kg /95 US$ to 3.77 kg /95 US$.

Table 1. Energy efficiency indicators in the ECE region, 1999

Region	Energy efficiency indicators					
	TS/GDP		CO_2/GDP (kg CO_2/95 US$)		$TECO_2$/GDP (kg $TECO_2$/95 US$)	
	(toe/000 95 US$)	PPP (toe/000 95 US$)	(toe/000 95 US$)	PPP (toe/000 95 US$)	(toe/000 95 US$)	PPP (toe/000 95 US$)
North America	0.27	0.27	0.66	0.65	0.72	0.71
Western Europe	0.16	0.18	0.34	0.39	0.40	0.49
Total market economies	0.21	0.23	0.49	0.52	0.55	0.60
Eastern & central Europe	0.68	0.28	1.90	0.80	2.46 *	1.09
Baltic States	0.87	0.33	1.84	0.71	2.72	1.05
Commonwealth of Independent States CIS)	1.99	0.62	4.97	1.56	9.23*	2.37
Total transition economies	1.37	0.49	3.51	1.25	3.27*	1.33
ECE region	0.26	0.26	0.62	0.61	0.60**	0.64
World	0.39	0.25	0.70	0.58	…	…

* Comparable data for all countries are not available. For example, estimates for eastern & central Europe include only Bulgaria, Czech Republic, Hungary, Poland and Slovakia. Also, the only data for CIS relate to Ukraine.
* * Since data for 18 individual economies in transition are lacking, the weight of economies in transition is considerably reduced and the total equivalent CO_2 emissions appear mistakenly lower that just CO_2 emissions in the previous column.
Source: Unless otherwise specified, all data used in this note are from the electronic database of the International Energy Agency, Paris and data available at the ECE, Geneva.

6. Based on the same GDP concept, energy efficiency in market economies is far from uniform. An average of 0.21 toe/000 95 US$ of GDP and 0.49 kg CO_2 /95 US$ of GDP masks considerable differences, between North America and Western Europe as well as among individual countries. Canada has the highest specific energy consumption and emission of 0.36 toe/000 95 US$ of GDP and 0.74 kg CO_2 /95 US$ of GDP. The United States of America follows closely with 0.26 toe/000 95 US$ of GDP and 0.65 kg CO_2 /95 US$ of GDP. At the same time, of the four largest European economies Italy has the lowest GDP energy intensity (0.14 toe/000 95 US$), while France differentiates itself with the lowest unit emission of 0.21 kg CO_2 /95 US$ of GDP. Otherwise, Switzerland is the most energy efficient developed country with GDP energy and emission intensities at a level of 30 and 18 per cent respectively when compared for example with the USA.

7. Differences in GDP energy and emission intensity in the ECE region become much less pronounced when GDP purchasing power parity notion is used. Still, GDP energy and emission intensities remain largest in selected CIS countries such as Uzbekistan, Ukraine and Turkmenistan: around 3.5 toe/000 95 US$ and around 3.7 kg CO_2 /95 US$ respectively. In this framework energy efficiency of E&C European countries is again lower than that of market economies with in particular low efficiency in The former Yugoslav Republic of Macedonia, Yugoslavia, Bulgaria and Slovakia. Their GDP energy intensity of 1.27 toe/000 95 US$ to 2.21

toe/000 95 US$ and GDP emission intensity of 1.77 kg /95 US$ to 3.07 kg /95 US$ are well above the ECE average.

Table 2. Energy efficiency indicators in the ECE region, 1999
Relative levels, ECE average = 1

Region	Energy efficiency indicators					
	TS/GDP		CO_2/GDP (kg CO_2/95 US$)		TECO$_2$/GDP (kg TECO$_2$/95 US$)	
	(toe/000 95 US$)	PPP (toe/000 95 US$)	(toe/000 95 US$)	PPP (toe/000 95 US$)	(toe/000 95 US$)	PPP (toe/000 95 US$)
North America	1.05	1.05	1.07	1.07	1.08	1.11
Western Europe	0.60	0.70	0.54	0.64	0.67	0.76
Total market economies	0.81	0.88	0.79	0.86	0.92	0.95
Eastern & central Europe	2.61	1.11	3.09	1.31	4.07*	1.71
Baltic States	3.35	1.30	3.00	1.16	4.51	1.64
Commonwealth of Independent States (CIS)	7.66	2.43	8.07	2.56	15.28*	3.72
Total transition economies	5.28	1.90	5.71	2.05	5.41**	2.08
ECE region	1	1	1	1	1	1
World	1.16	0.96	1.15	0.95	…	…

* See notes to Table 1.
* * See notes to Table 1. Note that the index for economies in transition in this column is much lower that it is presumably in reality.
Source: See Table 1

Table 3. Relative size of economies, total primary energy consumption and GHG emissions, 1999
ECE region = 100 per cent

Region	Indicator				
	GDP		Total primary energy consumption	CO_2 emissions	Total equivalent CO_2 emissions*
	(based on 95 US$ and market exchange rates)	(based on 95 US$ and PPP)			
North America	45.5	45.5	47.5	48.5	56.2
Western Europe	50.3	42.8	30.1	27.4	34.0
Total market economies	95.8	88.2	77.7	75.9	90.1
Eastern & central Europe	1.9	4.5	5.0	5.9	6.1
Baltic States	0.1	0.2	0.3	0.3	0.4
Commonwealth of Independent States (CIS)	2.2	7.0	17.0	17.9	3.3
Total transition economies	4.2	11.8	22.3	24.1	9.9
ECE region	100	100	100	100	100

* Since data are not available for most economies in transition, this and the previous column are not comparable. See notes for Table 1.

8. The focus of the Kyoto Protocol is the reduction in annual emission of six greenhouse gases (GHG): carbon dioxide, chloroform, methane, nitrous oxide, perflouro-carbons and sulphur hexafloride. Their global warming potential (GWP) could be expressed in GWP units of CO_2 which serves as a denominator. Thus, Tables 1-3 deal with CO_2 emissions and total equivalent CO_2 emissions ($TECO_2$). It should be noted that due to an incomplete availability of $TECO_2$ data, it is safe to take CO_2 as an ideal proxy on at least two grounds. Firstly, the correlation between CO_2 and $TECO_2$ emissions in a large sample of 27 ECE countries, which consumed roughly 85 percent of energy in the ECE region and were responsible for 84 per cent of CO_2 emissions in 1998/1999 was 99.93.[3] Secondly, CO_2 is by far the largest component of total GHG emissions in the region. In the same sample, its share in the total emissions varies from 92 per cent in North America, 86 per cent on average in Western Europe, 98 percent in Ukraine, 73 to 83 percent in the few countries in transition for which data were available and 68 per cent for the Baltic States.[4]

II. Unlocking key factors behind energy efficiency changes in the ECE region

9. The issue of factors determining energy efficiency changes may be seen from two angles. The first is obviously a cross-country approach. In this context the key questions asked are:

- Why do energy efficiency levels vary among different countries?
- Can tangible factors, which exert a significant influence on energy efficiency, be identified with the desired level of confidence?
- Can we reduce number of those key factors to only a handful so that they may have a practical meaning and significance for policy-makers, the private sector and the general public at the same time?
- If only a very small number of the factors can be identified, how could a meaningful energy and environmental policy be shaped in response?
- How do those factors fit alternative international approaches, such as emission caps explicit in the Kyoto Protocol versus alternative market measures such as energy tax, to raise energy efficiency levels?
- What are the repercussions if any of the analysis on relationships between increasing energy efficiency by alternative international approaches and economic and population growth?

10. This paper tests a hypothesis that differences in energy efficiency among countries in the ECE region, defined as a minimization of specific private energy cost or energy consumption that allows a national economy to operate on its production possibility frontier, i.e. its narrow form, are primarily a function of productivity and relative average national energy prices. The secretariat assumes that the total national productivity might determine the choice of technologies and techniques for the transformation of primary energy in final energy. In addition, it might have the major impact on the efficiency at which final energy is consumed by various sectors. Therefore, higher national total productivity would lead to lower energy intensity, expressed as, e.g. higher energy efficiency. In our model, productivity is expressed as GDP per capita (GDP/pop) in constant 1995 US dollars. Energy intensity is defined as energy consumption per unit of GDP also in constant 1995 US dollars (TS/GDP). It is also assumed that relative national energy end-user prices have a direct influence on the choice of energy-intensive versus energy-saving economic activities. A country with lower energy prices on average is conducive to the adoption of more energy-intensive production techniques when compared with another country characterised by higher average energy prices. Thus, for the same unit of GDP, the former is expected to have higher energy consumption than the latter. The statistical model also allows for a

difference in energy efficiency between market economies and economies in transition that is not explained by differences in productivity and energy price levels. All else being equal, a market economy should have lower energy consumption per unit of GDP than an economy in transition. A fully operational market mechanism will minimize specific energy consumption which, because of market distortions, would not be achieved in a typical economy in transition. Hence, we have introduced a dummy variable (Dummy) to distinguish between the two types of economies in the ECE region. In order to observe the influence of changes of independent variables on changes of dependent variables, the data, except the Dummy variable, were used in log(e) form.

11. The analysis relied on the most recent economic, energy and emissions data for a representative set of ECE countries: Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States of America (ME), Czech Republic, Hungary, Poland, Slovakia and Romania (European Transition Economies or ETE), Kazakhstan and Russian Federation (CIS).[5] The data extended from 1997 to 1999 and included gross domestic product in 1995 dollars (GDP), population (pop), total energy consumption (TS), consumer price index, total end-user energy prices in US dollars per ton of oil equivalent both for industry (high sulphur fuel oil, light fuel oil, automotive diesel, natural gas, coking coal and electricity) and households (light fuel oil, automotive diesel, premium unleaded gasoline 95 RON, natural gas, steam coal and electricity) Real energy prices per country for each fuel in US 1995 dollars were calculated as well as relative annual total energy price index per country when compared to the ECE average (RTP).[6] It should be noted that TS/GDP, GDP/pop and RTP are converted into natural logarithm form which in turn might provide a better insight into the policy implications of this exercise.[7]

12. The results of the multiple regression model based on the assumptions outlined in paragraphs 8 and 9 and completed by the data described in paragraph 10, provided support for the hypothesis that differences in productivity, relative energy prices and status of a country exert a controlling and statistically significant influence on variations in energy efficiency of individual ECE countries (Table 4).[8] Only those three variables explain the more than 95 per cent variation in energy efficiency. It should be noted, however, that the influence of productivity appears overwhelming i.e. much more important than the influence of relative energy prices and country status.

13. Interpretation of the MRM results is quite straightforward. Given the actual levels of energy efficiency, productivity, energy prices and status of each country (transition versus market), and other two independent variables unchanged, one percent increase in total national productivity decreases (increases) energy intensity (efficiency) by 0.33 percent. Respectively, one per cent increase in relative energy prices in one country decreases (increases) energy intensity (efficiency) by 0.82 per cent. Finally, a change in status from an economy in transition to a market economy is statistically real and would reduce (increase) energy intensity (efficiency). However when changes in all three are introduced simultaneously, productivity appears to have a decisive impact on changes in energy efficiency.

14. To arrive at possibly comprehensive policy conclusions, the above cross-country analysis was complemented by an appropriate time-series approach. Given the close relationships with productivity, the key component of GDP growth in market economies, it was assumed that major determinants of changes in energy and emission intensities in a time-series framework might differ from determinants of differences in energy and emission intensity in one particular point in time. The ECE secretariat therefore tested two competing hypotheses. The first was that used in

the cross-country analysis: energy efficiency in its narrow form is a function of productivity and relative average national energy prices. The second tested hypothesis was that time-series energy efficiency was essentially led by its own inertia. The analysis was based exclusively on annual time-series data from1981 to 1999. Since the time series data were not available for the same sample of countries used for cross-country analysis, a sample of all developed countries plus Czech Republic, Hungary, Poland, Slovakia and Mexico was used.[9] This framework for testing the hypothesis was also deemed appropriate since a good part of the energy market has truly global features where various energy suppliers and energy-efficient technologies from a number of countries compete against each other.

Table 4. Key determinants of energy efficiency measured as GDP energy intensity, ECE region, 1997-1999

- Cross section / time series pooled regression analysis, 26x3observations -

Regression Analysis summary

The regression equation is

LTS/GDP = 3.15 - 0.335 LGDP/pop - 0.819 LRTP + 0.451 Dummy

Predictor	Coef	StDev	T
Constant	3.1529	0.5995	5.26
LGDP/pop	-0.33503	0.07035	-4.76
LRTP	-0.8192	0.1342	-6.11
Dummy	0.4506	0.1708	2.64

S = 0.1954 R-Sq = 95.7%

Source: ECE secretariat

15. As expected, the time-series multiple regression model based on the first hypothesis did not produce satisfactory results. The hypothesis that changes in productivity and relative energy prices exert a statistically significant influence on changes in energy efficiency in the developed part of the world economy through time had to be rejected on clear grounds.[10] At the same time, the second hypothesis that energy intensity time-series data were drifting could not be rejected (Tables 5 and 6). As before, based on indications in preliminary statistical analysis, it was appropriate to use original data in natural logarithm form. The use of such a data form would also enable easier interpretation of results of the analysis.

16. The results of the econometric analysis, given in Table 6, confirm the hypothesis that long-term energy intensity data are meandering. The size and sign of all coefficients are as expected. Given the level of energy intensity of GDP in the 1981-1999 period, around 96 per cent of annual changes in the intensity are explained by the regression model. Both the lagged variable and the model as a whole are statistically significant at 99.99 percent.[11]

Table 5. Basic statistics for data used in time-series regression analysis, 1981-1999
Log(e) form , Sample of 30 countries

Data summary

Variable	N	Mean	Median	Tr Mean	StDev	SE Mean
LTS/GDP	18	-1.5434	-1.5676	-1.5449	0.0542	0.0128
LGDP/pop	18	3.0086	3.0335	3.0108	0.1061	0.0250
LTRP	18	6.3049	6.3063	6.3004	0.2283	0.0538

Source: ECE output

Table 6. Test of hypothesis that energy intensity of GDP are drifting through time, 1981-1999
Log(e) form
Time series regression analysis, 19x30 observations

Regression Analysis summary

The regression equation is

LTS/GDP = - 0.118 + 0.930 LTS/GDP-1

17 cases used 1 cases contain missing values

Predictor	Coef	StDev	T
Constant	-0.11772	0.07327	-1.61
LTS/GDP	-0.93032	0.04759	19.55

S = 0.009924 R-Sq = 96.2%

Durbin-Watson statistic = 2.23

Source: ECE econometric output

17. The econometric exercise proved that the energy intensity of GDP through time is essentially self-led. In addition, the intensity drifts at a certain annual rate. The calculation of that drift -1.049 per cent on average per year - is provided in Table 7.

Table 7. Calculation of drift rate of energy intensity of GDP, 1981-1999
Time series regression analysis, 19x30 observations, Log(e) form

Basic Statistics

Variable	N	N*	Mean	Median	Tr Mean	StDev	SE Mean
DLTS/GDP	17	1	-0.01049	-0.01157	-0.01023	0.01027	0.00249

Source: ECE econometric output

18. Modelling of energy efficiency in a broader sense, defined as minimization of specific private and social energy cost or energy consumption that allows a national economy to operate on its production possibility frontier, requires the introduction of one additional indicator – pollution emissions.[12] In this paper CO_2 emissions are taken as a proxy for the total emissions for

two reasons: it is the major pollution GHG element, and its data availability and comparability are the least contentious. The dependent variable in the statistical analysis is CO_2 emission per unit of GDP in 1995 US dollars (CO_2/GDP) observed in 1997-1999 time framework with the same representative sample of ECE countries (Tables 8 and 9). The statistical analysis in this part of the note attempts to address the following additional key questions:

- Do the same factors that determine the behaviour of energy intensity explain country differences as well as changes through time in broad energy efficiency in the ECE region?
- What might be the basic policy implications of the expected results both on energy and environmental policy?

Table 8. Basic statistics for variables used for modelling GDP emission intensity, 1997-1999
Cross country / time series regression analysis, 26x3 observations, Log(e) form

Basic Statistics

Variable	N	Mean	Median	Tr Mean	StDev	SE Mean
LCO_2/GDP	26	-0.498	-0.856	-0.524	1.023	0.201
LTS/GDP	26	-1.272	-1.628	-1.301	0.887	0.174
LRTP	26	4.5035	4.6889	4.5403	0.4506	0.0884

Source: ECE econometric output

Table 9. Key determinants of energy efficiency measured as GDP emission intensity, ECE region, 1997-1999
- Cross section / time series averaged regression analysis, 26x3 observations-

Regression Analysis summary

The regression equation is

LCO2/GDP = 4.69 - 0.621 LGDP/pop - 0.800 LRTP

Predictor	Coef	StDev	T
Constant	4.6926	0.7416	6.33
LGDP/pop	-0.62124	0.07925	-7.84
LRTP	-0.7995	0.1944	-4.11

S = 0.2968 R-Sq = 92.3%

19. The results of the statistical analysis reported in Table 9 point to the conclusion that differences in specific emission intensity of GDP (CO_2/GDP) among ECE countries are a function of variations in total national productivity and in relative total prices, the same two factors that control differences in specific energy intensity of GDP (TS/GDP) at the national level. Furthermore, this relationship proved to be statistically real.[13] As before, it appears that productivity variations exert the most powerful influence on variations in specific emission intensity of GDP (CO_2/GDP) in the ECE region. While relative energy prices do play a role in determining relative emission levels, it is somewhat surprising that the status of a country per se does not appear to have any influence on differences in GDP emission intensity. An insight into

original data, however, confirms a larger dispersion of GDP emission intensity compared to GDP energy intensity (Table 10). These wider variations in GDP emission intensity apply equally to market economies as well as to economies in transition.

20. The interpretation of the MRM results is simple. Given the actual levels of GDP emission intensity, national productivity and relative total energy prices, an increase of one per cent in productivity would translate into an 0.6 per cent decrease in GDP emission intensity. To be valid, this statement requires that relative total energy prices remain unchanged at the same time. Equally, given the actual levels of GDP emission intensity, national productivity and relative total energy prices, an increase of one per cent in relative total energy prices would translate into an 0.8 per cent decrease in GDP emission intensity. To be valid, this statement also requires that total productivity be unchanged.

Table 10. Variability in GDP energy intensity and GDP emission intensity, ECE region, 1999
- normal and loge data
- variability expressed as coefficient of variation

Country groups	Coefficient of variation			
	TS/GDP	CO_2/GDP	TS/GDP	CO_2/GDP
Market economies	0.3930	0.4833	-0.9196	-0.8748
Economies in transition	0.7433	0.7949	0.5276	0.5967
ECE region	1.1246	1.2017	1.8693	2.3814

Source: ECE secretariat econometric output

21. In a time-series framework, changes in GDP emission intensity are not however a function of productivity and energy prices.[14] The regression analysis given in Table 11 indicates that GDP emission intensity through time is essentially led by inertia but this time without a drift or certain statistically significant direction. The absence of the drift is confirmed by the lack of statistical significance of the constant in the regression model. The model's assumption that the next year's GDP emission intensity (LCO2/GDP) is best anticipated by the last year's GDP emission intensity (LCO2/GDP-1) is therefore clearly confirmed.[15]

22. The reason why annual improvements in GDP emission intensity are not statistically real comes from the best fitting shape of the regression model. The model has a negatively sloping quadratic form which means that the improvements in GDP emission intensity are decreasing. At the same time, as shown in the previous text, the regression model for GDP energy intensity resembles a downward sloping straight trend-line. However, both intensities did not in the past decrease at a smooth rate (Table 12). Interfuel substitution in the 1980s away from oil and coal and towards nuclear energy was a major reason for relatively high rates of GDP energy intensity and GDP emission intensity improvements. While this direction of interfuel substitution was no longer possible in the 1990s, a limited switch away from coal-fired to gas-fired electricity generation produced only modest energy efficiency gains. It is also probable that developments in interfuel competition in the current decade would resemble the trends in the 1990s.

Table 11. Test of the hypothesis that emission intensity of GDP is inertia-led through time, 1971-1999
Log(e) form, Time series regression analysis, 19x30 observations

Regression Analysis summary

The regression equation is

LCO2/GDP = 0.0260 + 1.23 LCO2/GDP-1 + 0.252 LCO2/GDP-1SQ

28 cases used 1 cases contain missing values

Predictor	Coef	StDev	T
Constant	0.02595	0.02539	1.02
LCO2/GDP	1.2331	0.1147	10.75
LCO2/GDP	0.2524	0.1163	2.17

S = 0.01364   R-Sq = 99.5%

Durbin-Watson statistic = 2.00

Source: ECE econometric output

Table 12. Declines in GDP energy intensity and GDP CO_2 intensity, developed countries, 1978-1999, Average annual in per cent

Period	GDP energy intensity	GDP emission intensity
1978-80	-2.5	-2.7
1980-90	-2.0	-2.8
1990-99	-0.6	-1.1

Source: ECE secretariat calculations

III. Policy implications of the analysis

23. The above analysis might bring us to the following conclusions:

- The effectiveness of energy policy and the improvement of energy efficiency in the ECE region depend to a great extent on the effectiveness of the general economic structure and economic policy via total productivity growth.

- Apart from exogenous productivity trends, energy policy in the ECE region aimed at smoothing differences in energy efficiency among countries can be conducted efficiently through market measures and instruments. Price policy can be the key powerful and predictable instrument of energy policy both at the national and international market level. In addition, our analysis indicates significant energy efficiency benefits associated with providing assistance to countries with economies in transition in order to develop efficient market structures.

- The rationale for a separate environmental policy aiming at removing differences in energy efficiency among ECE countries in present sets of markets is at best questionable, since it seems that no exclusive market-based policy instrument is at the disposal of this policy.[16]

- Energy efficiency improvements through time, when compared to GDP growth, have been relatively modest. Furthermore, these improvements are decreasing, indicating a probable continuation of slim gains in the immediate future.

- It seems that shocks to the economy and energy sector might be required if higher, hoped for, energy efficiency improvements may materialise by the end of this decade.

24. It thus comes as no surprise that the Kyoto Protocol, an attempt to conduct a separate international environmental policy, is based on a combination of non-market measures (emission caps) and market principles (pricing carbon emissions through trading) to compensate for the market failure to internalise all production costs, in this case the cost of polluting the air for others. In fact, use of the caps should assist the creation of a "missing market for clean air" in other words a market for releasing GHG emissions into the air.

Table 13. CO_2 emission trading: examples and carbon cost estimates

Actual examples		
Participants	Country	Price per CO_2 /ton or C/ton
Arizona Public Service & Niagara Mohawk Power Company	USA	\$2.70/ ton of Carbon
Government of New Zealand	New Zealand	£2.50-5.00 / ton of CO_2
British Petroleum	UK	\$17-22 / ton CO_2
Consorcio Noruego & The Government of Norway	Norway	\$10/ ton of Carbon
Government of Denmark	Denmark	Penalty for non-compliance of \$6/ ton CO_2
GERT	Canada	\$ 1.33 - \$ 6.67 / ton of CO_2
UK emission trading	UK	£53.37 / tone of CO_2
Cost estimates		
Author	Region / Country concerned	Price per CO_2 /ton or C/ton
Eyckmans-Cornillie (2001)	European Union	Euro 152-154 / ton of CO_2
Ellerman-Decaux (1998)	ECE region plus Japan	\$ 200-230 / ton of Carbon
Ellerman-Tsukada (2001)	Japan utilities	\$20-200 / ton of Carbon
Charles River Ass. (2002)	USA	\$72/ton of Carbon
Burtraw (2001)	USA	\$80-140 / ton of Carbon

Note: One ton of carbon (C) is equivalent to 3.667 tons of CO_2.
Source: Compilation of the ECE secretariat

25. A number of experimental CO_2 emission trading schemes are already operating. Although very limited in scope and rather diverse in structure, coverage and implementation, they might provide initial indications as to possible future trends in emission trading In addition, selected estimates of marginal abatement costs of CO_2 within expected more comprehensive national and regional trading schemes are also available (Table 13).[17] Given that in 1999 one ton of CO_2 "supported" the creation of US$ 1,625 of GDP on average in the ECE region, the estimates in Table 13 might look overly optimistic. The same ratio in market economies, central and eastern Europe and CIS was US$ 2,050, US$ 526 and US$ 201. These differences by themselves strongly advocate the creation of an ECE-wide trading emissions scheme.

26. Based on the range of estimates of the cost of abatement of one ton of CO_2 from US$ 10-150 and, say, the anticipated reduction of the total CO_2 emissions in the amount of 626.4 million tons, or 5 per cent compared to their level in 1999, the total base for the creation of a "clean air" market in the ECE region would range from 6.3 to 93.9 billion US$.[18]

IV. Possible implications for the Kyoto Protocol and UNECE future activities

27. This note indicates that the average annual drift at which market economies reduced their specific energy consumption in the last two decades was –1.05 per cent. The GDP emission intensity fell at the same rate in the last ten years in that group of countries, from which the progress towards the meeting targets of the Kyoto Protocol essentially depends.[19] Despite the proof provided that inertia has a strong influence of rate of improvements in energy use, for the sake of providing an example only, we would assume that the GDP energy intensity data would drift in the future at exactly the same rate as it has in the past. Looking at the period 1999-2010, such a hypothetical reduction in the GDP energy and emission intensity would amount to 11 per cent. An annual real economic growth of 3 per cent in those circumstances would produce 38 per cent higher GDP, total energy consumption would increase 23 per cent and necessarily emissions would increase. The same procedure would bring us to the "required" annual drift of –2.93 per cent to stabilize energy consumption.

28. Since "business as usual" developments in market economies as a whole do not provide a sufficient impetus to meet the Kyoto Protocol goals by 2008-2012, economies in transition could be a valuable part of the solution. The enormous disproportion between the size of their GDP and their energy consumption, total GHG and CO_2 emissions given in Tables 1-3 as well as the estimates of much lower marginal abatement cost of one ton of CO_2, indicate that they could certainly play an important role. It is easy to see that all required reduction of CO_2 emissions by market economies at least in the first ten to fifteen years could come from abatements achieved in countries in transition.[20] Furthermore, a number of these countries achieved sizeable reductions in energy and emission intensity in the 1990s (Table 14).

Table 14. GHG emissions, selected countries with economies in transition, 1990 and 1998/99

Country	TS/GDP			TCO_2/GDP		
	1990	1999	Annual average change 1990-99	1990	1998	Annual average change 1990-98
Bulgaria	1.93	1.57	-2.28	10.19	6.89	-4.35
Czech Republic	0.87	0.74	-1.83	3.43	2.73	-2.56
Hungary	0.56	0.49	-1.63	1.96	1.60	-2.26
Poland	0.88	0.59	-4.29	4.64	2.47	-7.01
Slovakia	1.07	0.82	-3.01	3.66	2.37	-4.82
Total	0.89	0.66	-3.38	4.10	2.53	-5.34

Source: ECE secretariat calculations

29. To maximize gains from differences in the marginal cost of CO_2 abatement and move towards the establishment of an ECE-wide emission credits trading system, a number of issues would need to be addressed. First, a trading mechanism for earning "GHG emission credits or

quotas" needs to be elaborated.[21] Second, a mechanism should be designed and promoted that would foster energy efficiency investment by market economies in countries with economies in transition. Third, energy efficiency projects would require a more precise definition than is the case today. This applies in particular to countries where energy prices are absolutely and relatively low with a low probability of being raised to economic levels in the near future. While such countries and sectors provide potentially considerable energy efficiency improvement opportunities, their realization within a emission trading scheme calls for further elaboration.[22] Fourth, despite the fact that more advanced economies in transition achieved substantial energy efficiency gains in the last decade, the continuation of those gains would be more likely with an uninterrupted flow of foreign investment. UNECE has been an appropriate platform for addressing these and similar issues which might be critical for the success of the Kyoto initiative in the ECE region.

30. Thus, to meet the Kyoto targets ECE market economies would need either to reduce substantially energy consumption or to be subject to policy-induced shocks such as large energy price increases. Countries with strong economic and population growth might be in a particularly difficult position in that respect. Thus, ECE policy-makers are facing the challenging task of reconciling somewhat conflicting goals of setting a productive international environmental policy and efficient economic and energy policies.

NOTES

[1] In 1998 the ECE secretariat produced a document entitled: Energy intensity in the ECE sub-regions, 1960-95(6), Focus on countries in transition, ENERGY/1998/11, which provided a wealth of basic data on energy intensity until the mid-1990s and its valuable statistical analysis was focused only on economies in transition in a cross-country framework. Readers interested in past trends in energy intensity should consult that document. This short note deals with the whole ECE region and its two major components: market economies and countries with economies in transition both in a cross-country and time-series framework. It relies heavily on a computerised database, which was not unfortunately available when the research published in the document ENERGY/1998/11 was carried out

[2] For an explanation of this relationships see the results of the regression model used in part two of the note.

[3] All consuming countries with a share in the ECE region energy consumption higher than 1 per cent were included in the sample: USA, Canada, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK, Bulgaria, Czech Republic, Hungary, Poland, Slovakia, Estonia, Latvia, Lithuania and Ukraine. The only exception was the Russian Federation.

[4] The only outlier was Bulgaria, otherwise a particular case, with a share of 56 percent

[5] This choice of countries was dictated by the availability of consistent and comparable economic, energy and emissions data. Fortunately the choice provided a representative sample for the ECE as a whole: almost all market economies are included in the sample with practically 100 per cent of GDP; the five European transition economies have a 76 per cent share in the total ETE GDP; and the Russian Federation and Kazakhstan make roughly three quarters of the GDP of the CIS.

[6] The immense data manipulation needed to carry out this innovative research was facilitated by the availability of selected International Energy Agency data and by ECE secretariat information and knowledge in particular with regard to economies in transition. More than 10,000 data were examined while around 4,500 data were directly used in the statistical and regression analysis.

[7] Basic statistics for those three variables indicated that loge transformation might make a difference in further analysis.

[8] Table 1 reveals that the MRM model used satisfies the stringent statistical checks for significance and coherence. All independent variables and the model itself are statistically significant at 99 percent confidence level. Signs of coefficie nts of all independent variables are as expected: negative for productivity and relative energy prices and positive for dummy variable. In addition, the variation in changes in energy efficiency in the MRM is much lower than the variation in the original data. The MRM is checked for various inadequacies and possible violation of the MRM. The checks provided a very solid confirmation of the statistical validity and consistency of the model.

[9] The sample is in practice composed of 30 OECD countries whose shares in the world GDP and energy consumption are 81 percent and 53 per cent respectively. Except for Australia, Japan, Republic of Korea, Mexico and New Zealand, all countries belong to the ECE region with 97 and 85 per cent shares in its GDP and total primary consumption respectively.

[10] The MRM is checked for various inadequacies and possible violation of the MRM. The checks indicated that there was serious persistence in the data that disqualified an assumption of independence. For example DW statistics were 1.07. For this and related reasons the first hypothesis clearly had to be rejected.

[11] The regression model complies with all needed standard checks. The checks provided a very solid confirmation of the statistical validity and consistency of the model.

[12] We advocate simultaneous use of both TS/GDP and CO_2/GDP as two key indicators of broadly defined energy efficiency in the ECE region

[13] Table 9 indicates that the MRM model satisfies the most stringent statistical checks for significance and coherence, but it is slightly less robust in statistical terms than the MRM used for unlocking determinants of GDP energy intensity. Two independent variables and the model itself are statistically significant at 99.99 percent confidence level. Sign of coefficients of the independent variables is as expected negative. Also, the variation in changes in energy efficiency in the MRM is incomparably lower that the variation in the original data. The model clearly supports the hypothesis that variations in only two variables, total national productivity and relative total prices of energy, explain more than 91 per cent of national differences in GDP emission intensity. Also, the MRM is checked for various inadequacies and possible violation of the MRM. As in the previous case, the checks provided a very solid confirmation of the statistical validity and consistency of the model. Material on all statistical procedures on validity of MRM used in this note are available upon request.

[14] The sample of countries is used as in the time-series analysis for GDP energy intensity.

---

[15] It should be noted that a quadratic form of the previous year's GDP emission intensity (LCO2/GDP-1SQ) is added to the equation. The model itself is robust and satisfies all statistical requirements to be statistically real.

[16] The assumption is that a market for clear air does not exist

[17] The UNECE secretariat also estimated the marginal cost curve for the reduction of CO_2 in a static framework. Depending on the model used for the estimation, the cost of reduction of the first one percent of the total CO_2 emissions today would be between US$ 67 and 131. The cost of reduction of the first 2.5 per cent of the total CO_2 emissions would be between US$ 170 and 330. According to this model, further increases in the CO_2 abatement would require much higher marginal costs

[18] It represents a 5 per cent reduction when compared to the emissions level in 1999. In 1990-99 OECD countries increased their CO_2 emission by 9.8 per cent on average

[19] Given the convergence of the GDP emission and energy intensity improvements and the fact that the same factors determine both GDP energy intensity and GDP emission intensity in a cross-country framework, the terms GDP energy intensity and GDP emission intensity could be used interchangeably.

[20] Assuming as a realistic goal the abatement of 5 per cent of CO_2 emissions by 2008-2012 when compared to the level in 1999, market economies and economies in transition should abate 475 and 151 million tons of CO_2 respectively. Even if all the reduction were achieved in economies in transition, their GDP energy and emission intensity would still be higher than in market economies.

[21] The EU intends to open its own GHG emission trading market by 2005.

[22] The Economic Commission for Europe has dealt in depth with energy efficiency issues in economies in transition since the early 1990s. The experience of its successful EE 2000 and EE 21 programmes has proved the complexity of the energy efficiency issues in economies in transition.