Energy and the Economy
Analyzing the Past and Modeling the Future

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1 The Relation between Energy and the Economy: Examples of the Past

With the number of energy projections and forecasts increasing in the past decades, the question about the relation between economic growth and growth of energy consumption has been a controversial issue. Before going into further detail, it seems useful to talk about some basic principles. In a first approximation, the economic product is the "good" thing and energy is the "necessary evil", the cost paid for the benefit of economic output. Clearly then, economic growth, decoupled from energy inputs is an attractive proposition guaranteeing attention to those who forward it. In our view though, the term "decoupling" here is as misleading as suggesting that one can aspire to have benefits without costs in a sustainable way.[1] "Decoupled" would imply "uncorrelated", but no one would seriously want to hypothesize that. Rather — and this is the scientific method — one should try to find parameters and other variables such as price, GDP structure, development stage of an economy, etc. that describe the relation between energy and economic output in a plausible way.

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[1] All that was originally meant by decoupling is a deviation from the "rule" that growth rates of energy consumption have to match those of economic growth.

2 Conceptualizing the Relation between Energy and the Economy

There are several approaches to energy demand analysis. The most common methodology is based on an analysis of past trends, which are extrapolated to arrive at future demand. The estimates so derived may be useful for short-term projections but are often inadequate for the long-term. This is because economic development is a dynamic process accompanied by structural and techno-economic evolutions, which may not be reflected in simple extrapolations of past trends.

In contrast to the above, the econometric method of demand estimation assumes a statistical relationship between energy demand and certain explanatory variables at the macro-economic level. The simplest conceptual model describing energy demand uses the price of energy and total economic output as the two independent explanatory variables. Two plausible but hypothetical assumptions lead to a functional form of this relationship. The first assumption is that the production of an additional unit of GDP requires the same energy input as an average unit of GDP. Second, assuming that energy consumers operate with a fixed budget, a price increase of 1% is assumed to lead to a decrease of demand by 1%.These assumptions lead to the following formula

$$\frac{E_t}{E_0}=\frac{GDP_t}{GDP_0}/\frac{P_t}{P_0} \tag{1}$$

In other words, growth in energy consumption is a direct function of economic growth and is inversely related to price changes. This literally translates the verbal description into a mathematical formula. The subscript *t* expresses time, *0* a reference time, relative to which changes of the three variables are measured.

The first refinement of this formula is to introduce elasticities into the rigid relationship by introducing exponents that, depending on their size, either dampen or magnify the reaction of energy demand to changes of production or price. The elasticities have the form of exponents. The original formula (1) then becomes

$$\frac{E_t}{E_0}=A(\frac{GDP_t}{GDP_0})^{\alpha}(\frac{P_t}{P_0})^{\beta} \tag{2}$$

For easier reading, the quotient of (1) has turned into a product. As a consequence, β, the *price elasticity*, is negative. The exponent α is called *income elasticity*. Our subject is the relationship between GDP and energy, but we want to briefly touch on the price elasticities. It is obvious that the existence of durable energy consuming devices generates a "lock-in" effect that makes it difficult to respond quickly to price changes. Accordingly, a distinction is usually made between short-term and long-term elasticities. Numerical values are different for different economic sectors, but -0.2 and -0.5 are indicative values for short-term and long-term elasticities. These values indicate that the first, "naive" assumption about a (negative) unitary elasticity is a far shot from what is observed in reality.

To complement this theoretical discussion with actual developments of energy prices, we turn to Figure 1, showing the development of real energy and oil price in the U.S. over more than 100 years. The overall picture is one of a generally horizontal trend with interspersed spikes. This picture is in distinct contrast to long-term developments of GDP which, in most countries, show a persistent upward trend. In the light of the previous formulae, more significant information can therefore be expected from looking at the relationship between energy consumption and GDP.

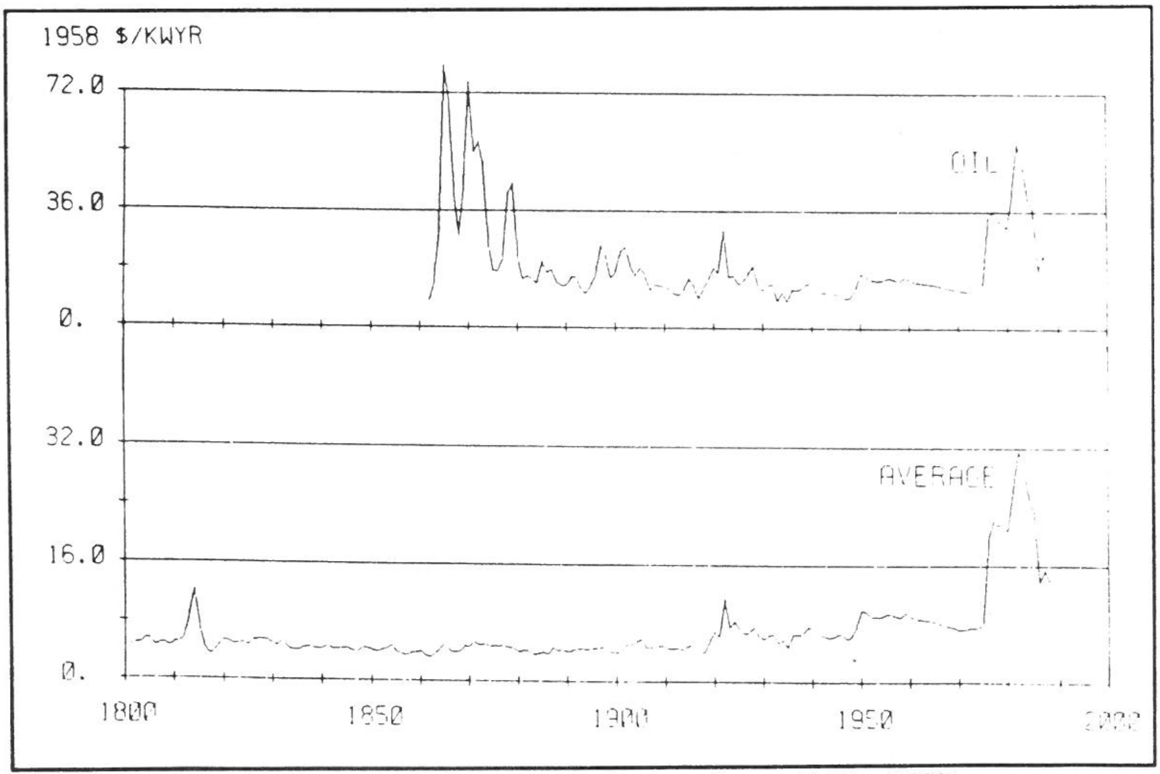

Figure 1: Long-term development of U.S. energy and oil prices. Source: Grübler (1990).

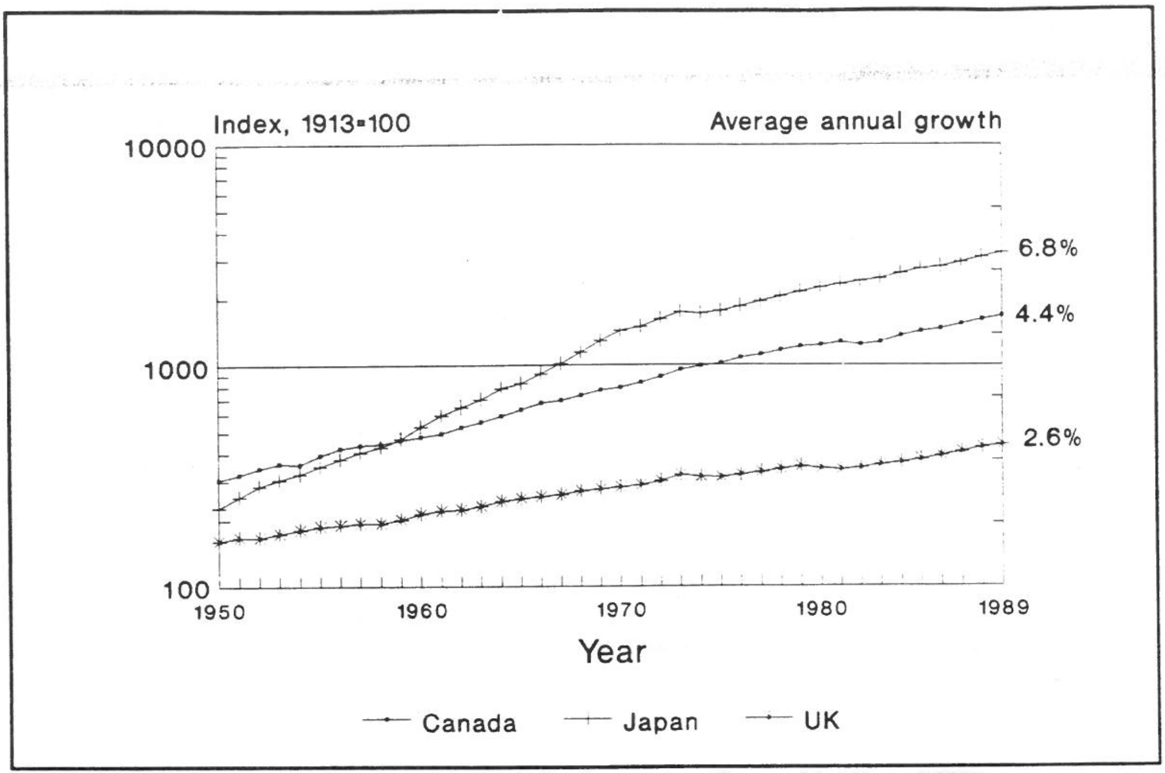

Figure 2: GDP development in selected industrialized countries. Source: Maddison (1991).

Figure 2 shows, on a logarithmic scale, the long-term GDP development in selected industrialized countries. Although they include the extreme (and one typical in the middle) examples of a sample of 16 countries, one has to go back all the way to the year 1913 to see major differences. During the time period shown in the graph (1950-1989), we see a more or less parallel GDP growth in the three countries. The only cross-over happens in the late 1950s when Japan's GDP passes Canada's (in relative units, using 1913 as a base).

The time series for developing countries are not available for comparatively long time periods. Shorter time periods in recent history give examples of rapid economic growth. (See Figure 3, showing economic growth in China and South Korea between 1971 and 1991.)

One factor to consider in the comparison between GDP figures in developing countries with those for industrialized countries is the different purchasing power in these two groups of countries. In most old comparisons, market exchange rates were used to convert both into comparable units, usually U.S. dollars. Recent studies (e.g., UNDP 1993) have shown that the purchasing power in developing countries can be more than five-fold (per U.S. dollar) the corresponding value in industrialized countries. (See Figure 4, showing a comparison exchange rates and purchasing power parity.) With increasing per-capita GDP, the purchasing

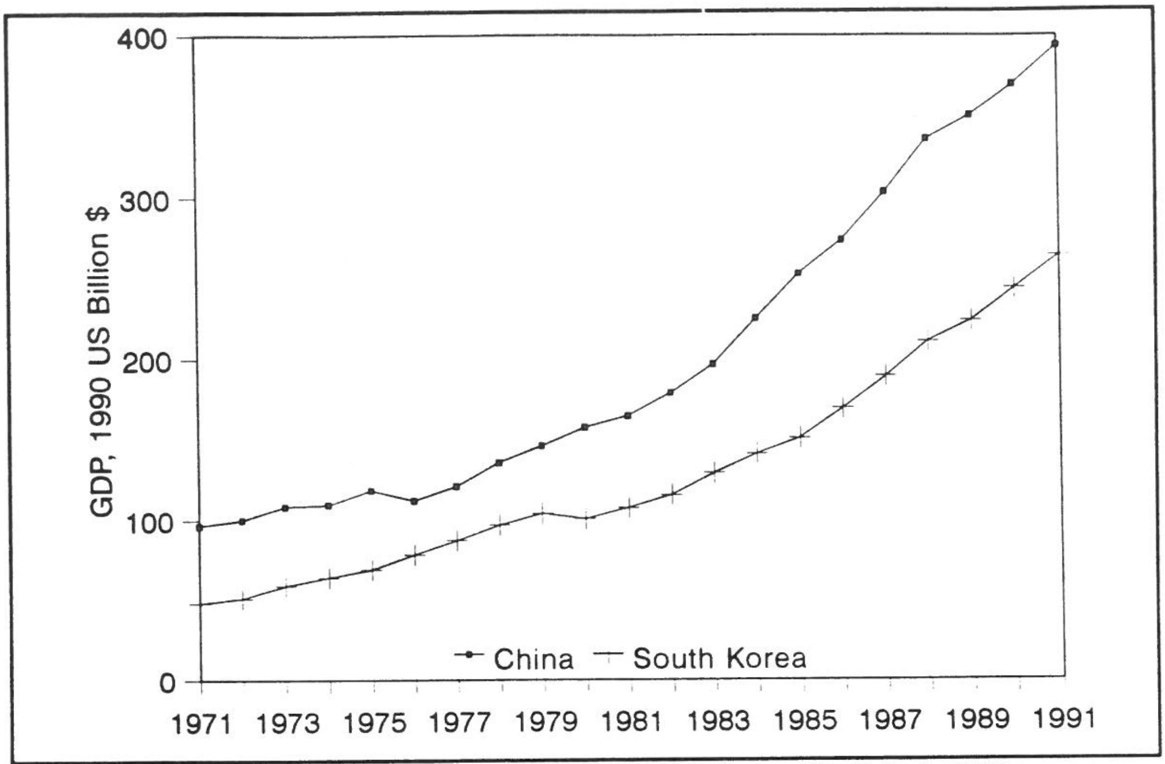

Figure 3: Economic growth in China and South Korea, 1971-91. Source: World Bank (1993).

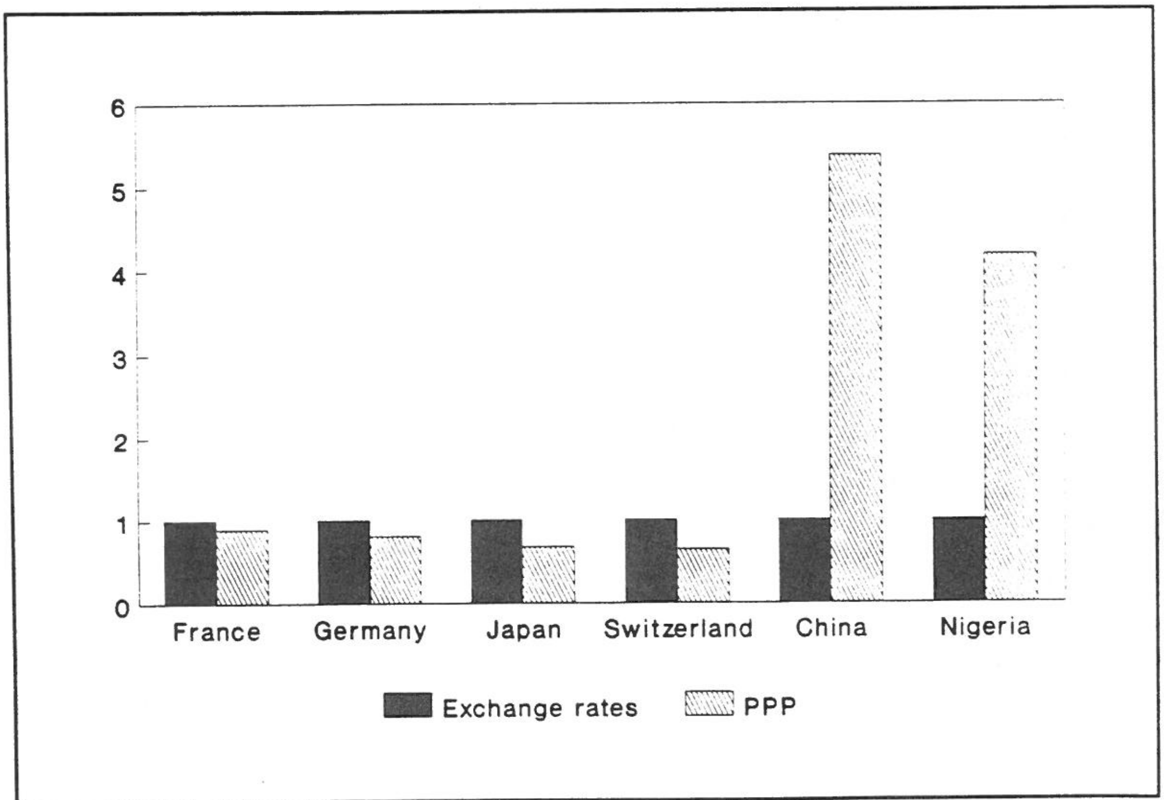

Figure 4: Exchange rates and purchasing power parity. Source: UNDP (1993).

power decreases relative to the dollar. GDP growth rates calculated using the purchasing-power parity (PPP) method are therefore lower than those based on exchange rates. Table 1 illustrates the divergence in GDP growth rates using the market exchange rates and the purchasing power parity, for the Chinese economy.

Table 1 : Average annual rates of growth for China (%)

Period	**GDP at MP**	**GDP at PPP**
1971—1981	5.32	4.31
1981—1991	8.73	6.48
1971—1991	7.03	5.45

MP: Market Prices; **PPP:** Purchasing Power Parity.

Economic growth is not universal, though. Regions undergoing economic restructuring can experience drastic reductions of economic output. The formerly Planned Economies of Eastern Europe and the Soviet Union are an example. There, reductions of annual economic output reached 25%, as illustrated in Figure 5.

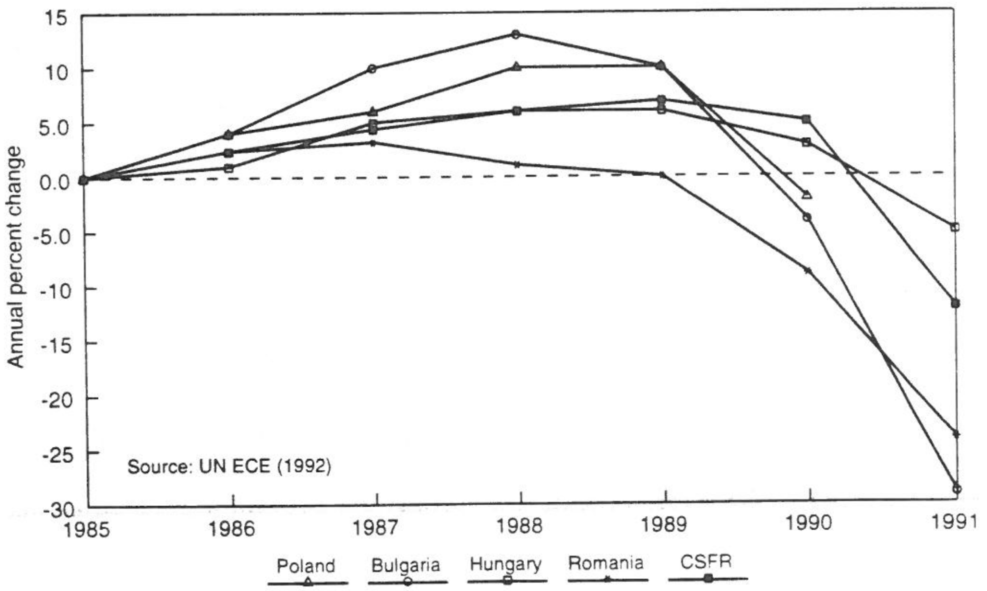

Figure 5: Economic output in Eastern Europe, 1985-91. Source: UNECE (1992).

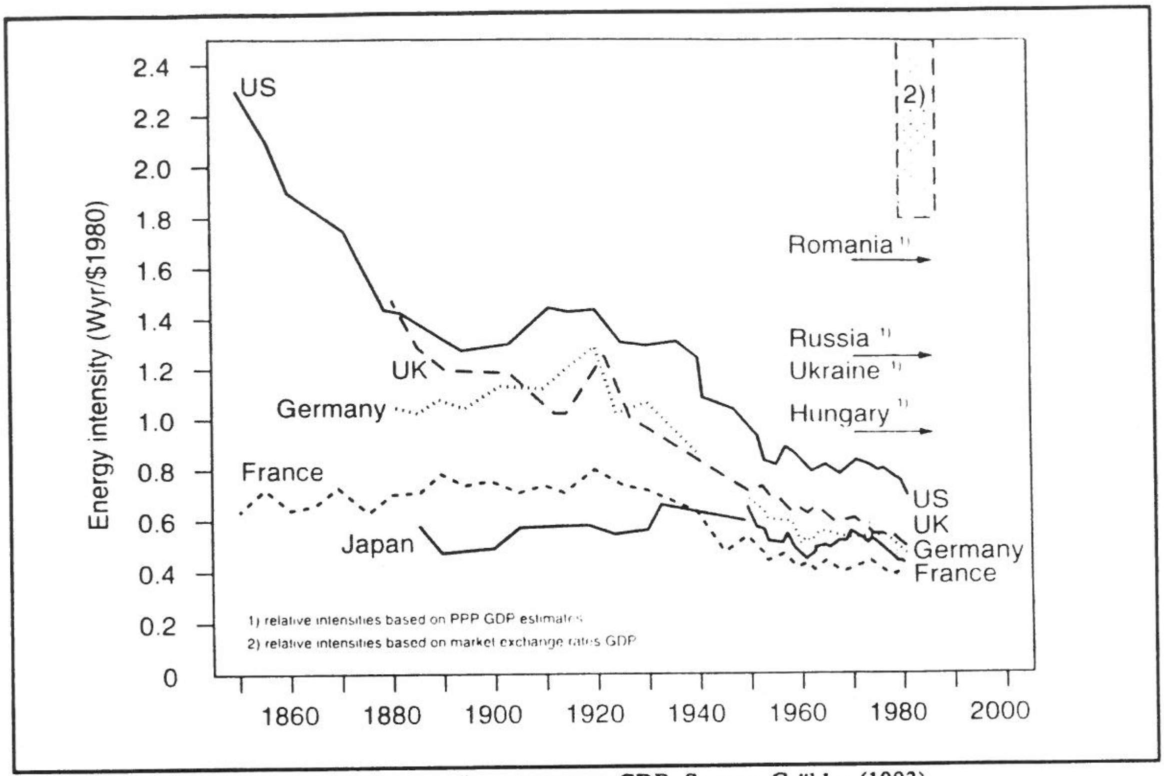

Figure 6: Primary energy (including wood) per constant GDP. Source: Grübler (1993).

The historical development of the relation between energy and economic output, the energy intensity, is depicted in Figure 6, for selected industrialized countries.

For some economies in transition, recent values of energy intensity, calculated with the PPP method, are marked by arrows. For comparison, a shaded area indicates that calculating the energy intensities of those countries with market exchange rates would lead to unrealistically high values. The general picture is one of ever decreasing energy intensity with significant differences between countries. (It should be emphasized here that we include non-commercial energy, wood, in our analysis. Others, e.g., Goldemberg et al. (1990), do not include non-commercial energy in their calculations of energy intensity and therefore find peaks that we do not see.)

Examples of average annual decline rates of energy intensity, based on Figure 6 are given in Table 2.

Table 2 : Average annual decline rates of energy intensity (%)

	1913 — 1988	1970 — 1988
United States	(-) 0.93	(-) 1.76
United Kingdom	(-) 1.32	(-) 2.59
Germany	(-) 1.31	(-) 1.58
France	(-) 0.93	(-) 1.06
Japan	(-) 1.30	(-) 2.73

Typical and long-term decline rates are between 1 and 1.5% per year. In periods of higher energy prices (e.g. during the seventies and eighties of our century), we find higher rates. From this we conclude that a third factor, further to GDP and energy price, influences energy demand and energy intensity. This factor reflects changes in the composition of GDP, technological progress, fuel switches, and others. In economic models, it has been dubbed "Autonomous Energy Efficiency Improvement" (AEEI) to emphasize its price independence. The AEEI factor plays a major role in the model described in the next section.

3 A Model of Energy-Economy Interactions

In this section, we go from one simple relation describing energy demand as a function of economic output and energy prices to a full model of energy-economy interactions. The model is Global 2100, and we will describe the model together with a typical application. Our description is based on Manne and Richels (1992).

3.1 Model overview

Global 2100 is a dynamic nonlinear optimization model. Its objective function is the total discounted utility of a single representative producer-consumer. The maximization of this utility function determines a sequence of optimal savings, investment, and consumption decisions. In turn, the levels of savings and investment determine the capital stock. The capital stock, together with labor and energy inputs, determines total economic output according to a nested constant elasticity of substitution (CES) production function. The model calculates how to provide, at minimum cost, the energy demanded by the economy, subject to resource and environmental constraints specified by the user.

The inputs to Global 2100 are assumptions about potential economic growth, autonomous energy efficiency improvements (AEEIs), energy substitution elasticities, international oil prices, data on energy resources, and technological data. The main model output is the energy demand in the electric and nonelectric categories. These demands are consistent with macroeconomic development. This consistency is important in reference cases, but is even more important in sensitivity runs.

3.2 Model description

Figure 7 presents a schematic description of Global 2100. The left side shows Global 2100's reference energy system (RES), which interacts with the macroeconomic module at two points: E, the demand for electricity, and NE, the demand for nonelectric fuels.

We begin the model description with the macroeconomic module. Overall economic output is described by the following Constant Elasticity of Substitution (CES) production function.

$$Y_t=[a(K_t)^{\rho\alpha}(L_t)^{\rho(1-\alpha)}+b(E_t)^{\rho\beta}(N_t)^{\rho(1-\beta)}]^{\frac{1}{\rho}} \qquad (3)$$

On the highest level, the production function combines two production factors, a capital-labor aggregate (variables *K* and *L*) and energy (*E* for electric and *N* for non-electric energy). Each of these factors is the result of an aggregation by a Cobb-Douglas (C-D) production function. Both production functions (CES and C-D) have the property that one and the same output can be achieved by different compositions of the inputs. The optimal input mix is determined by the prices of the production factors. The parameter α is the optimal share of capital in the capital-labor aggregate, β is the optimal share of electricity in the energy aggregate. The parameters *a* and *b* are estimated from base-year values. The elasticity in the CES production function, $\sigma = 1 / (1 - \rho)$, describes the "ease" with which one of the two factors can be substituted for the other. The extreme values of σ describe situations in which one unit of one production factor can be substituted by one unit of the other without a loss of output (as $\sigma \to \infty$) and one in which a given output level can be achieved by exactly one combination of inputs ($\sigma = 0$). In the runs presented below, σ is equal to 0.4 in the industrialized regions and 0.3 in the developing regions. Figure 8 shows iso-lines of production for different values

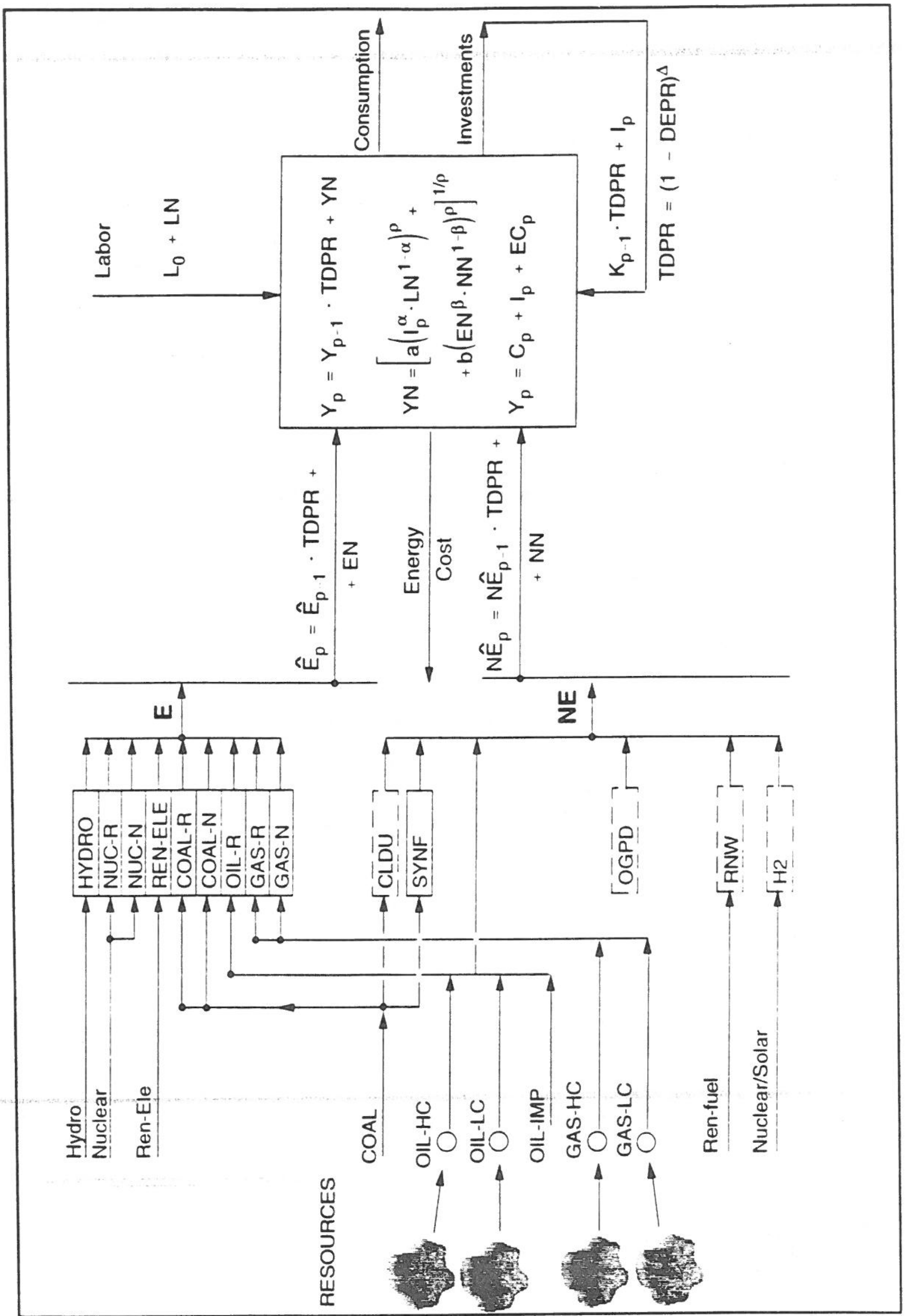

Figure 7: Schematic description of Global 2100 including the reference energy system (RES).

of σ, i.e., factor combinations that yield a given output. For more information on production functions, see Allen (1967).

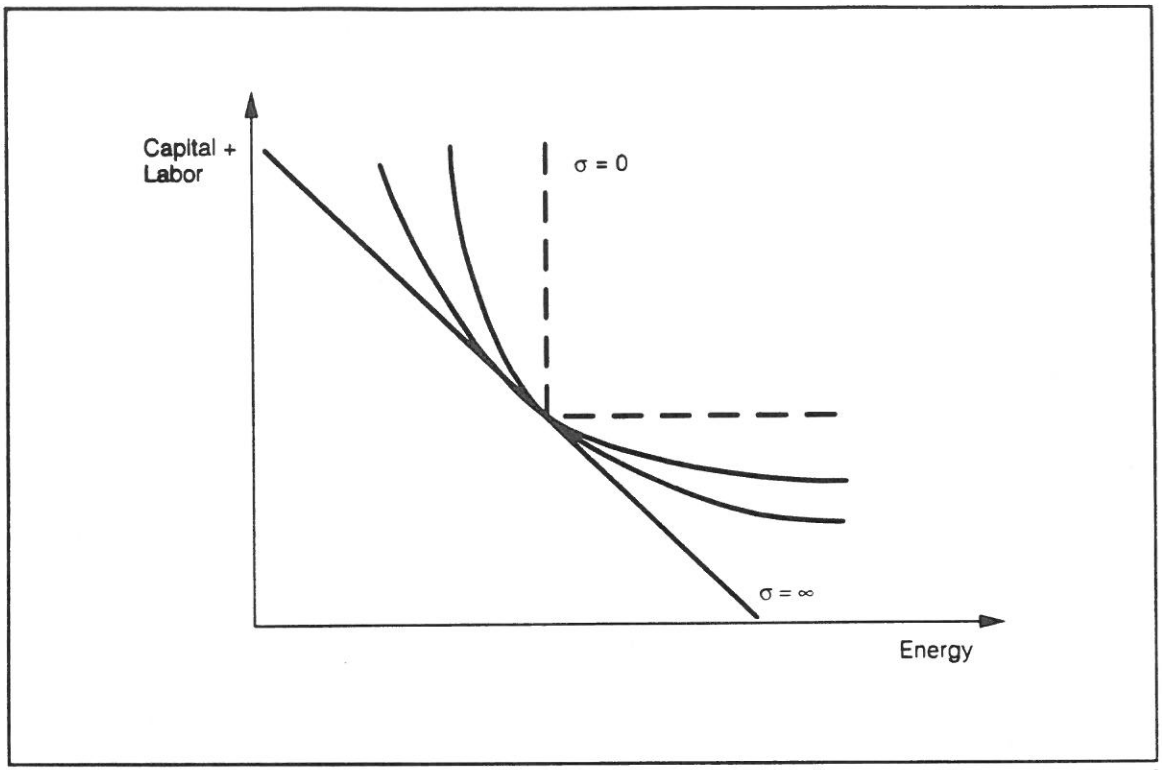

Figure 8: A schematic representation of a CES production function with different values for the elasticity of substitution.

Global 2100's production function is of the ''putty-clay'' type, i.e., it distinguishes between new and existing production factors. Total output in time period p (Y_p) is therefore composed of output produced by the existing production factors (which decrease over time depending on a depreciation factor, TDPR) and output produced by the new production factors (the letter N is appended to the model variables).

Between the production function and actual energy demand is a factor, the autonomous rate of energy efficiency improvement (AEEI), describing price-independent reduction of energy intensity. This empirical factor describes a number of real-world phenomena including technological progress, structural changes of GDP composition, and fuel switching. In the schematic model description, the application of the AEEI factor makes the difference between the variables E and NE and Ê and NÊ. The ''hatted'' quantities denote demand by the economy in the absence of ''autonomous'' efficiency improvements. In the absence of changes in the relative factor prices, the projected energy demand grows as fast as GDP, reduced by the AEEI factor.

The energy submodule of Global 2100 is divided into electricity generation and non-electric (i.e., fuel) supply. In electricity generation, a distinction is made between existing (ending in -R) and new technologies. The existing capacities are phased out according to a schedule specified by the user, and no additional buildup is permitted for them. The only existing technology that is treated differently is hydro electricity, which is assumed to follow a fixed path during the entire time horizon. Future electricity demands can be supplied by hydropower, new coal power plants (COAL-N), combined-cycle gas power plants (GAS-N), nuclear power plants (NUC-N), and electricity generated from renewable sources (REN-ELE).

Some of the activities describing the supply of nonelectric energy demand are given in the boxes with dashed lines. Those activities are not modeled as genuine technologies converting primary to secondary energy at some efficiency but only as providing energy in units that are comparable to oil, which therefore serves as the ''reference'' nonelectric fuel. Other fuels are gas (for which a price markup, OGPD, is defined to reflect the actual competition between oil and gas in the market for nonelectric energy), coal (CLDU-direct uses of coal), renewables, synthetic fuels, and hydrogen.

In the resources module of Global 2100, uranium, coal and synthetic fuels are assumed to be unlimited within the time interval considered. Renewable resources are limited by annual availability constraints. Domestic oil and gas are limited and modeled in some detail. For each of these fuels, two cost categories and two kinds of resources (reserves and resources in the narrow sense) are defined. Following the usual definitions, only reserves are available as primary energy supply. The annual availability of reserves is constrained by a factor that limits the ratio between annual extraction and remaining reserves. Resources are converted into reserves at an annual fixed rate. In addition to domestic primary energy Global 2100 includes oil imports. Trade of other primary energy carriers is not included.

3.3 An illustrative model application

As an illustration of global scenarios that have been generated by the Global 2100 model, we present two runs with inputs that have been derived from two networking activities, IEW and CHALLENGE.[2] Both networks use poll forms to collect energy projections for the world and world regions. CHALLENGE in particular is concerned with reductions of global greenhouse gases (GHG) emissions. We therefore present a Reference case and one GHG reduction case to illustrate Global 2100's responsiveness, in terms of energy-economy

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[2] Both networks have IIASA as a focal point. For a description of CHALLENGE, see, e.g., Schrattenholzer (1994); and Manne et al. (1991) for the IEW.

interactions, to variations of the input data.

3.3.1 A Reference Case

Global 2100 has a time horizon through the year 2100. For the purposes of this general discussion, we restrict the presentation of model inputs and outputs to the more foreseeable time period 1990-2020.

Table 3 presents the two most crucial inputs. One input is potential economic growth, given as growth rates of total labor (i.e., the combined effect of labor productivity and labor force) assumed for the five regions and the three 10-year time periods. The low growth rate for the EEFSU region in the time period 1990-2000 reflects the current developments in that region. The other important input is the AEEI factor. The numbers used here are based on the original inputs by Manne and Richels (1992). They have been modified for the OOECD region and for China to reflect the IEW and CHALLENGE poll responses.

Table 3: **Potential rates of economic growth and AEEI Factors in five world regions, inputs into Global 2100.**

	USA	**OOECD**	**EEFSU**	**China**	**ROW**
Average annual rate of growth, %					
1990-2000	2.5	2.5	0.7	5.0	4.0
2000-2010	2.0	2.0	2.8	5.0	3.75
2010-2020	2.0	2.0	2.4	4.5	3.5
AEEI, % per year					
1990-2000	0.5	0.9	0.5	0.5	- 0.1
2000-2010	0.5	0.9	0.5	0.5	0.0
2010-2020	0.5	0.9	0.5	0.5	0.1

For our purposes, the most relevant indicators of model outputs are the growth rates of the two region-specific variables: economic output and total primary energy consumption.

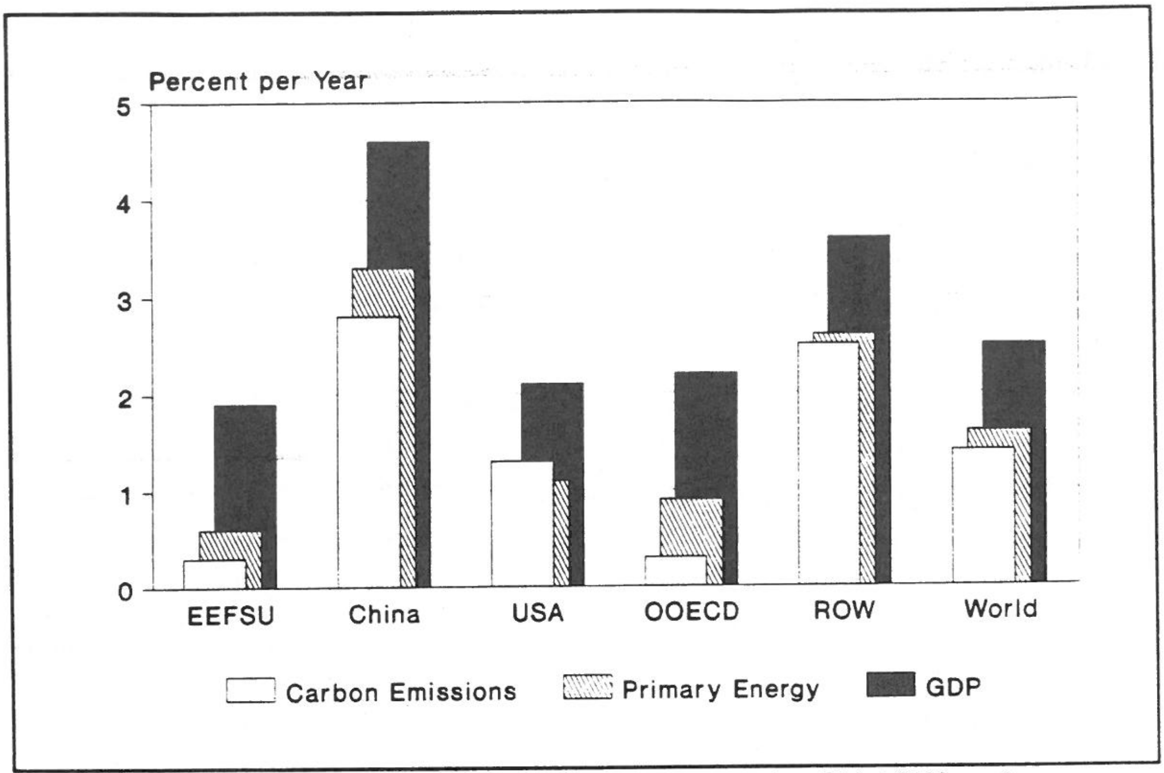

Figure 9: Growth of economic output and of primary energy consumption; Global 2100 results.

Figure 9 shows these indicators for the five Global 2100 world regions and for the world as whole. As expected, the figure shows a decrease of total primary energy consumption per unit of GDP in all world regions. (See also Table 4.) The most pronounced decline of energy intensity occurs in EEFSU and OOECD — for different reasons. In the countries with formerly planned economies, the historically subsidized energy prices are assumed to approach world market levels inducing a higher energy efficiency. In the OOECD region, the present trends of energy intensity reduction are expected to continue.

In absolute terms, primary energy consumption in the Global 2100 model increases from just below 8 billion tons of oil equivalent (Gtoe) in 1990 to approximately 13 Gtoe in 2020.

3.4 A Carbon Tax Scenario

The relation between energy demand and a carbon tax was included in Global 2100 to analyze the consequences of such a tax on economic growth, on energy supply, and on carbon emissions. Here, we just want to illustrate how energy price changes influence the relation between energy and economic growth. In order to have a "controlled experiment", the only change of input data relative to the Reference case was a carbon tax of $200 per ton of carbon emitted during the consumption of fossil fuels. In effect, this definition assumes domestic lump-sum recycling of the revenues generated by such a carbon tax.

According to Global 2100 outputs, introducing a $200 per ton carbon tax could reduce global primary energy consumption to under 11 Gtoe (instead of 13) in the year 2020.

Table 4 shows the decline rates of primary energy intensity in the year 2020, for the Reference case and the Carbon tax case of Global 2100. The results of the Reference case are in good agreement with the long-term historical rates reported in Section 2. Those in the Carbon Tax case are in line with the rates observed after 1970.

Table 4: Average annual decreases (in percent) of primary energy intensity of GDP in the year 2020, Global 2100 outputs for the Reference and the Carbon Tax cases.

Region	**Reference Case**	**Carbon Tax Case**
USA	-0.94	-1.74
OOECD	-1.29	-1.83
EEFSU	-1.28	-1.63
China	-1.32	-1.97
ROW	-0.95	-1.58
World	-0.95	-1.56

To describe the costs, we look how much deadweight GDP losses such a scenario might entail. Figure 10 shows GDP losses in five world regions as a consequence of a $200 per ton carbon tax. According to this particular model run, the largest percentage losses could occur in China. The ROW (all other developing countries) would also be major losers from an agreement to institute a uniform global tax.

Looking at the impact on long-term percentage GDP growth rates, (see Table 5, showing GDP growth rates for China for both the Reference and the Carbon Tax cases) we find that absolute losses in excess of 4% (in the year 2020) correspond to a reduction of the growth rate (between 2010 and 2020) of not more than a fraction of one percentage point annually. But this is only a manifestation of the well-known effect that slight average growth rate differences lead to big absolute differences in the long run.

Table 5: **Annual GDP growth rates for China, Global 2100 outputs for the Reference and Carbon Tax cases**

	1990-2000	2000-2020
Reference Case	5.04	4.58
Carbon Tax	4.79	4.51

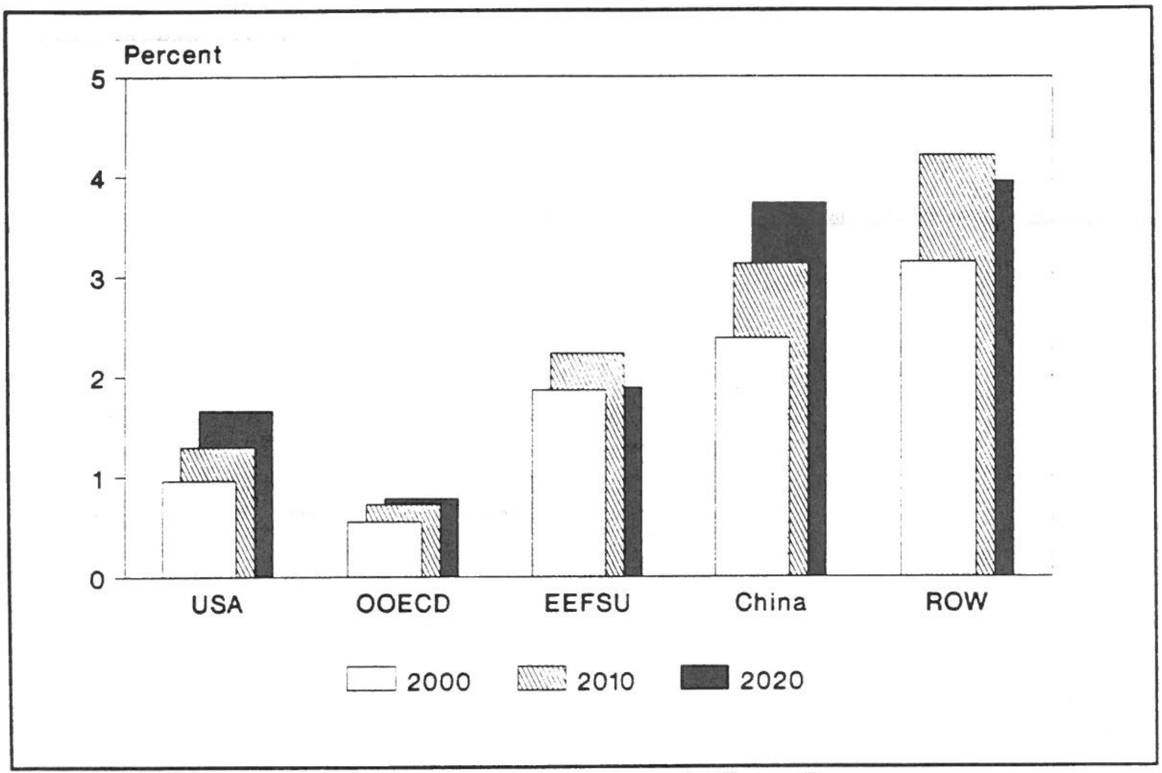

Figure 10: GDP losses in five world regions, Global 2100 results, Carbon Tax case.

4 Other Projections of Energy Intensity

In the previous section, we presented modeling results that were based on contribution to the IEW and CHALLENGE networks. As a separate result, we show here a summary of all poll responses received within these activities that can be classified as reference cases. This restriction eliminates reduction cases as such as the Carbon Tax case presented above.

Figure 11 shows mean values and ranges (defined as the mean plus and minus one standard deviation — assuming a log-normal distribution of the original intensity values) of energy intensity development, based on IEW and CHALLENGE reference-case projections for all world regions and countries for which they could be calculated. The result is that the means are in good agreement with the historically observed values presented in Section 2.

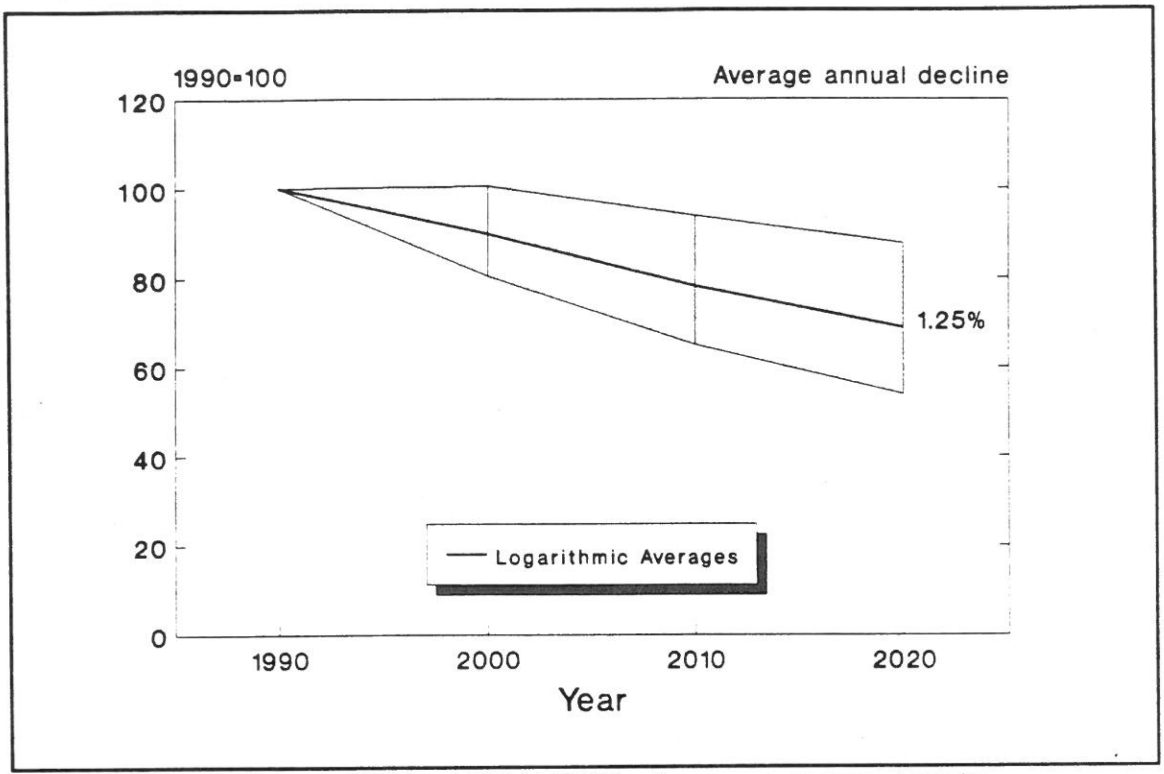

Figure 11: Means and ranges of IEW and CHALLENGE poll responses on energy intensity.

If the probability underlying all projections were indeed distributed according to the log-normal model, the ranges would cover roughly two-thirds of all poll responses. The total range, defined as the interval spanned by the highest and the lowest response, would be much larger. This fact lets us pursue further the analysis of perceptions leading to large discrepancies between the different views in the following section.

5 Contrasting Views of the Link between Energy and the Economy

The range of opinions about the relation between energy and the economy is characterized by two contrasting views of the costs of energy conservation. These can be dubbed the economists' and the engineers' views. Often these are referred to as "top-down" and "bottom-up". According to the former, there are costs involved in any improvement of efficiency relative to a reference case ("There is no free lunch") whereas the latter group believes that a substantial amount of energy intensity reductions is possible at negative "costs", i.e., that costs and energy inputs can be reduced at the same time. The latter view is exemplified in Figure 12, reported by the National Academy of Sciences (1991). It says that about 50% of energy inputs into the U.S. residential and commercial sector can be avoided without incurring costs or reducing energy services.

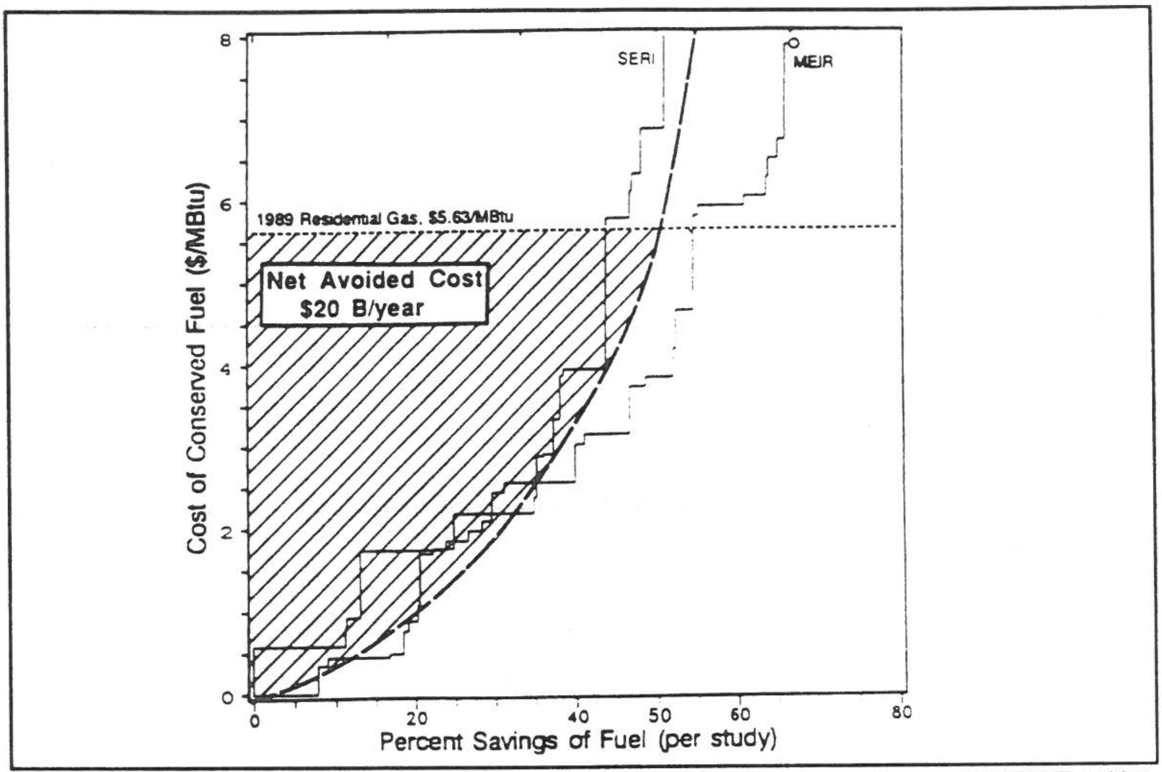

Figure 12: Cost of conserved energy for the residential sector in the U.S. 1989. Source: COSEPUP (1991).

In contrast, the economists' view attaches a positive cost to reduction in emissions. Nordhaus (1991) has expressed this paradigm clearly by estimating a curve that expresses reductions of CO_2 emissions (or, equivalently, energy intensity) as a function of energy price increases. (See Figure 13.)

In view of these large discrepancies, the question arises: *Can "Bottom-Up" and "Top-Down" be reconciled?* The heat with which the discussions between followers of either approach are often conducted may suggest an answer in the negative. Nevertheless, we want to offer here some thoughts could serve as a partial explanation of the differences between the results of the two approaches. First, it should be realized that the two types of analysis address two different questions. The economists ask: *By how much does a given energy price increase (e.g. through an carbon tax) reduce energy demand?* In contrast, the engineers' question is: *How can a given energy intensity reduction task be achieved with minimal costs?* Obviously, these two questions are not equivalent. To begin with, only the economists' question explicitly addresses the problem of forecasting. The engineers' question and the resulting savings potential (as shown in Figure 12) cannot have immediate predictive power, because

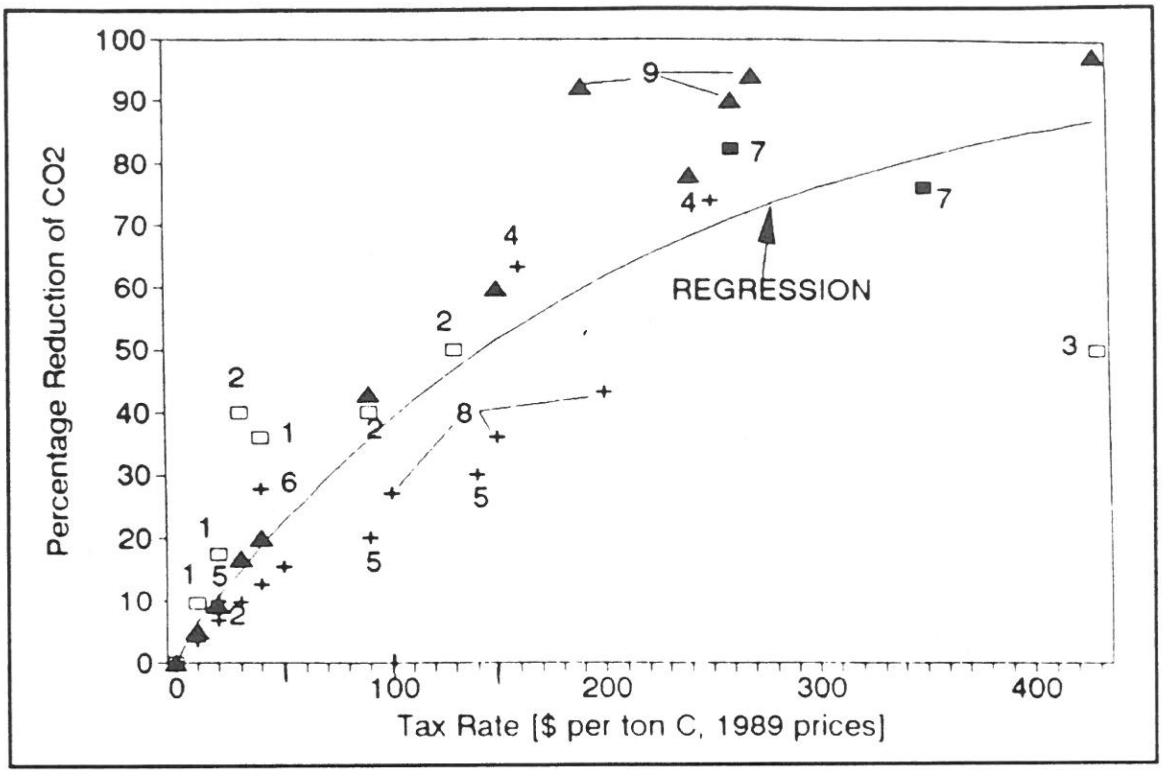

Figure 13: Estimated relationship between emission reductions and energy price increases. Source: Nordhaus (1991).

if they had, at least some of the theoretical potential would have been realized already.

The obvious next question therefore is: *Why is such a significant energy savings potential not realized by the consumers?* One possible answer is that the market discount rates often used in engineering studies to annualize investment costs are often unrealistically low for adequately describing consumer behavior and that they therefore underestimate costs and overestimate potential savings. This possibility has been suggested by Hausman (1979), who calculated implicit discount rates by observing consumer decisions trading off initial investments against later savings when purchasing air conditioners.[3] His results are given in Table 6.

They show that consumer behavior, particularly in low income classes, is consistent with discount rates that are very much higher than bank rates. But not only private consumers can act as if their individual discount rate is very high. According to Ross and Steinmeyer (1990), a typical criterion for U.S. companies to decide whether they should invest into energy saving measures or not is an estimated pay-back time of 2 to 4 years. This criterion

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[3] Meanwhile, this phenomenon has been investigated further, and more examples have been reported. See, e.g. Train (1985).

corresponds to discount rates of the order between 25 and 50%.

Table 6: Implied discount rates in purchases of airconditioners in US households

Income Class US $ (1979) per year	Implied Annual Discount Rate (%)
6,000	89.0
10,000	39.0
15,000	27.0
25,000	17.0
35,000	8.9
50,000	5.1

Source: Hausman (1979).

Does this mean that economic agents behave irrationally? This question cannot be answered by a simple analysis of these figures because there are several kinds of non-monetary costs (e.g. transaction costs) involved in buying energy-efficient equipment. If they are not explicitly added to the market price, they have an influence on the implied discount rate. For households, such transaction cost can arise in the form of inconveniences when a home is retrofitted with better insulation. Another, more abstract example of non-monetary costs is the effort to collect enough information to make an economically rational decision. The latter problem is addressed by demand-side management (DSM) programs which have been initiated, e.g. by electric utilities in the U.S. In these programs, consumers are provided with energy-saving equipment for which they pay, in effect, by sharing subsequent electricity cost savings with the utility.

But even when a theoretical saving potential is actually realized, the resulting overall reduction of energy demand can be less than expected. This is exemplified by Figure 14, showing that a more than 30% reduction of specific gasoline consumption by U.S. passenger cars between 1970 and 1989 did not achieve a reduction of total gasoline consumption. The offsetting factors preventing it were an increase of the total distances driven and a decrease of the average number of passengers per ride.

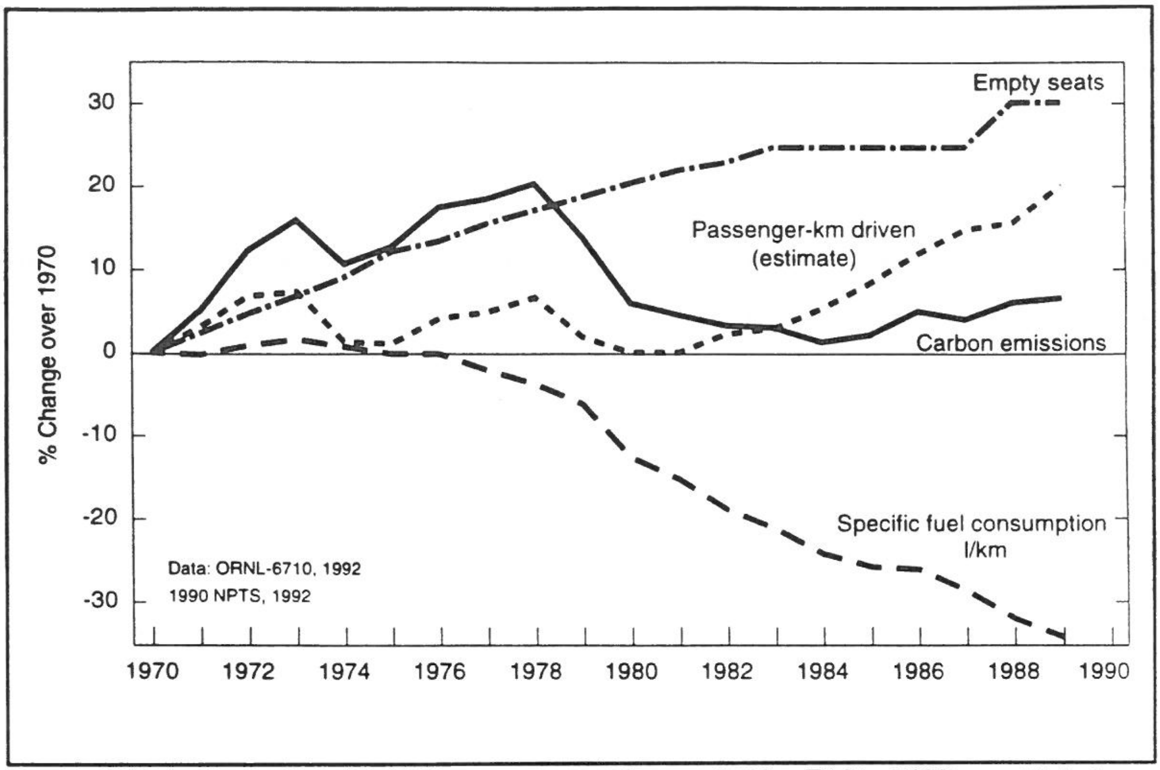

Figure 14: Carbon emissions from U.S. passenger cars. Source: Grübler, IIASA, (1993), unpublished.

These points explain some of the differences between the two types of modeling approaches by qualifying results of engineering-type models. Attempting to bridge the gap from the side of the economic models, the Autonomous Energy Efficiency Improvement (AEEI) can be used to describe energy savings. Savings due to the use of advanced technology can be expressed as higher values of the AEEI factor. Total savings as calculated by the engineering models can be calculated by top-down models as differences relative to a reference case. Of course, the AEEI factor cannot as readily be interpreted as a control variable as investments are in the bottom-up models.

6 Summary and Conclusion

There is no law that governs the relation between energy consumption and economic output. In particular, historical evidence shows that, in general, energy consumption does not grow as fast as the economy. At the same time, there is no evidence for the possibility of a "decoupling" of these variables. A good empirical value for the decrease of energy intensity of an economy is 1% per year. This value of the Autonomous Energy Efficiency Improvement, i.e., the overall efficiency improvement in the absence of energy price changes, is a useful reference for evaluating scenarios of future relations between energy and the economy. If a given scenario implies significantly faster improvements, the chances are high that such a scenario is meant as *normative*, i.e., either describing the consequences of a proposed policy or probing limiting cases. The mere description of energy savings potentials, however, does not imply that it will be realized entirely (as illustrated by the case of gasoline consumption in the previous section). Rather, it is the description of a factor that influences patterns of energy consumption. The mechanism by which this factor influences demand is a social phenomenon. The AEEI can be interpreted as an abstract descriptor this socioeconomic process.

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