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Autor: Patzak, Richard
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Dynamic Simulation as Decision Aid in Energy Policy

by Richard Patzak, Jülich

Die Unmöglichkeit einer empirischen Vorgehensweise bei Energie- und Umweltplanung sowie die Tatsache, dass das menschliche Gehirn zur Verarbeitung einer nur sehr begrenzten Anzahl interdependenter Zusammenhänge befähigt ist, legen es nahe, einen mathematischen Algorithmus zu erstellen, der eine Vorausberechnung der Ergebnisse alternativer Strategien ermöglicht. Einen weiteren Grund für die Verwendung eines mathematischen Modells in der Energie- und Umweltplanung hat die Vergangenheit durch die Notwendigkeit interdisziplinären Denkens sehr deutlich vor Augen geführt. Die Berücksichtigung aller Facetten eines bestimmten Problems ist der Systemanalyse inhärent, wodurch die Vernachlässigung eines wichtigen Aspekts unwahrscheinlich wird. In diesem Zusammenhang muss besonders darauf hingewiesen werden, wie wichtig die Einbettung von Energiesystemen in ihre soziale Umgebung ist, durch die technisch machbare Lösungen des Energieproblems öffentliche Ablehnung finden können. Die vorausgegangenen Bemerkungen umreissen die Philosophie, die dem dynamischen Simulationsmodell zugrunde liegt, das von der Systemanalysegruppe der Kernforschungsanlage Jülich «Systemforschung und Technologische Entwicklung» (STE) innerhalb des Projektes «Systemanalyse und Modellbau auf dem Energiesektor» der EG erarbeitet wurde. Die Hauptaufgabe des Modells ist die Möglichkeit, Energieplanern und Politikern eine Entscheidungshilfe an die Hand zu geben, um vernünftige Langfristplanungen für die Entwicklung der Energieversorgung zu ermöglichen sowie eine Verringerung oder aber eine Strukturänderung des Energieverbrauchs zu erreichen. Besondere Aufmerksamkeit verdient die Möglichkeit, nicht nur die Einführung von für die Länder der EG wichtigen Energieversorgungstechnologien zu simulieren, sondern auch diverse Energieeinsparungsstrategien modellmässig zu erfassen.

La modélisation des systèmes énergétiques nécessite un mode de pensée interdisciplinaire pour prendre en considération l'environnement et l'économie afin d'augmenter la fiabilité des modèles. Le modèle présenté permet de trouver des stratégies à long terme afin de développer le système de production tout en agissant sur la demande d'énergie et sa structure. Les nouvelles technologies sont introduites grâce à la conception dynamique du modèle. La simulation de différentes stratégies permet d'évaluer leurs impacts sur l'environnement et l'économie, dont les réactions sont elles-mêmes prises en compte (feedbacks). Ce modèle est une partie du projet «Systems Analysis and Modelling in the Energy Sector» des Communautés européennes.

The impossibility of applying the method of «trial and error» in energy and environment planning and the fact that the human brain can simultaneously treat only a very limited number of interdependent data do suggest the construction of a mathematical algorithm which can show the diverse results of alternative policies in advance. Another reason for applying a mathematical model in energy and environment planning is the fact that the recent past has very distinctly shown the necessity of an interdisciplinary thinking. It is inherent to the methods of applied systems analysis that all facets of a given problem are considered, thus reducing the probability of omitting a vital aspect of it. In this context particularily, the embedding of the energy system into the social environment should be stressed where technically feasible solutions of the energy problem were discarded by public «non-acceptance». The above reflections are briefing the underlying philosophy of a dynamic simulation model which was set up by the systems analysis group «Systemforschung und Technologische Entwicklung» (STE) of the «Kernforschungsanlage Jülich» within the project «Systems Analysis and Modelling in the Energy Sector» of the European Communities (EC). The main objective of this model is to provide a decision aid for energy planners and politicians to find reasonable long-term strategies for developing the energy supply system and for reducing the energy demand or for changing the structure of the demand. Special attention should be paid to the possibility of the simulation of implementing new energy supply technologies important for the countries of the Community and of modelling various energy conservation strategies.

Characteristics of the model

Due to these special problems of energy planning a model was developed which can be characterized by the following properties:

First – the model is not an isolated model of the energy system but an *integrated model which also covers the economic and environmental systems.*

Second – the model is *dynamic*, thus having the advantage that the interdependency between the economic and the energy systems and the existing feedback-loops can be taken into consideration. Furthermore as the model describes the development of the system's variables continuously over time, the critical points of time in the development of the energy system can easily be realized. Third – the model is a *long-term simulation model. The considered period reaches from 1960 to 2010.* So it is possible to compare the model results with the statistical values of the past on the one hand, and, on the other hand, the long-term aspect of energy planning is taken into consideration.

Here it should be pointed out clearly that *it is not the aim to give a forecast of the development* of the overall economy and of the total energy system up to the year 2010. The model is a *simulation model* and the results of the model runs are *based on exogenous assumptions*. By varying the corresponding assumptions one can simulate, for instance, different possible strategies for the energy supply, or different rates of the economic growth can be taken as a basis for simulation runs. By developing the structure of the model it was also taken into account that the problems and the questions in energy planning are so complex and numerous that one cannot expect all questions to be answered by one model. *The model presented here mainly deals with the following four questions:*

- What future energy demand is expected under different developments of the economic system?
- What possibilities of energy conservation exist and how great are their effects on the energy demand?
- What alternative developments of the energy supply system are still possible?
- What are the consequences of these alternatives on the energy industry, the economy and the environment?

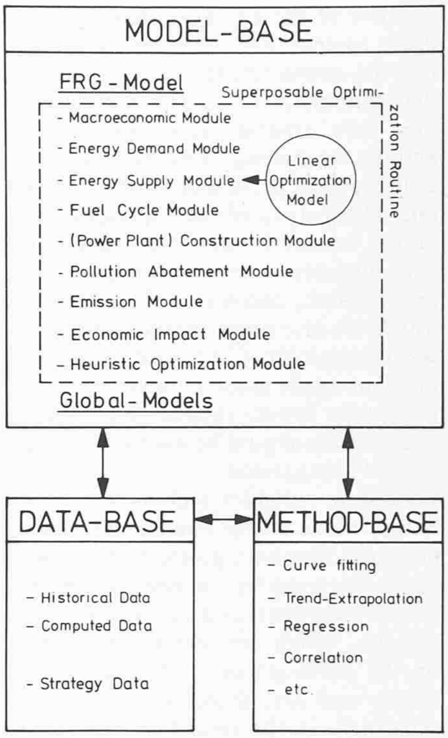

Fig. 1. The KFA-STE integrated Model System

Structure of the model

Figure 1 shows the modules of the model.

The macroeconomic module

This module is to assess possible developments of those economic variables which are *particularly important for the* *analysis of the energy system as reference, comparative or marginal quantities*. To assess future energy demands, the economy as a whole must be subdivided into separate economic sectors, and the most energy-intensive branches of industry in particular must be singled out. The growth of the individual economic sectors is one important reference quantity for determining the energy demand. Income and population trends are also important in order to assess the amount of imported energy, dependent on the grade of development of the energy supply system; total exports and imports should be used for the purpose of comparison.

Economic variables such as the contribution made by the energy industry to the gross domestic product, the capital goods required by the energy industry as well as imports and exports of energy carriers, which are directly dependent on the development of the energy industry and are, therefore, determined separately in the model in the energy modules must be taken into account in a consistent projection of the economic development and therefore must be incorporated appropriately into the economic module.

The economic module is not merely designed to forecast one single future trend, but to supply several consistent projections of possible economic developments on the basis of clearly defined assumptions. The economic variables, however, that are determined endogenously in the energy modules of the model as a function of the development of the energy system are incorporated into the economic module.

Figure 2 shows the *structure* of the economic module and, in simplified form, the interlinking of the system variables. The functional relationships between the variables are indicated by arrows. In those cases in which variables are dependent not only on the current value of their reference quantities but also on their past trends, the arrows are broken by the symbol ϑ. Those points are indicated at which functional relationships can be affected exogenously by policy parameters. In addition, the points are marked where the economic module and the energy demand and supply modules meet.

In the *macroeconomic module* the economy is broken down into the following *nine economic sectors:*

1. Energy products
2. Agricultural products
3. Ferrous and non-ferrous ores and metals
4. Mineral (non-metallic) products
5. Chemical products
6. Machinery (metal products and transport equipment)
7. Other manufactured products
8. Building and construction
9. Services

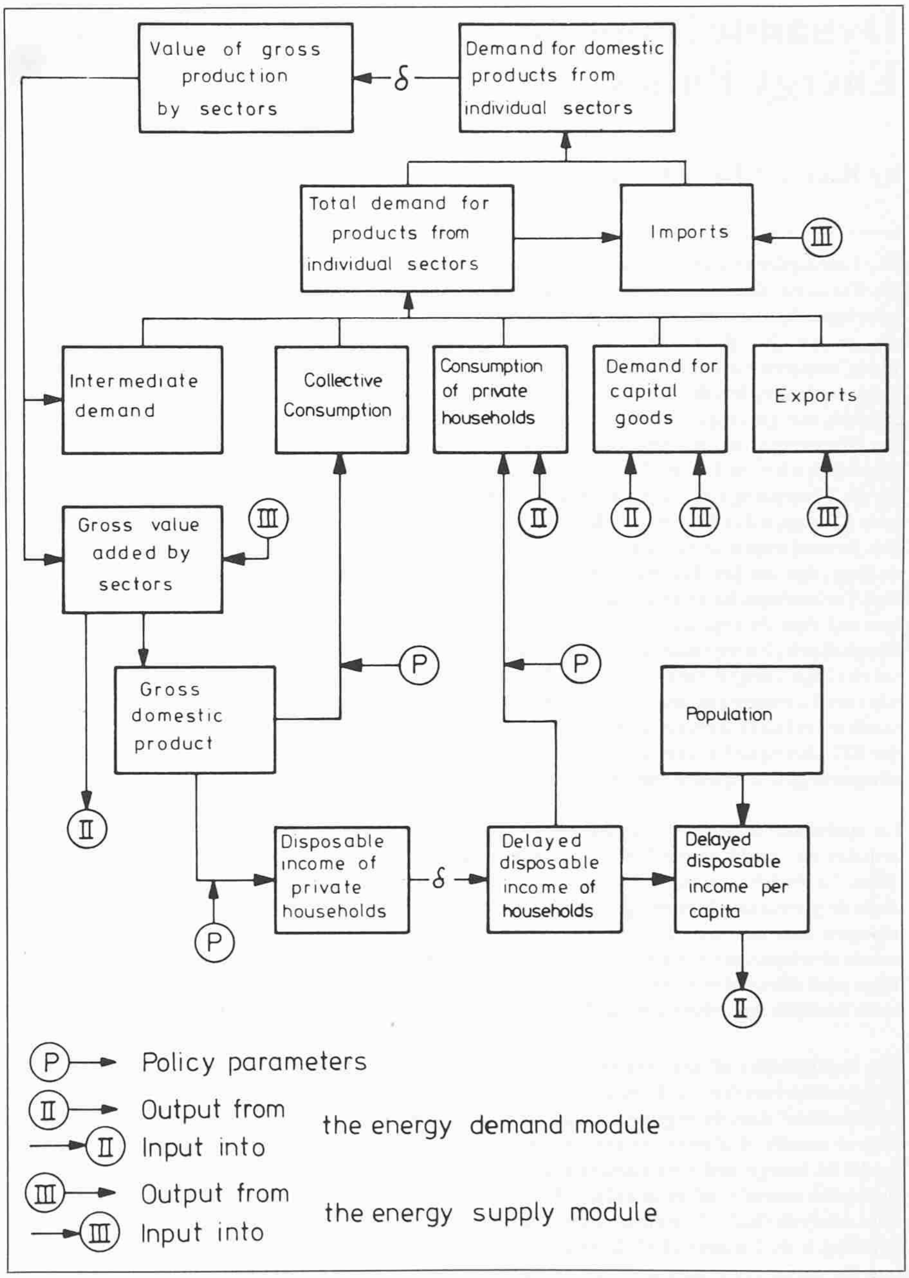

Fig. 2. Structure of the macroeconomic module

The aggregation system shown above was chosen because of its including the five main economic sectors, i.e. energy, agriculture, industry, building and construction, and services. Furthermore, within the category «industry» the four most energy-intensive branches are distinguished, such providing a direct link between the chosen economic sectors and the energy consuming sectors defind in the EEC's energy statistics. Economic sectors 3-6 correspond to the following branches of industry, which are also singled out in the energy demand module:

3: Iron and steel plus non-ferrous metals industry
4: Glass, pottery and building materials industry
5: Chemical industry
6: Engineering and other metal-working industries

After having been divided into nine economic sectors, the economy there is further subdivided on the basis of an input-output table. On the *input* side, gross value of production and contribution to the gross domestic product are considered for each economic sector. On the output side, i.e. demand side, a distinction is made between intermediate and final demand for the products of the individual economic sectors, the final demand being further subdivided into the following components:

- Consumption by private households
- Collective consumption
- Demand for capital goods
- Exports.

Figure 3 shows, in the form of an input-output table, the relationships between the economic variables listed above. It is also designed to show more clearly the *interdependence between the energy industry and the other economic sectors*. Those areas which are covered by the energy industry and treated separately in the model in the energy demand and supply modules are shaded in the diagram. The sum of intermediate and final demand gives the total demand for products of the individual economic sectors. If imports of similar foreign products are subtracted, the demand for domestic products is obtained. The demand for the domestic products of one economic sector is equal to the gross production value of that sector.

The *demand for capital goods* is indicated as an *exogenous factor* since, on the one hand, the future trend of the demand for capital goods depends considerably on economic policy decisions such as decisions involving investment programmes to be promoted by public authorities and tax incentives and, on the other hand, the explicit inclusion of various economic policy control mechanisms into the model would be beyond its general scope.

Exports, with the exception of exports of energy carriers, are likewise listed as exogenous values, since export figures depend on trends of external markets, which are not included in the model system.

For taking into account possible alternative trends in the components of final demand, the model design is such as to enable the assumed functional relationships to *be changed exogenously by policy parameters*. In the case of those components of final demand which are not determined endogenously, possible alternative trends can be indicated by changing the exogenous values accordingly. Any effect of an alternative trend in final demand on the economic growth and on the trend in the volume of production, resulting from changes in the assumptions adopted, are estimated endogenously. Thus different possible developments of the economy can be estimated by varying the corresponding assumptions.

AVERAGE GDP - GROWTH RATES (% P.A.)

TIME PERIOD	4-3-2 CASE	3-2-1 CASE
1975-1985	4	3
1985-2000	3	2
2000-2010	2	1

Fig. 4. Two reference cases of economic growth. Average GDP-growth rates (% P.A.)

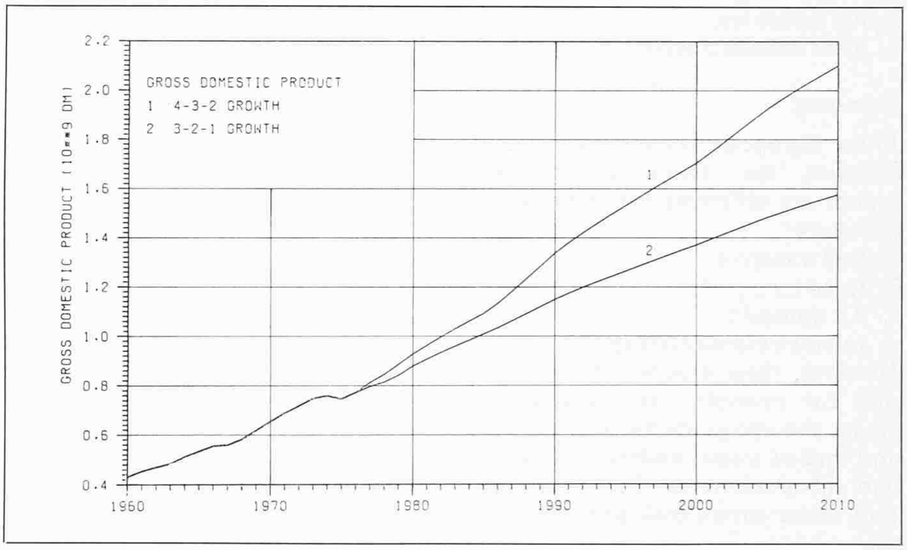

Fig. 5. Plot of the 4-3-2- and 3-2-1- reference case

The energy demand module

This module is *subdivided into five subsectors:* the industrial sector with five industrial branches analogous to those in the economic module; the transportation sector, in which the four transportation possibilities - road, rail, water and air - are distinguished; the residential sector in which the energy demand for the three purposes - space heating, water heating and other uses - are considered; the commercial sector; and the petrochemical sector.

In order to estimate the future demand of energy in each consuming sector a functional relationship was sought between social or economic values and energy consumption. When studying the trends in the individual sectors through time, it is found that the share of industry declined during the period from 1960 to 1975, whereas the shares of the households, services and transport sectors increased considerably. Consumption for non-energy uses is also taken into account. The consumer

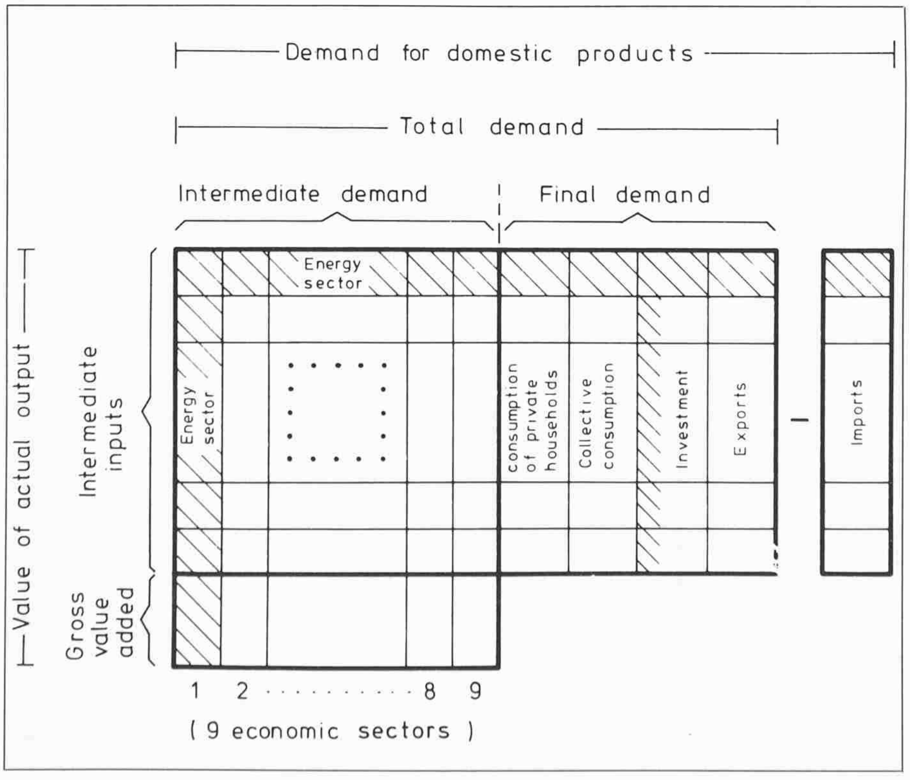

Fig. 3. Input-output table

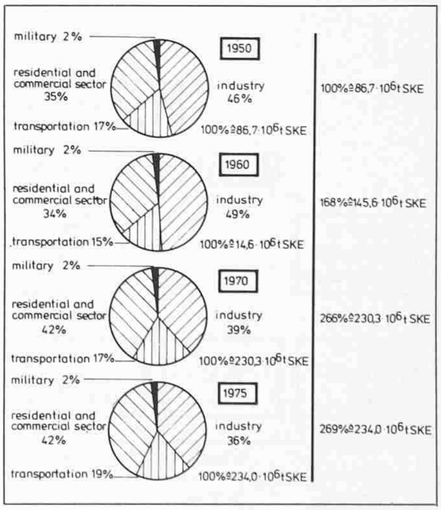

Fig. 6. Structure of the final energy demand in the FRG

groups listed above are not considered as being independent of each other in the model. In view of their links with the other parts of the model, the interdependence of these sectors is also taken into account. This is particularly true in the case of the industrial sector, the services sector, the transport sector and consumption for non-energy uses.

Industry

The industrial sector has been subdivided into the following sectors

a. Iron and steel industry and non-ferrous metals industry;
b. Chemical industry;
c. Glass, pottery and building materials industry;
d. Engineering and other metal-working industries;
e. other industrial sectors.

Transport

In the European Communities' energy statistics the following consumer groups are differentiated in the transport sector:

a. Rail transport;
b. Road transport;
c. Air transport;
d. Inland waterway transport.

However, these groups are *heterogenous;* for example, rail transport includes the energy demand of railways and that of trams, underground trains and suburban trains. The road transport sector covers both private person transport (predominantly passenger cars), public road transport and road haulage (predominantly lorries). Furthermore, since the factors determining trends in the various purposes of persons and goods transport differ, the transport sector has to be subdivided in such a way that:

(a) each individual mode of transport can be classified according to the energy carrier used; and, furthermore,
(b) the factors determining the various purposes of transport can be clearly defined.

The transport sector was therefore subdivided into:

a. Persons transport

- Private persons transport
- Public persons transport
  - Rail
  - Tram, trolley bus
  - Motor bus
  - Air

b. Goods transport

- Road haulage
- Rail
- Waterway
- Air

Private households

Private households require energy for the following main uses:

a. Space heating;
b. Water heating (non-drinking water);
c. Cooking;

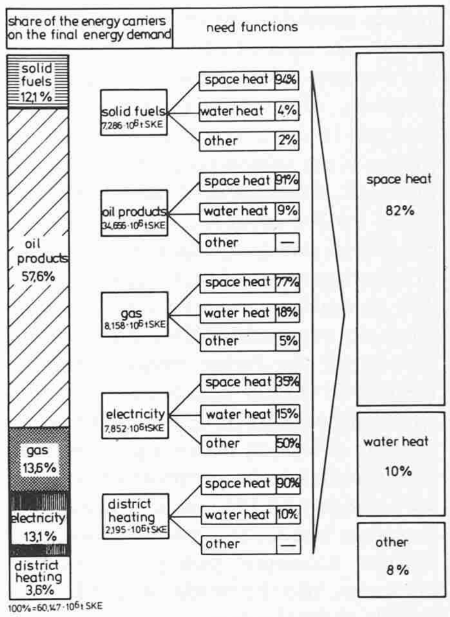

Fig. 8. Need functions and energy carriers in the residential sector

d. Generation of light, power and local sources of heat;
e. Air conditioning.

As *space heating is the major part of the energy demand,* it was considered separately.

Demand for space heating

Demand for space heating depends *not only on climatic conditions but* also on

a. The population trend;

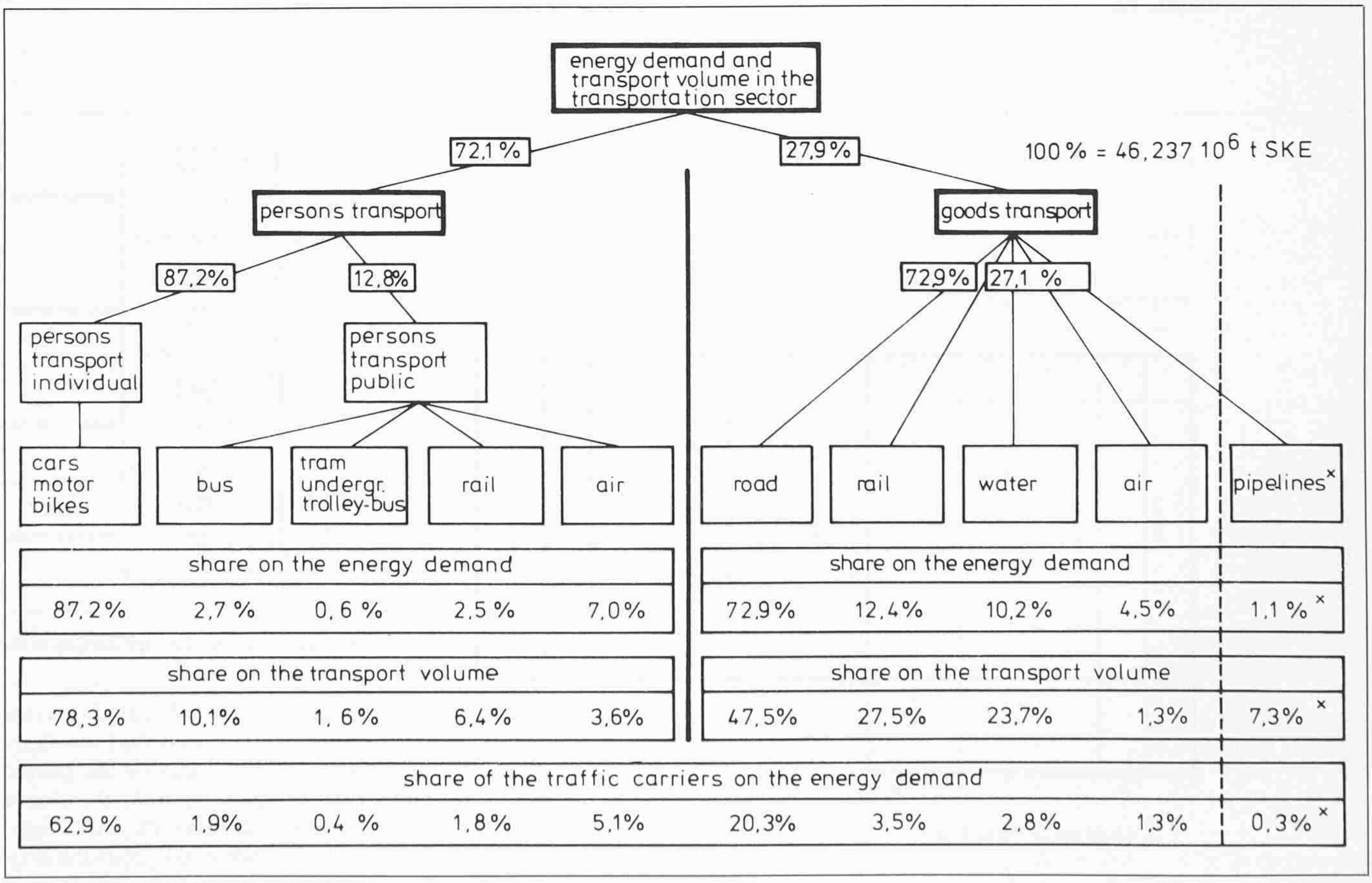

Fig. 7. Energy demand and transport volume in the transportation sector

b. The number of dwellings and the number of occupants per dwelling;
c. The breakdown into one-, two- and multi-family houses;
d. The average room temperature; and
e. The temperature and type of heating.

However, nearly all of these factors are dependent to a greater or lesser extent on the disposable income of private households (Figure 9) and can therefore be regarded only as indirect factors for determining demand for space heating. In the analytical calculation of demand for space heating shown below, the trend in total floor area is determinded first. It is then broken down between one-, two- and multi-family houses. Once the heating structure (collective or individual heating, broken down between the various energy carriers) and

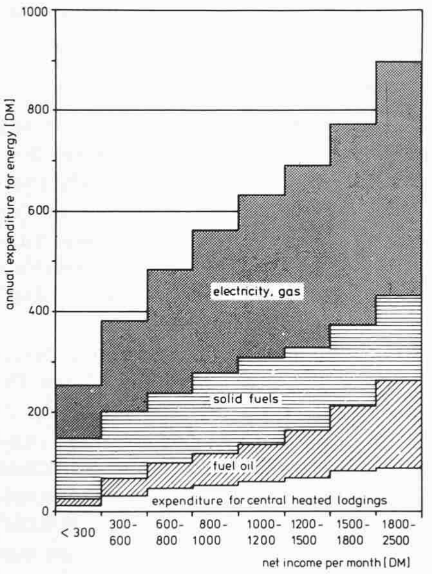

Fig. 9. Annual expenditure by private housholds for energy

the specific energy consumption of the various heating systems have been determined, the demand for space heating can then be calculated by energy source.

Services and other economic sectors

The energy demand of this extremely heterogeneous consumer group, which, according to the classification system used in the European Communities' energy statistics, essentially comprises the following areas:

a. Craft sector;
b. Commercial sector;
c. Banking and insurance;
d. Agriculture, fisheries;
e. Public utilities,

They cannot be determined precisely for *lack of sufficient data*. Although distinctions between energy sources are made in some of the European Communities' energy balances, nevertheless no standard method of classifying the individual sectors according to energy sources is in use.

Consumption for non-energy uses

The chemical industry and the transport sector account for a large part of the demand for fuels for consumption for non-energy uses. In view of this concentration of demand, a distinction is made in the sector between the demand for non-energy uses of:

a. The chemical industry;
b. The transport sector;
c. Other industrial sectors

One gets, as an output of the energy demand module, the development of the demand for final energy carriers. This projection is based, as already mentioned, on assumptions for the development of the social economic system and on assumptions for the use of energy conservation technologies. Furthermore, the energy demand module allows the computation of energy saving strategies by introducing energy conservation technologies like heat pumps and solar energy for room heating and water heating purposes and better insulation of buildings. The demand for capital goods and the expenditures of private households needed for implementing these technologies are also calculated and fed back into the economic module.

The energy supply module

The supply module of the energy model has two functions:

(1) To calculate *primary energy consumption*, by energy carrier, from the figures for final energy consumption. This requires, for example, the determination of imports and exports and of the output from all the conversion processes.
(2) To determine the *number of persons employed in the energy industry*, the *net production* (contribution to the gross domestic product), and the *gross capital investments* required to make the necessary capacities available for the production, conversion and distribution of energy.

Figures for final energy consumption and consumption for non-energy uses are fed into the supply module from the demand module at every step in the calculation process and for every energy carrier considered. Consumption for non-energy uses includes both the consumption of non-energy products resulting as by-products of the conversion process and the consumption of energy carriers used for non-energy purposes (mainly for the petro-chemical industry).

Each process is mainly characterized by its energy output, broken down into the different energy carriers, the inputs and the self-consumption given by quotients of the total output, that means by its efficiencies, conversion factors, and structure shares.

Furthermore *fourteen different energy carriers are distinguished*. These are balanced with the following equation

$$M_i+I_i-E_i-B_i+S_i=P_i$$

$$P_i=F_i+D_i+\Sigma(I_{j,i}-O_{j,i}+C_{j,i})$$

The index i corresponds to the different energy carriers. The index j to the different processes.

On the one hand the primary energy consumption P_i equals the indigenous production M_i plus the imports I_i minus the exports E_i minus the bunkers B_i plus the net stocks-decrease S_i. On the other hand the primary energy consumption equals the final energy demand F_i plus the distribution losses D_i plus the result of the sum of the energy inputs $I_{j,i}$ minus the outputs $O_{j,i}$ plus the self consumption $C_{j,i}$ over all processes j.

As a result of the simulation one gets for each chosen strategy, as the most important quantities the primary energy demand, the domestic energy production, the amount of imported energy required and the shares of the individual conversion systems in meeting final energy demand. Furthermore, the demand for capital goods needed for the development of the energy system, the number of persons employed in the energy industry and the contribution made by the energy industry to the gross domestic product are calculated.

The fuel cycle module

The fuel cycle module is designed to *portray the fuel cycle of a combination of LWRs and FBRs on the one hand and of the HTRs on the other hand*. In this module seven different HTR cycles are incorporated including prebreeder and nearbreeder analogous to LWR and FBR. The variables which are computed in that module are: the demand of *nuclear fuel*, the demand of *natural uranium* and the *corresponding separation work units*, the *accrue of irradiated heavy metal*, the demand for *reprocessing and refabrication of* U-233, U-235, Pu-239 *and* Pu-241. The parameters which can be changed exogenously are amongst others: the life time of the reactors, the annual hours of operation, the tails assay, the efficiency of the converters, the out of pile time, the loss when refabricating the fuel, the first core and the inventory in equilibrium. With the help of this module it is possible, for example, to evaluate the optimal strategy for FBR construction, dependent on the Pu stock the LWRs have produced.

The (power plant) construction module

This module calculates the *necessary erection of power plants in order to meet the demanded capacity*. For this purpose the exact age structure of the existing plants is determined by tracing back the time of erection and the capacity of

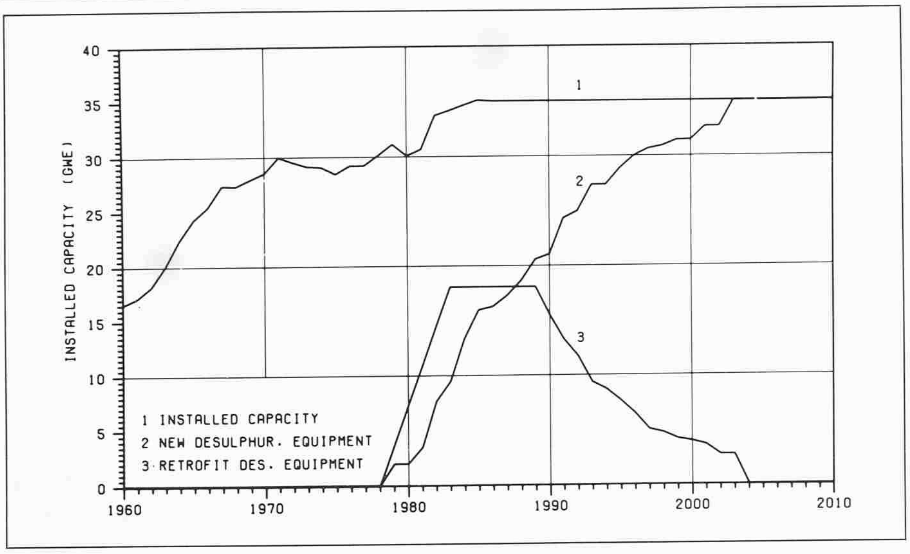

Fig. 10. Flue gas treatement of hard coal power plants

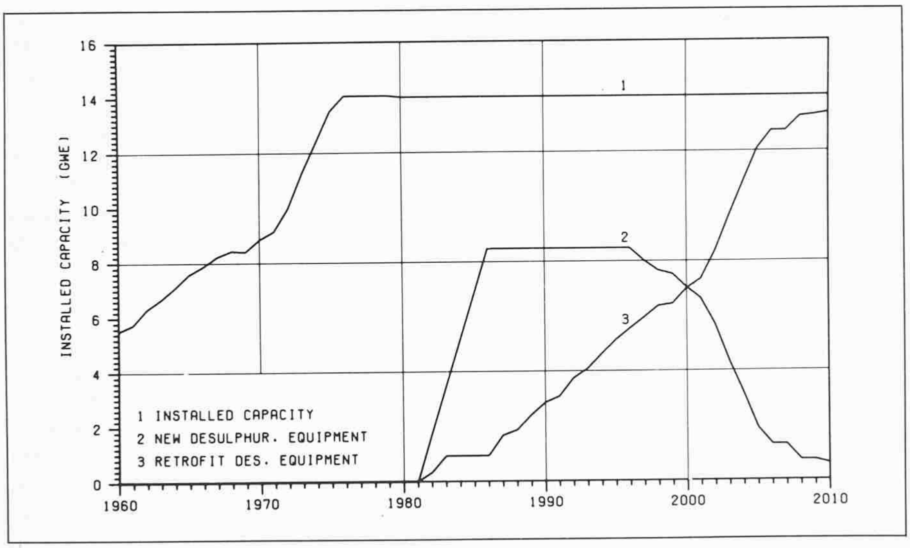

Fig. 11. Flue gas treatement of brown coal power plants

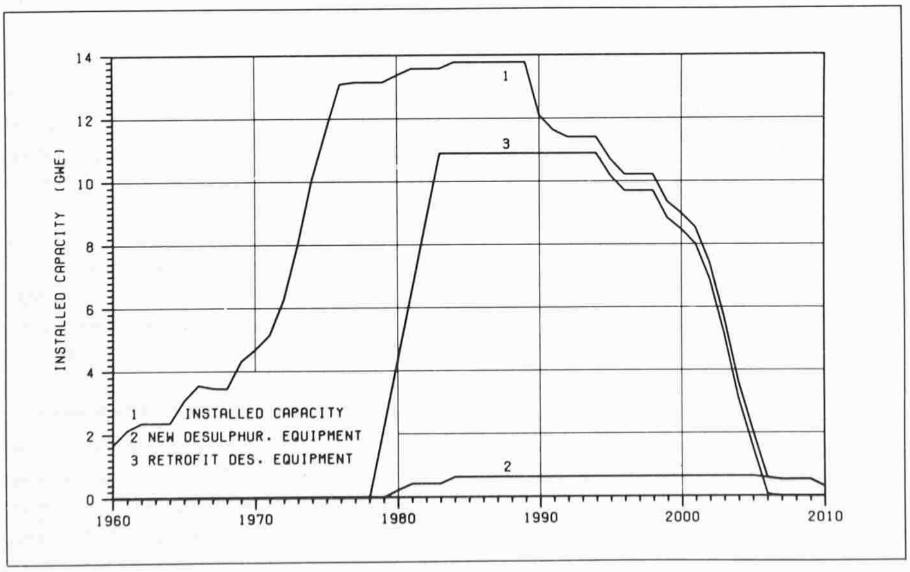

Fig. 12. Flue gas treatement of mineral oil power plants

all public and industry plants to World War II. Based on that data material and assuming a life time characteristic for this particular power plant the probable date of its decommissioning is calculated. The input to this module is either the demanded capacity or the annual construction. This module presently used for calculating the construction programme of 18 electricity generating plants (including nuclear coal gasification and liquefaction) is constructed in such a general way that it can be used also for investigating the age structure of dwellings, houses, heating systems (e. g. heat pumps) etc., in principle this module can be used for all devices and installations with a limited life time.

The main purpose of this module within the model concept is the *calculation of the necessary investments of the energy economy for power plants and infrastructure* which are fed back to the macroeconomic module.

The emission abatement module

This module serves mainly for assessing the *impact of various environment policies and emission standards on the energy economy and consequently on the macroeconomy. In this module seven different methods of fuel gas desulphurization and fuel desulphurization are dealt with.*

So far, the module is restricted to desulphurization, but it is planned for the near future to widen the capability of the module to the extraction of NO_x and to methods of simultaneous extraction of SO_2 and NO_x. The future construction of power plants and the age structure of the existing ones, being an output of the construction module, is used in this module to calculate the fixed and maintenance cost of desulphurization by evaluating the investments, fuel and energy consumption and expenses for work labour. Since the construction module provides information about the amount of power plants which are supposed to remain in operation for a given time period and this period being the economic threshold value for adapting these power plants to the demanded emission standards, it is possible to differentiate between new and retro-fit equipments. Besides, the increase of the electricity generating costs, both the energy carrier specific ones and the mean value are calculated. The latter one is fed back to the macroeco nomic module via the inverted I-O matrix, in order to reveal the effects higher energy prices have on the economy. Figures 10, 11, 12 show the installed capacity of the three energy carriers which are to be desulphurized, the capacity of new and retro-fit equipments.

Figure 13 shows the consequence of a given environment policy on the development of the gross domestic product. This figure shows very distinctly that af-

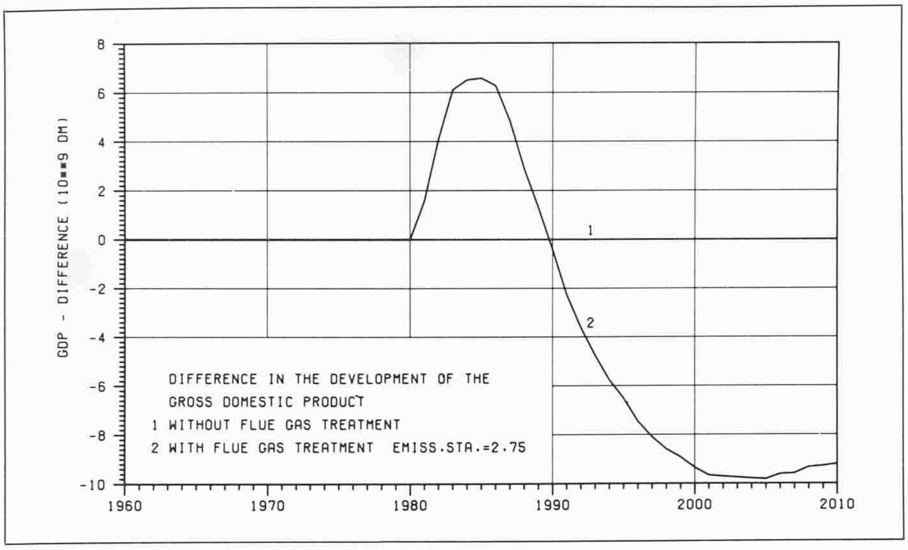

Fig. 13. Impact of desulphurization measures on the GDP

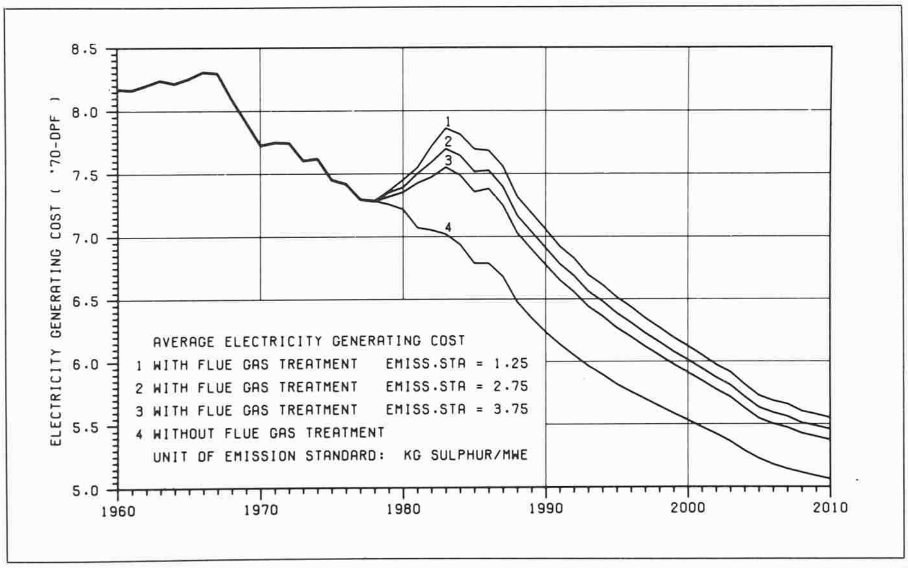

Fig. 14. Increase of electricity generating cost due to desulphurisation

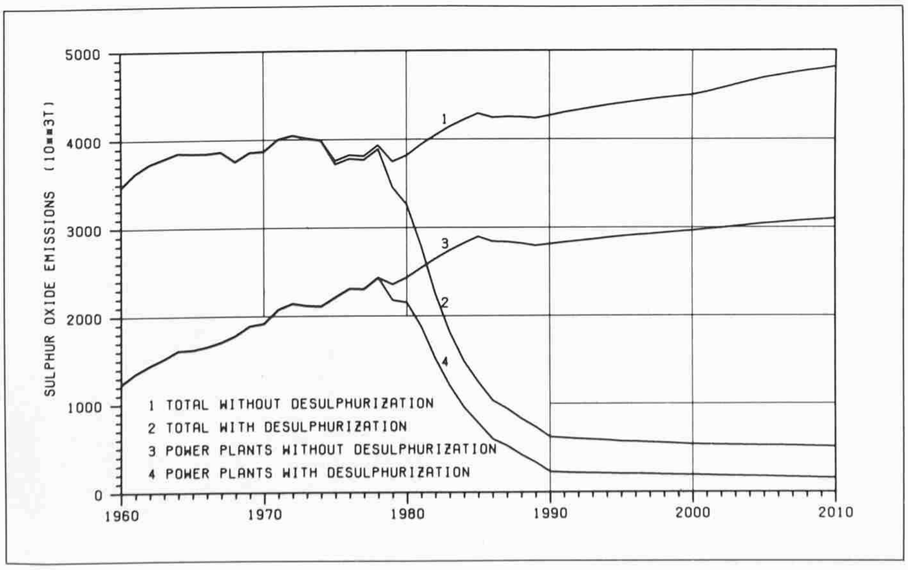

Fig. 15. SO_x emissions total and by electricity production

ter a short time the increase of the GDP, caused by the capital investments made for desulphurization equipments, is overcompensated by the impact of the higher energy (electricity) price on the economy. Figure 14 shows this price increase.

Besides monetary values this module calculates the output of elementary sulphur, gypsum and sludge, the consumption of mechanical (electrical) and thermal energy and the efficiency of the pollution abatement which itself serves as an input to the emission module.

The emission module

The emission module calculates *total emissions, caused by energy production, conversion, distribution and consumption by multiplying the energy flow through the various processes with the corresponding specific emission coefficients*. The specific coefficients are either given as exogenous values derived from statistics or they are calculated in the emission abatement module. Emission of the following pollutants are assessed:

- sulphur oxides
- carbon monoxide
- carbon dioxide
- nitrogen oxides
- hydrocarbons
- fluorine compounds
- heavy metals
- dusts and aerosols
- waste heat in air
- waste heat in water
- tritium
- krypton-85
- xenon-133
- iodine-131

As the emission module is part of an energy model, only those emissions which can be attributed exclusively to energy flows are considered. Fig 15 shows the emission of sulphur oxides both in total and those for which the electricity generating power plants can be accounted for. The remarkable reduction of emissions is a consequence of an emission abatement strategy described above.

The economic impact module

This module which has not yet been accomplished is supposed to answer the following questions:

- How large are the direct capital investments and material requirements of alternative energy supply strategies in comparison with the indirect ones?
- How do the requirements of different energy supply systems differ with regard to the necessary development of other economy sectors?
- How large is the influence of the intermediate demands on the structure of the rest of the economy?
- How much capital (direct and indi-

rect), man power and materials is necessary to realize a given energy supply policy and when are they demanded?

This module which will run in the beginning as a satellite module is planned to endogenously dynamize the I-O coefficients of the macroeconomic module if fully integrated in the model system.

The optimization module

This module is used for *transforming the simulation model* (with variable participation of modules) which so far could only answer the question "What will happen, if..." into a model which can give answers to the question "What has to be done in order to reach a specific goal or development". The mathematical algorithm for transforming the descriptive model into a goal oriented one belongs to the family of the so-called "Direct Search Methods". In the optimization module, which is only very loosely linked to the module sequence which is to perform the model run, the kind of optimization algorithm can be chosen - there are seven different ones in the model library - ,the boundary conditions have to be set, the parameters to be involved in that specific optimization procedure are determined and the utility function is defined. In most cases the utility function is defined as an integral over time of the deviations of the calculated values from the preset values.

This optimization procedure has the unquestionable advantage that the entire model with all its non-linearities, differential- and integral equations remains as it is without any simplification for calculatory reasons.

The data model interface (DMI)

For operationality and comfortability reasons this interface was developed which enables the model user to handle the model in a - compared with its complexity - very simple way. The DMI, being a kind of master program in which all modules, data bases and method bases are embedded, serves for the selection of the modules which shall perform the model run, it then decides which data must be read in from the data base, characterizes which variables are exogenous or endogenous or both, gives a warning if a variable is evaluated in two or more modules and thus determines the feed back loops occuring between the various modules. Since most of these feedbacks lead to simultaneous equations, the DMI also serves for solving these equations by a perturbations theoretical approach.

With the help of DMI the start and the end of the simulation period is fixed, the integration intervals are determined and the time steps of in- and output are chosen. This output can then be displayed in a conversational mode either in form of numerical tables or plots in various formats.

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Adresse des Verfassers: *Dr. R. Patzak*, Kernforschungsanlage Jülich, Systemforschung und Technologische Entwicklung, D-5170 Jülich.

Bautechnische Forschung mit Erdbebensimulatoren

Von John Garratt

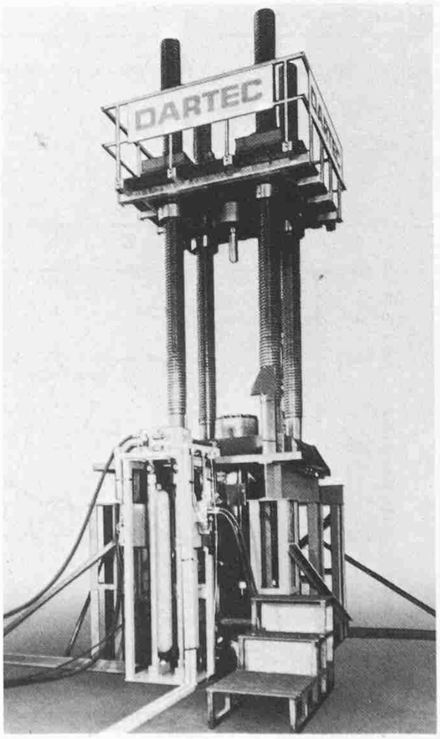
Erdbeben richten immer wieder verheerende Verwüstungen an und fordern ungezählte Menschenleben. Dank wissenschaftlichen Fortschritten im Maschinenbau konnten jedoch in den vergangenen Jahren umfassende Forschungsarbeiten über alle Aspekte von Erdbeben durchgeführt werden.

Das Schwergewicht ihrer Bemühungen legten die Forscher dabei auf Möglichkeiten, den Einsturz von Gebäuden bei Erdbeben zu verhindern. Eine der Institutionen, die sich mit diesem Thema befassen, ist die Universität Canterbury in Neuseeland. Ihre Wissenschaftler konzentrieren sich in erster Linie darauf, Richtlinien für Entwurf und Konstruktion von Bauwerken zu erarbeiten, die auch starken Erdbeben standhalten können. Ihr Ziel ist die Entwicklung erdbebensicherer Bauweisen durch Untersuchungen über die Beschaffenheit von Bauprofilen, die Wahl von Baumaterialien und die Bauverfahren als solche.

Eine Methode, Konstruktionen und Materialien auf ihre Erdbebensicherheit zu prüfen, besteht darin, grosse Teile von Bauwerken erdbebenartigen Bedingungen auszusetzen. Dies wird in Neuseeland mit Hilfe der Dartec-Testmaschine versucht.

Die Maschine, die von der britischen Firma Dartec entworfen und hergestellt wurde, erzeugt zyklische Kräfte und Spannungen zur Simulierung der Belastungen, denen ein Gebäude während der seismischen Bewegungen eines Erdbebenstosses ausgesetzt ist. Auf diese Weise wollen die Forscher an der Universität Canterbury zuverlässige Richtwerte für den Bau von erdbebensicheren Hochhäusern zusammenstellen.

Um den Auftrag für diese Maschine



Gesamtansicht des Dartec-Erdbebensimulators wie er an die Universität von Canterbury, Neuseeland, geliefert wurde