Computer-Based Analysis Tool for the Economic Appraisal of Energy Services with Consideration of their Load Impacts

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SYNOPSIS

The presentation discusses the economics and structure of a computer-aided tool for appraisal of energy services, specifically their economic and load impacts over time.

ABSTRACT

Energy supply utilities can use targetted, novel energy services to exploit technically economic demand-side savings potentials that would otherwise remain untapped. Until recently, such programmes have been conceived and implemented in Germany without any systematic cost-benefit analysis.
Within the context of the "Hanover LCP Case Study", the "ADEL" (Analyse von Dienstleistungsprogrammen zur Energieeinsparung unter Berücksichtigung von Lastwirkungen) computer-aided analysis tool has been created. This tool permits the systematic modelling and imaging of the principal economic impacts of energy service programmes on the societal and macroeconomic levels, upon the financial situation of the utility, and upon the individual customer groups. The model allows a systematic comparison of different energy service variants, and thus supports the selection of savings programmes according to specific criteria (e.g. macroeconomic benefit, rate increase effect, load shape impact). Furthermore, ADEL can image the load impacts caused by energy service programmes and the development of power demand over the service life of technologies (showing both diurnal and seasonal patterns). The presentation sketches the technical background and the structure of the computer model.

1. GOAL OF THE PROJECT

End-use efficiency measures implemented "behind the meter", i.e. at the customer, differ substantially in their impact upon the balance sheet of energy supply utilities from measures geared to the provision of supply-side technologies. Accordingly, the goal of the project was to describe and systematically analyze the economic impacts of various end-use efficiency measures (also known as "negawatt resources").
Particular emphasis was placed on:

- performing a systematic cost-benefit comparison of electricity generation measures and targetted electricity savings programmes (negawatt resources);
- taking into consideration the load impacts of end-use efficiency measures and the associated effects upon the avoided costs of power generation and distribution;
- analyzing and appraising the impact of savings measures upon the balance sheet of utilities, both from a short-term, purely operational perspective, and from a long-term perspective;
- calculating the macroeconomic and societal benefit of electricity savings programmes; and
- taking into consideration the impacts upon the electricity bills of customers, and upon the revenues of local authorities (i.e. concessionary levies upon gas and electricity).

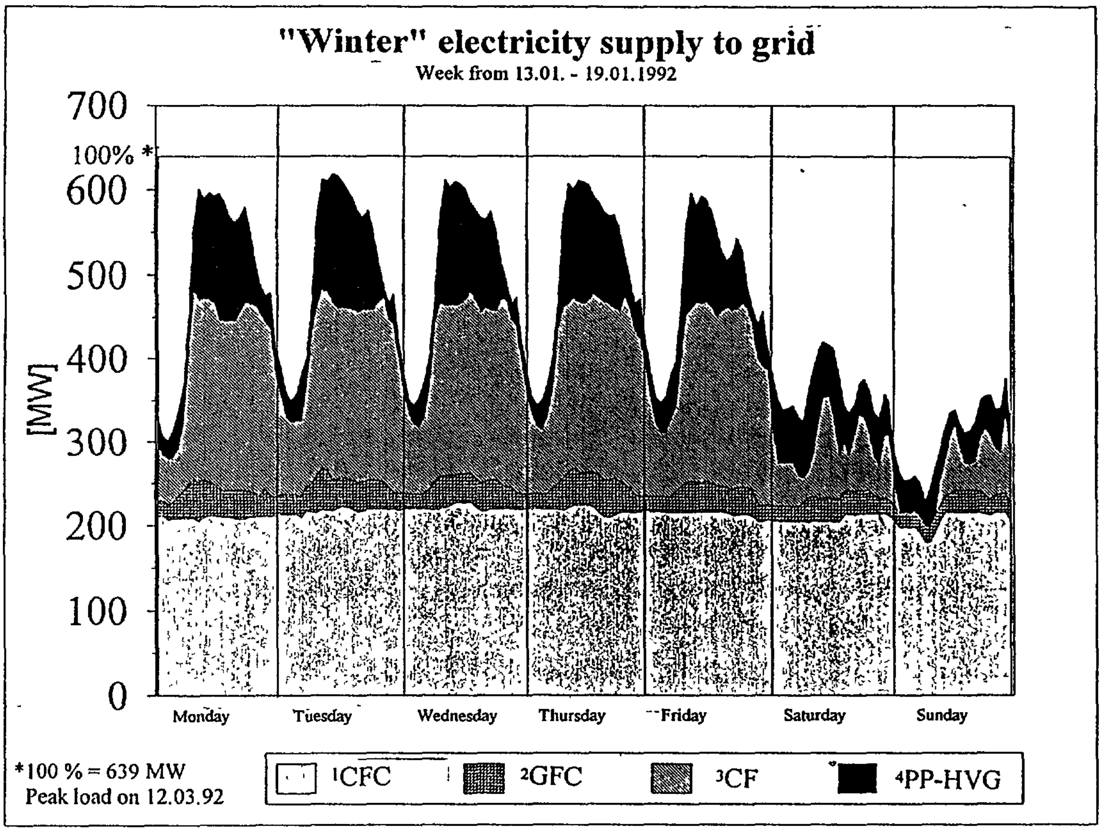
In the specific context of the Hanover LCP Case Study, the impacts of a bundle of measures, comprising nine service packages, upon the net earnings of the Stadtwerke Hannover (the regional utility of Hanover, the capital city of Lower Saxony) were to be described, using a reference scenario as baseline.

2. DEVELOPMENT OF AN APPROACH ALLOWING THE CONSIDERATION OF LOAD IMPACTS OF POWER SAVINGS MEASURES IN GENERATION PLANT PLANNING AND IN THE UTILITY BALANCE SHEET

2.1 Load Impact and Avoided Cost

A great number of studies have already shown that investments in enhancing the efficiency of the end use of electricity are, in both the perspective of pure economics and from the perspective of the customer, more cost-effective, environmentally sounder and less resource-intensive than a further expansion of energy supply. This is also confirmed by the detailed analyses of pilot projects performed in the context of the Hanover LCP Case Study (Öko-Institut / Wuppertal Institute 1995). However, previous studies have not taken the load impacts of savings measures into account. The marginal cost of electricity demand is in fact not a fixed quantity that only depends upon the amount of kWh delivered. It is instead largely determined by the point in time at which the demand arises or is saved. Both the long-run and short-run marginal costs of electricity generation must therefore be differentiated in time zones, according to the load pattern. Figure 1 shows the load shape in the area serviced by the Stadtwerke Hannover during a winter week in 1992.

Fig. 1: *Load shape for the Stadtwerke Hannover in a winter week in January 1992*



1= coal-fired cogen
2= gas-fired cogen
3= coal-fired cogen
4= power purchase from high-voltage grid

Reference: SWH - OE 31 FK/BI

Proceeding from this load shape and the cost structure of electricity acquisition, the following time zones were defined for the purposes of calculating marginal costs:

Panel 1

- Winter peak load: In the months of October to March inclusive, from Monday to Friday inclusive, in the period from 8.00 to 13.00 hours.
- Summer peak load: In the months from April to September in the period from 8.00 to 13.00 hours.
- Normal load: Monday to Friday from 6.00 to 8.00 and from 13.00 to 21.00.
- Minimum load: On weekdays in the period from 21.00 to 6.00, and on Saturdays, Sundays and holidays throughout the day.

Proceeding from this time zoning, the marginal costs of additional power demand in the individual zones were determined in cooperation with the Electric Power Generation and Corporate Planning Departments at the Stadtwerke Hannover. The calculations were disaggregated to show both the short-run and the long-run marginal costs in order to be able to compare the results of these two different approaches.

2.2 Short-Run Versus Long-Run Marginal Costs

The costs for expanding the power plant system that can be avoided by the Stadtwerke by means of implementing savings programmes form the monetary benefit of these negawatt programmes from the macroeconomic and - if we include the externalities - societal perspectives.
That the customer compares the supply and demand side resources, as is aimed at in the LCP process, would require, according to the criteria of economic theory, that rate formulation is oriented to the long-run marginal costs in the respective time zones. The determination of the long-run marginal costs, or of the time zone tariff, is thus a central issue within the LCP approach. Marginal cost tariffs give both the utility and the consumers the proper scarcity signals necessary in order to balance various (supply-side and demand-side) investment alternatives against each other (EWI 1988, Seifried 1991).
This view of marginal costs is, however, based on an idealized concept characterized as follows:

- Existing generating capacities are assumed to be optimally geared to the existing load structure.
- Additional demand during a time zone is assumed to lead to an expansion of the corresponding generating capacity.
- It is assumed that capacity can be added in as small units as required, and that
- the utilization rate of additional installed power is the same as the average utilization rate of the respective generating capacities.

With these assumptions, an optimum generation mix and the costs caused by it can be modelled for every level of additional, persistent demand. The long-run marginal system costs of power acquisition can be determined by including the costs arising for maintaining capacity reserves and from grid losses and the costs for expanding the transmission and distribution network.

2.3 Methodology for the Determination of the Short-Run and Long-Run Marginal Costs of Generation, and of the Marginal Costs Avoided by Electricity Savings Programmes

The following procedure was used to determine long-run marginal costs:

1st Step: Assignment of power plant types to time zones

On the basis of the daily load shapes and the annual load duration curve, time zones are set (cf. Figure 2), to which the utilization of specific power plant types (peak, medium and base load) is assigned. It is thus assumed that, for instance, additional power consumption during the summer period of minimum load is covered with additional generation in a base-load plant, while additional demand during the winter period of peak load entails installing peak-load capacity or the purchase of peak-load power from the upstream supplier. Here it must also be considered that additional base- or medium-load capacity at the same time provides an additional coverage of the power demand in the peak load period.

2nd Step: Selection of supply-side resources

Concrete power plant facilities or, respectively, purchase conditions, are defined for the production of power for the various load zones:

For additional power consumption in the winter and summer peak load periods, the electricity purchase contract with PREAG 2000, one of the companies operating the high-voltage electricity grid in Germany, is assumed. For medium load, a mix of a combined-cycle plant and a conventional cogeneration plant is assumed. For base load, a cogeneration plant fired with imported coal is assumed.

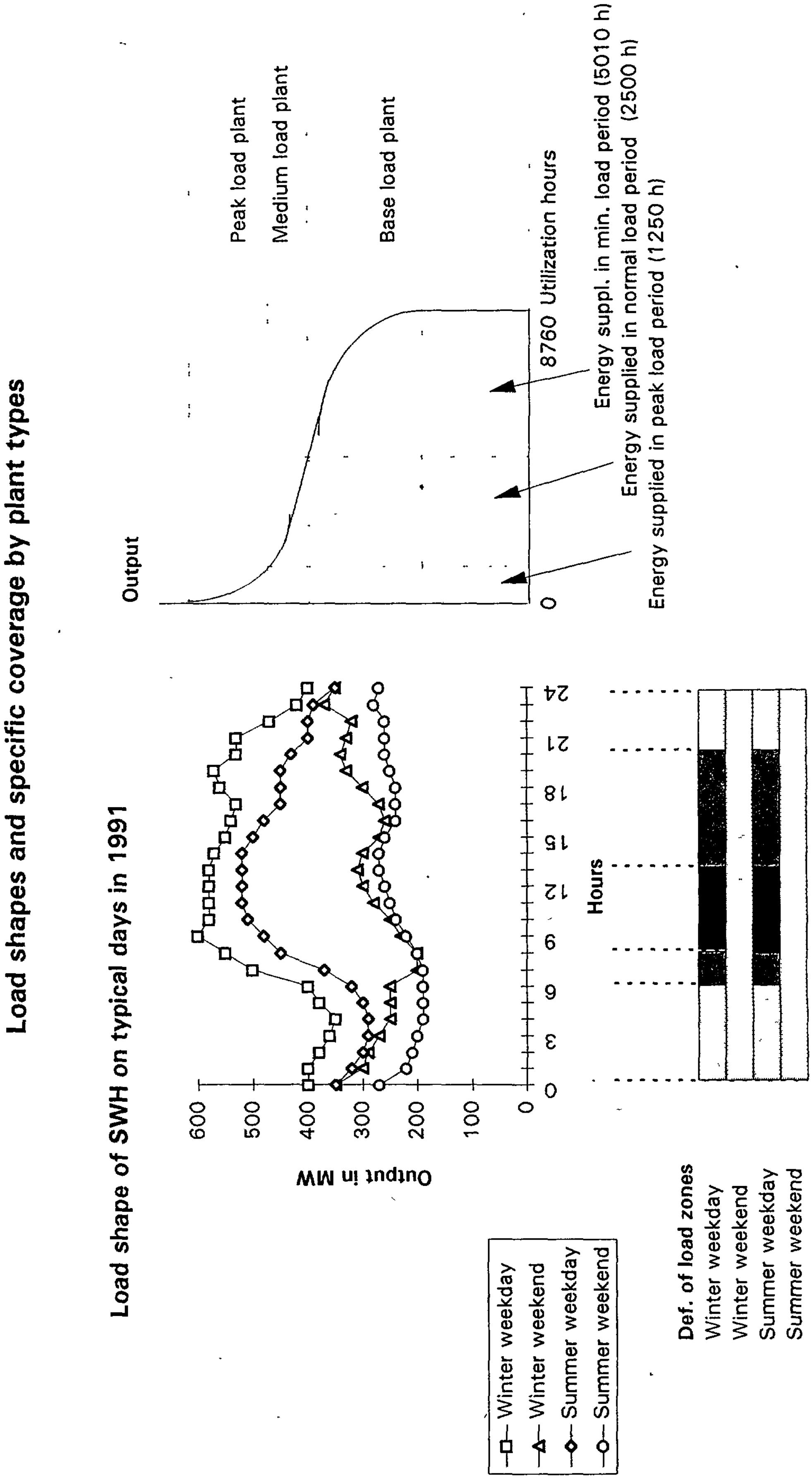
3rd Step: Determination of fixed and variable costs

Here the power generation (or purchase) costs are determined for the four different load zones. First the specific fixed costs of the various plant technologies, or, respectively, of power purchase are determined.

Table 1 shows the the avoided long-run marginal cost of electricity:

Time zone	number of hours/year	costs (production and distribution)
Peak-load winter	625	42.9 Pf/kWh
Peak-load summer	625	24,7 Pf/kWh
Med.-load (summer and wint.)	2500	14,4 Pf/kWh
Base-load	5010	12,5 Pf/kWh

Fig. 2: *Load shapes and definition of time zones*



4th Step: Inclusion of fuel price developments in the model

The avoided long-run marginal costs of power production and distribution have a fixed-cost component (avoided capital costs for power plants and distribution) and a variable component (fuel costs, miscellaneous variable costs such as flue gas purification, and distribution losses).
The fixed-cost block is apportioned over the whole service life according to the annuity method, whereby a 4% interest rate in real terms is assumed. (The real interest rate can be defined as the difference between the average value of the nominal interest rate over a long period and the average rate of inflation over the same period.) The fuel costs (including the network losses) are extrapolated by means of mean factors.

5th Step: Determination of load impacts of savings measures

For all the savings programmes that were examined, standardized load curves were assumed for each type of end use or customer group for four typical days of the week (a winter and a summer weekday, a winter and a summer weekend day) or load cases. The standardized load curves represent the load shapes on these four days, whereby the peak load arising is given the value 1.

The savings programmes have specific impacts upon the load shapes of each end use. The load change of power demand is determined with the aid of the standardized load curves and the savings factor (this being the percentage by which demand alters, in every hour, through the savings measure). From the load change over time we then calculate the energy saved by time zone. The model thus determines how many kWh are saved during the winter and summer peak load periods and during the other time zones.

6th Step: Determination of the costs avoided by savings programmes

Proceeding from the avoided marginal costs of power generation and distribution and the avoided generating capacity, we can then determine the costs avoided by individual electricity savings programmes.

From the societal perspective, neither contributions under equalization of burdens law nor concessionary levies represent costs. They are therefore not taken into account in the determination of macroeconomic costs. They are, however, considered in the microeconomic perspective of the utility (and in the economy calculation from the perspective of the customer). The concessionary levy was differentiated according to customer groups (tariff customers and special contract customers) and energy carriers (electricity and gas).

7th Step: Cost situation with respect to gas and district heat

In order to image the effects of electricity savings, or, respectively, substitution upon the cost and sales situation of gas and district heat, the acquisition and distribution costs of gas and district heat supply were determined according to a similar procedure; the documentation of this would exceed the space available here.

3. STRUCTURE OF THE "ADEL" MODEL

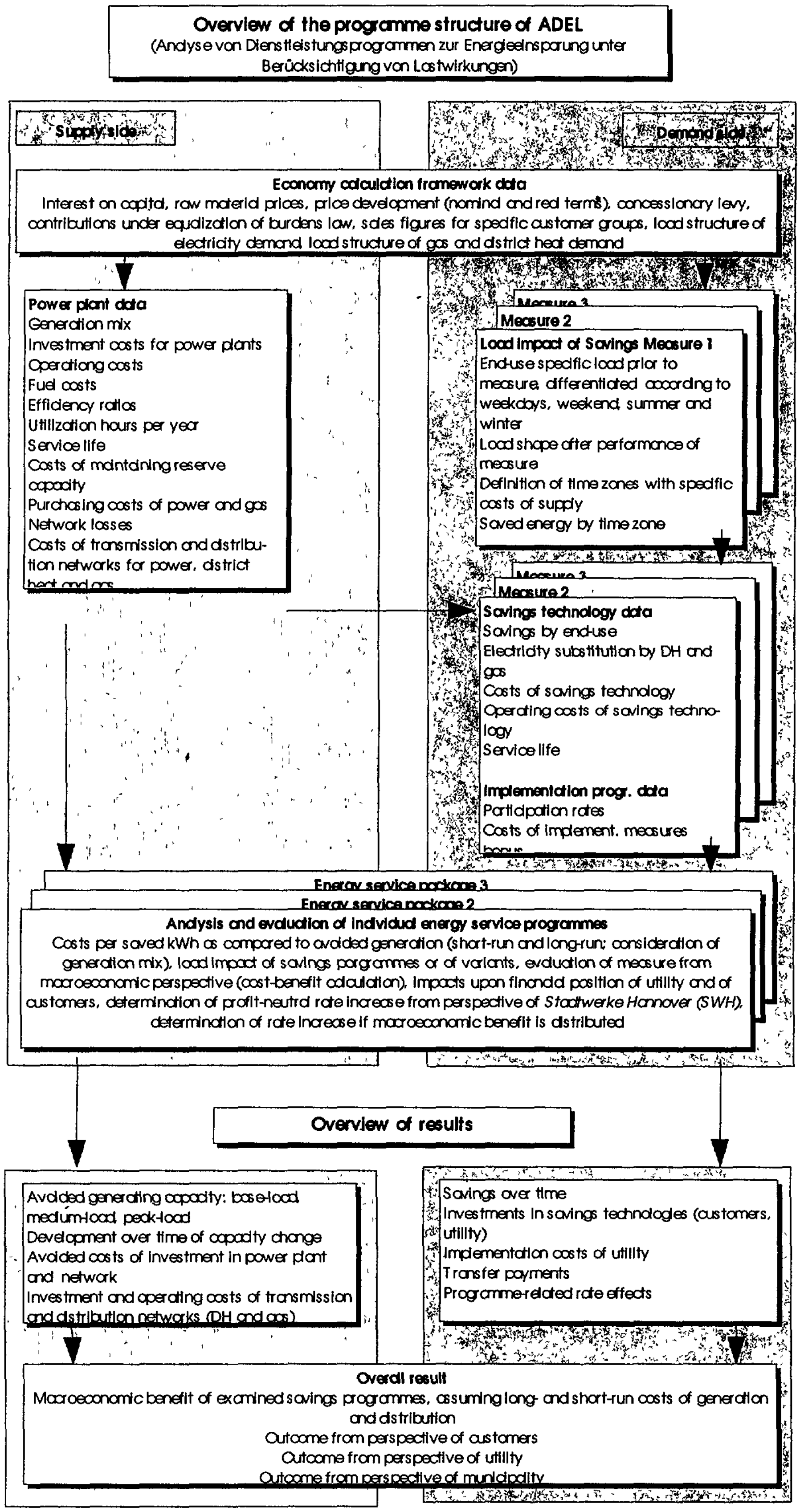
Within the context of the Hanover LCP Case Study a computer-aided model was developed for the analysis of energy service programmes for energy conservation that takes load impacts into consideration (termed ADEL, short for Analyse von Dienstleistungsprogrammen zur Energieeinsparung unter Berücksichtigung von Lastwirkungen). The programme offers a tool with which variants of electricity savings programmes can be depicted and evaluated with regard to both their macroeconomic cost-benefit side and their microeconomic impacts.

Figure 3 gives an overview of the programme structure of ADEL. The programme was written with a spreadsheet programme.

The heart of the programme is formed by "work files", where the cost-benefit analysis of individual energy service packages or different variants takes place. These "work files" take up as input the results or parameters from other "work files":

- The avoided short- and long-run marginal costs of the system come from the "Power plant and network data" file.
- The "Load input" file delivers the results of the load calculation to the cost-benefit analysis.

- **The "Economic framework data" file stores the fundamental parameters for the economy calculation. This file is also where the market segmentation for the evelopmentof energy service programmes takes place.**



Overview of the programme structure of ADEL
(Analyse von Dienstleistungsprogrammen zur Energieeinsparung unter Berücksichtigung von Lastwirkungen)
Supply side
Demand side
Economy calculation framework data
Interest on capital, raw material prices, price development (nominal and real terms), concessionary levy, contributions under equalization of burdens law, sales figures for specific customer groups, load structure of electricity demand, load structure of gas and district heat demand
Power plant data
Generation mix
Investment costs for power plants
Operationg costs
Fuel costs
Efficiency ratios
Utilization hours per year
Service life
Costs of maintaining reserve capacity
Purchasing costs of power and gas
Network losses
Costs of transmission and distribution networks for power, district
Measure 2
Load impact of Savings Measure 1
End-use specific load prior to measure, differentiated according to weekdays, weekend, summer and winter
Load shape after performance of measure
Definition of time zones with specific costs of supply
Saved energy by time zone
Measure 2
Savings technology data
Savings by end-use
Electricity substitution by DH and gas
Costs of savings technology
Operating costs of savings technology
Service life
Implementation progr. data
Participation rates
Costs of implement. measures
Energy service package 3
Energy service package 2
Analysis and evaluation of individual energy service programmes
Costs per saved kWh as compared to avoided generation (short-run and long-run; consideration of generation mix), load impact of savings porgrammes or of variants, evaluation of measure from macroeconomic perspective (cost-benefit calculation), impacts upon financial position of utility and of customers, determination of profit-neutral rate increase from perspective of Stadtwerke Hannover (SWH), determination of rate increase if macroeconomic benefit is distributed
Overview of results
Avoided generating capacity: base-load, medium-load, peak-load
Development over time of capacity change
Avoided costs of investment in power plant and network
Investment and operating costs of transmission and distribution networks (DH and gas)
Savings over time
Investments in savings technologies (customers, utility)
Implementation costs of utility
Transfer payments
Programme-related rate effects
Overall result
Macroeconomic benefit of examined savings programmes, assuming long- and short-run costs of generation and distribution
Outcome from perspective of customers
Outcome from perspective of utility
Outcome from perspective of municipality

Panel 1

4. CAPABILITIES OF THE MODEL

The computer tool can help to perform the following tasks:

a) The tool allows a systematic examination of savings and supply-side options under the same framework conditions, and an evaluation of the options according to a uniform method.

b) The effects of savings programmes and of conçeivable variants can be shown. In particular, the following aspects can be determined and documented:

- the impacts of energy service programmes upon electricity, gas and district heat sales and upon the load structure of electricity demand;
- the necessary investments of the utility and the customers;
- the macroeconomic benefit of negawatt resources, as compared to a baseline scenario;
- the impact upon the balance sheet of the utility and upon the energy bill of the customer;
- the necessary rate increase/decrease for the case of a profit-neutral price adjustment or the case of a distribution of the macroeconomic benefit of a service programme; and
- the external costs of energy supply that are avoided by the savings programmes.

5. PRESENTATION OF THE IMPACT OF A "SAVINGS POWER PLANT" COMPRISING 9 ELECTRICITY SAVINGS PROGRAMMES

5.1 Brief Description of Savings Programme Package

The 9 electricity savings programmes pursued within the context of the Hanover LCP Case Study can, taken together, be viewed as a "savings power plant" that can be used, just like a "proper" power plant, to satisfy future demand for energy services. The individual service programmes address the following customer groups: residential; public sector and SME tariff customers; public sector and SME special contract customers; and industrial special contract customers.

Table 2 lists the 9 electricity savings programmes.

Tab. 2: Typology of programmes and technologies

Progr. No.	Customer sector	Programme type	Technology
1	Residential	Direct installation	Efficient lighting
2	Residential	Premium programme	Efficient refrigeration
3	Commercial, tariff	Direct inst. / Consult. / Premium	Efficient lighting and misc.
4	Commercial, special contract (SC)	Consult / Premium	Efficient lighting
5	Commercial, SC	Consult / Premium	Efficient ventilaton
6	Commercial, SC	Consult / Premium	Refrigeration and misc.
7	Public building	Lighting contracting	Efficient lighting
	Industrial, SC	Consult / Premium	All end uses
9	Large industrial	Consult / Premium	All end uses

5.2 Construction Period

Savings power plants need, just like "real" power plants, a construction period. This can vary according to the type of programme, the end use of electricity and the customer group. While, for instance, a direct installation programme in the residential sector can be performed within a year, such a programme in the field of public sector and SME tariff customers needs, with the associated consulting programme, a construction period of about 3 years.
Figure 4 shows the commencement, completion and service life of the individual service packages. Thus, for instance, the lighting programme for special contract customers in the public sector and SME group (No. 4) is to commence in 1997 and be concluded in the year 2010. Between 1997 and 2010, a part of the savings potential will be tapped every year. As the service life offlighting installations is assumed to be 12 years, the period of full annual savings within this programme extends up to the year 2008. After this point in time, annual savings sink with the demise of the technical installations.

Fig. 4 Point of introduction and duration of effect of electricity savings programmes of the Stadwerke Hannover

No.	Programme	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'00
1	Res 1: Light																
2	Res 2: Refrigeration																
3	Com.1: Light a. misc.																
4	Com. 1SC1: light																
5	Com., 1SC1a: Light.serv.																
6	Com.1SC2:Refrig a. misc.																
7	Com. 1SC3: Ventilation																
8	1SC Total industrial																
9	Industrial, "The Big 16"																

1SC = Special Contract

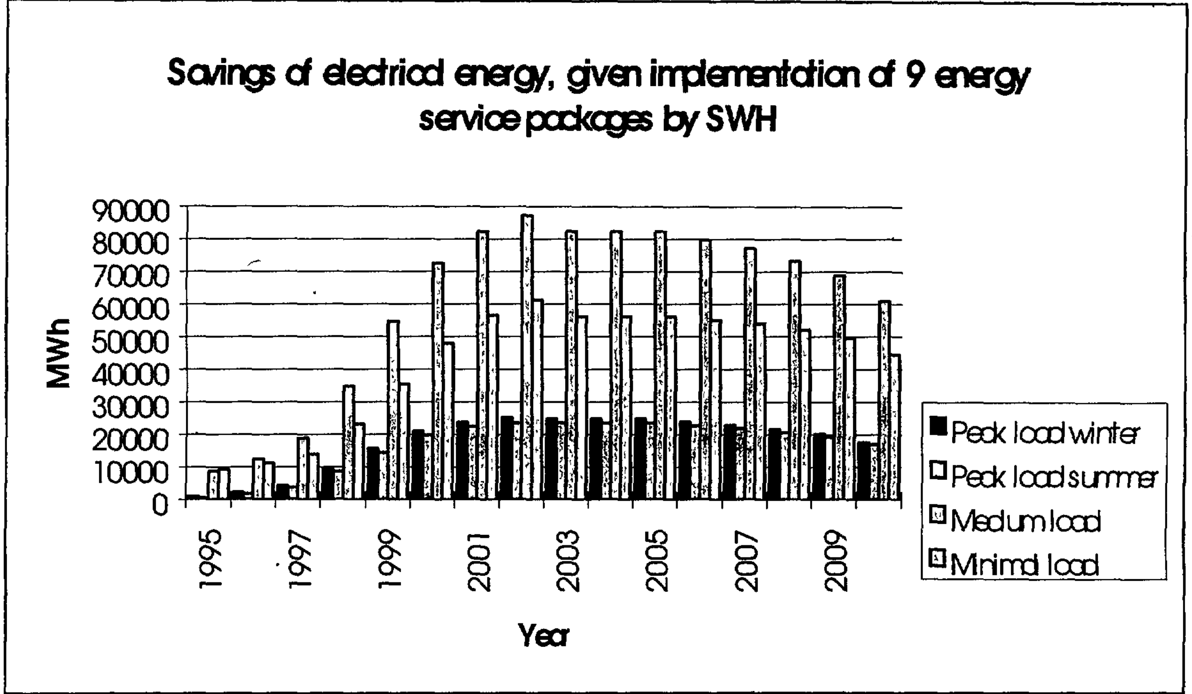
The different shading shows the degree of implementation of a programme. The black areas indicate the period in which the electricity savings programme impacts fully.

5.3 Presentation and Interpretation of Results

5.3.1 Energy saved by time zone

Figure 5 shows the energy saved by time (load) zone. Due to the differing commencement times and periods of construction, structural shifts also arise between the proportions of end-use specific minimum-, medium- and peak-load savings (e.g. the proportion of peak-load savings is far lower in the residential lighting programme than in the commercial programmes).

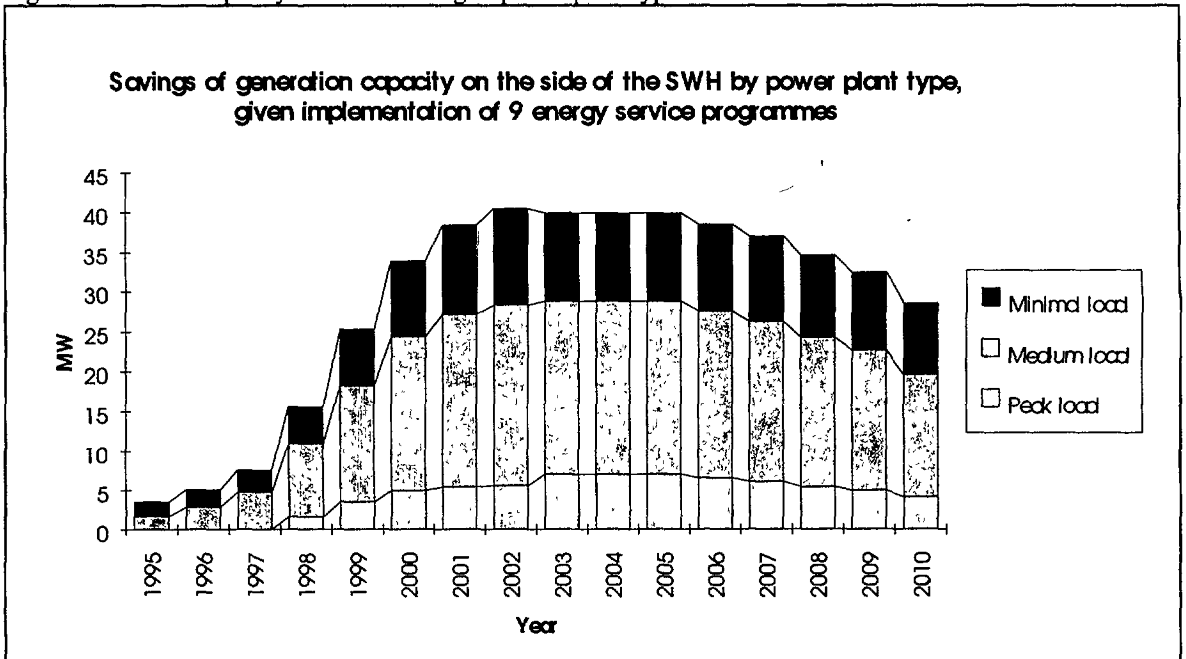
Fig. 5: Saved energy according to time zone



5.3.2 Saved generating capacity

The saved generating capacity is determined according to power plant type on the basis of the method described in Section 2 above (see Figure 6). With the 9 energy service programmes, a

Fig. 6: Capacity saved according to power plant type



capacity reduction totalling some 40 MW can be achieved by the year 2002. Of this, 12 MW are saved in base-load plants, 23 MW in medium-load plants and 5 MW in peak-load plants.

5.3.3 Macroeconomic and societal benefits of the savings power plant

The macroeconomic benefit of the programme was calculated for each of the nine electricity savings programme as compared to the costs of supply of electricity. Here, first the long-run costs of the supply option are determined. These are compared to the costs of the efficiency technology (inclusive of implementation costs).

Applying avoided long-run marginal costs, we arrive at a macroeconomic benefit of 154 million DM over the whole service life of all service packages. On the basis of long-run marginal costs, all the selected savings programmes show a macroeconomic benefit.

This value was calculated without including external costs. If we assume that the supply strategy would create average external costs of 4ÿPf/kWh as compared to a savings strategy, then we arrive, for a total savings of 2,4 million MWh over the entire period of the programmes, at an additional societal benefit of some 96 million DM.

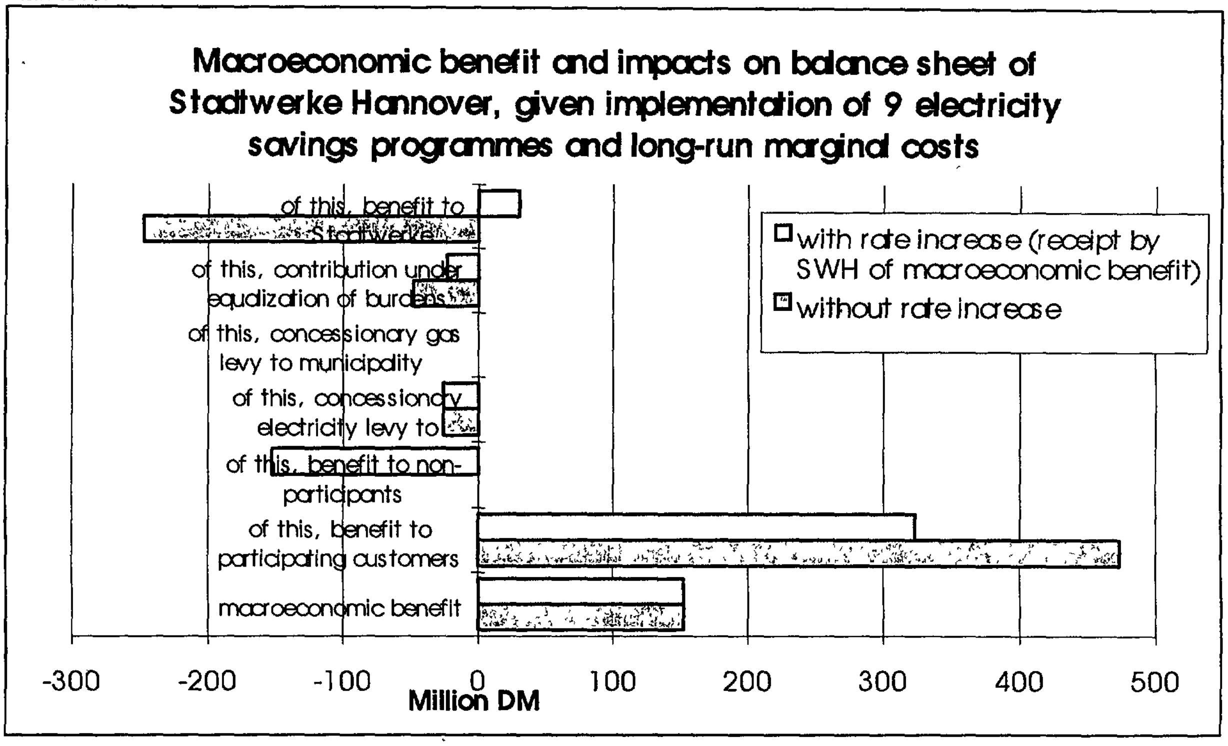
5.3.4 Impacts upon the net earnings of the utility

From the perspective of the Stadtwerke Hannover, the 9 electricity savings programmes can be economically appraised from two different aspects:

- Taking a long-run approach, the Stadtwerke apply the long-run avoided marginal costs of generation and distribution for the determination of net earnings. This approach is, by the standards of economic theory, indispensable and expedient for a "fair" appraisal of savings programmes. Over the long run, the construction of savings power plants avoids the otherwise necessary expansion or replacement of existing generating plants. If long-run marginal costs are applied, we arrive at a deficit - assuming the rates being charged to the customer are held constant - for the Stadtwerke Hannover of about 242 million DM (see Figure 7).
- With a purely business management and short-run approach, a utility will, for given generating capacity, only take the marginal costs prevented over the short run into the profit and loss statement as saved generating costs. The deficit of the Stadtwerke would then grow to 332 million DM.

In Section 5.3.6 below, however, we show that these deficits can be compensated by relatively slight rate increases (with furthermore substantial additional services), and that ultimately all involved parties can recieve significant benefits from such a strategy.

Fig. 7: Macroeconomic benefit and impacts on balance sheet of Stadtwerke Hannover



5.3.5 Impacts upon customers, the City of Hanover and other "involved parties"

If the rates or prices per unit are not raised by the Stadtwerke, then the customers are the sole benefitors of a savings strategy. At unaltered prices, the customers would receive a benefit of some 470 million DM from the savings power plant. The investment they would have to provide for this (net) benefit is comparatively low: the customers would only have to invest 104 million DM in more efficient end-use technologies.

The savings power plant has direct and indirect impacts upon the budget of the City of Hanover. On the one hand, the coffers of the City lose some 26 million DM revenue from the concessionary levy. On the other hand, there are a series of indirect impacts leading to revenue gains. These, however, are generally very difficult to quantify.

The substitution of coal and gas deliveries by savings technologies shifts demand from areas where it creates employment in regions outside of the Federal Republic to such areas where domestic, qualified jobs are created. There is further a reduction of environmental burdens, that ultimately benefits all the customers and inhabitants of the city and its region.

5.3.6 Price changes

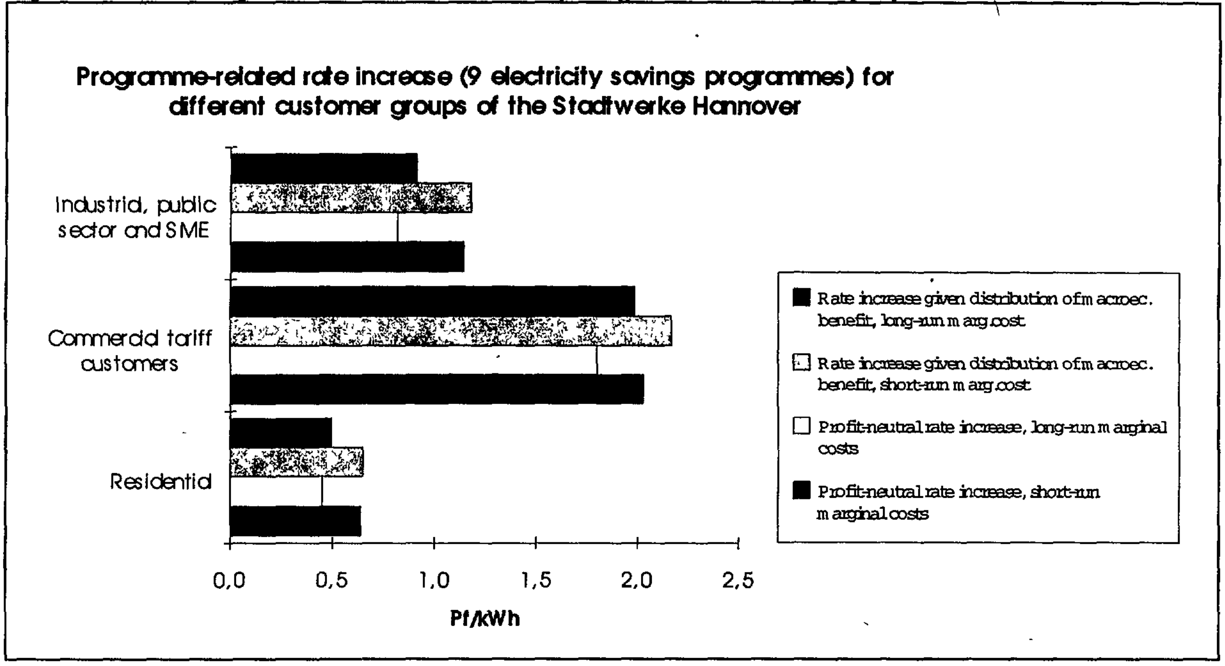
As presented above, the construction of savings power plants provides a substantial macroeconomic benefit. The distribution effects of the savings power plant, however, are very uneven: the customers receive a benefit several times larger than the macroeconomic benefit, while the Stadtwerke experience cumulated profit losses or deficits.

Moderate rate increases offer a way out of this dilemma. These are determined for each individual programme and customer group. Two cases can be distinguished:

- Case 1: The rates are raised such that the utility makes the same profit when performing the programme as it would without the programme.
- Case 2: The rates are raised such that 20% of the macroeconomic benefit acheived by the savings power plant is apportioned to the Stadtwerke.

Figure 8 compiles the rate increases for the individual customer groups necessitated by the performance of the 9 energy service programmes. In addition to the Cases 1 and 2, rate increases are also differentiated according to whether long-run or short-run marginal costs are applied.

Fig. 8: *Programme-related rate increase for different customer groups of Stadtwerke Hannover*



The results as illustrated in Figure 8 clearly show that in the most unfavourable case (Case 2, short-run marginal costs) the rate increase for commercial tariff customers would amount to slightly over 2 Pf/kWh. For the special contract customers, the maximum rate increase would be 1,2 Pf/kWh, and it would be less than 0,7 Pf/kWh for the residential customers. These rate increases refer to the entire period under consideration, i.e. up to the year 2010. As the programmes are to be introduced over several years, the increases would take place in appropriate steps, and would thus not lead to inacceptable burdens for the customers.

5.3.7 Necessary investment of utility and customers

The ADEL programme can determine the technology and implementation costs and the transfers (premiums, non-cash contributions) involved in the examined energy service programmes. For the programmes discussed above, the Stadtwerke would have to invest some 90 million DM for these three groups of costs.

6. LITERATURE

Hennicke, P. u.a.: Die Energiewende ist möglich. Für eine neue Energiepolitik der Kommunen, Frankfurt 1995

SWH: Energiekonzept Hannover, Baustein 9. Wirtschaftliche Bewertung, Hannover 1993

EWI (Energiewirtschaftliches Institut) 1988: Kostenorientierte Stromtarife, Forschungsauftrag 22/86, Juni 1988

Seifried, Dieter: Least-Cost-Planning und die Reform der Energiepreise, in: Hennicke, Peter (Hrsg.): Den Wettbewerb im Energiesektor planen. Berlin, Heidelberg 1991

Öko-Institut 1992: Entwicklung eines methodischen Instrumentariums für ein örtliches/regionales "Least-Cost-Planning"-Modell (incl. CO2-Reduktionskonzept). Gutachten im Auftrag der BEWAG Berlin, der Stadtwerke Hannover AG, und der Energieleitstelle der Senatsverwaltung für Stadtentwicklung und Umweltschutz Berlin. Freiburg, Darmstadt, Mannheim 1992.

Öko-Institut/Wuppertalinstitut 1995: LCP-Fallstudie Hannover, Freiburg/Wuppertal 1995