THE EVALUATION OF DEMAND-SIDE MANAGEMENT IN GERMANY: AN APPROACH BASED ON ENERGY SYSTEM MODELLING AND MULTIPLE CRITERIA ANALYSIS

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Summary

Demand-Side Management (DSM) activities of German energy utilities are far less numerous and extensive than DSM in the United States. The same applies to the evaluation of these programs. The future of DSM in a competitive energy sector is not clear. However, regardless of the future role of DSM, evaluation is likely to gain importance as a way to improve DSM.

In this paper, a two-part tool for evaluation of DSM is presented that is adapted to the practice of evaluation at German utilities. The first component of the tool assesses energy, environmental and economic impacts using energy system modelling techniques. The second component is a multiple criteria analysis, that incorporates weighted user-defined criteria and makes use of the results of the energy, economic and environmental analysis.

DSM in Germany

The Present Situation

Demand-side management is defined as the planning, implementation and evaluation of programs that aim at a change of energy demand taking into account its pattern in time. In Germany, more than 400 DSM programs are carried out by electric utilities. This number is still increasing. Of these programs (1):

- 32% deal with the promotion of energy efficient appliances through financial incentives,
- 16% with contracting,
- 14% with project consultancy, and
- 10% with load management.

In addition, gas utilities are carrying out many DSM programs as well, including 180 programs for the promotion of condensing boilers (2).

At the moment, the main motives for DSM are political pressure, environmental objectives (partly self-imposed), improving the company's image and customer relations, opening new fields of business and, finally, reducing costs (the latter in particular for load management programs). The total impact of the programs in terms of energy or capacity saved however is very small and has, load management excluded, no significant impact on energy supply.

The Future of DSM

The future of DSM in Germany is uncertain with utilities preparing themselves for the liberalised deregulated German energy market. No different than in the US, but at a far less developed stage, one can roughly distinguish two different future roles for DSM (3,4), (see figure 1).

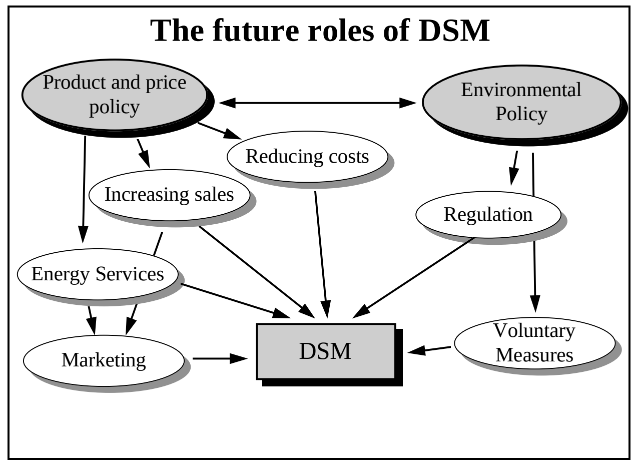

Figure 1

<u>*DSM as an energy service or a marketing instrument*</u>. As a result of increased competition, product and pricing policy gains importance. DSM could play a part in this. First, DSM can directly increase sales by promoting electricity applications, like heat pumps. Second, DSM can be incorporated in the marketing strategy for the core products. For instance, some German municipalities are likely, as a result of environmental policy, to select a supplier on the basis of prices and environmental factors. They will demand additional services, for instance energy efficiency programs. Third, DSM could play a role in a product portfolio that encompasses the core products and also energy services. Several German utilities are experimenting with these concepts on a limited scale.

<u>*DSM as an instrument of environmental policy*</u>. At the moment, DSM, in particular the energy efficiency programs, is to a large extent motivated by environmental concerns. These are sometimes internalised in the utility's business policy, or, in other cases, are a result of political pressure. Contrary to many states in the USA, in the German proposal for the restructuring of the energy sector, which is being discussed at the moment, no new regulation

or incentive is foreseen to promote environmentally motivated DSM activities of energy utilities. Only the possibility to recover DSM costs through the rates is to be extended (5). On another level, however, the electricity sector plans to include demand-side activities in the self-imposed utility goal to reduce CO_2 emissions of the electricity sector. At the moment this encompasses the production-side emissions only. At this stage it is difficult to predict what role the German energy sector will play in the implementation of environmental policy in the future and what the extent of the resulting DSM activities will be.

Evaluation of DSM

Current Evaluation Practice

Evaluation of DSM programs includes the assessment of the impacts, costs and benefits of the programs and of the related contribution to the utility's objectives. The results of the evaluation can be used ex-ante, on the basis of expected values, in the design and selection of the programs, and ex-post on the basis of realised and measured values, in checking if the program achieved results as planned and to improve future programs. At the moment, in Germany, DSM programs are evaluated to a small extend only. This is caused by:

- the limited size of the programs.
- the absence of regulation of DSM.
- having a program is often more important than achieving specific goals, for instance when image improvement is the main motivation.
- the limited experience of utility staff with evaluation methods and tools.
- the limited resources (staff, finances) available for evaluation.
- the lack of adequate tools.

In general, programs are either not evaluated at all or a simple spreadsheet calculation is made to make rough engineering estimates of the impacts and to project, for instance, the specific CO_2-reduction costs. No specific software for DSM evaluation is used. Empirical surveys and analysis to assess the impacts of programs more accurately are seldom carried out.

Some exceptions are the limited number of larger projects, that are often supervised by a scientific institution or consultancy. In these cases, evaluation is more extensive and often includes a customer survey. See for instance the programs of the Stadtwerke Hannover (6), of RWE (7) and of PreussenElektra (8).

Existing commercial software for DSM evaluation from the US, is not used in Germany, mainly because it is adapted to the evaluation practice in the US, both in extent of the evaluation as well as in the resources (expertise, staff) required.

Requirements for an Evaluation Tool

Why bother with developing new methods and tools for evaluation, given the current evaluation practice and the uncertain future role of DSM in Germany? The main reason is that, regardless of the future role of DSM, evaluation will gain importance. If DSM is used as an instrument of environmental policy, cost-effectiveness will be more important than it is now to ensure that the utility's budget is spent as efficiently as possible. If on account of increased competition, marketing strategies and energy services gain importance, DSM has to be evaluated accordingly and include a wide range of other criteria, relevant to this application, e.g. customer value.

What are the mayor requirements for an evaluation tool, if it is to be used by German utilities?

- Keep it simple. Utility staff cannot afford to spent much time and effort in getting acquainted and working with the tool. The tool should be simple to use and easy to understand.
- Include multiple criteria. The evaluation framework should not be limited to the direct energy, environmental and economic impacts, but also allow for the incorporation of other, user-defined criteria.
- Provide reference data, when possible. The lack of data is a major barrier for evaluation. In many cases, an evaluation on the basis of general, non-utility-specific data still provides useful results.
- Secure flexibility. It must be able to evaluate different types of DSM programs and cope with multiple objectives and evaluation criteria.
- Support decision making. The tool should support the decision making process at the utility.

The Methodological Approach

Given the major requirements listed in the previous section, the following two-step methodological approach is chosen as illustrated in figure 2.

The first evaluation step consists of the assessment of the DSM impacts on energy demand, emissions and total costs, and of the calculations of cost-effectiveness indicators. (to be further called energy-environment-economics evaluation). This assessment is based on an engineering approach. It uses techniques from energy system modelling and will be embedded in an existing planning and modelling environment.

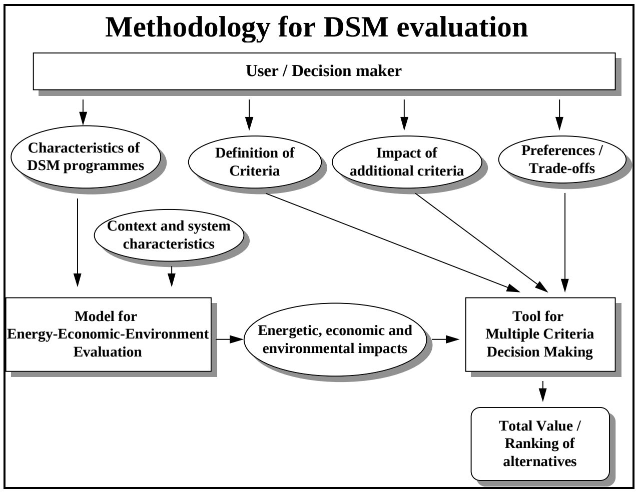

Figure 2

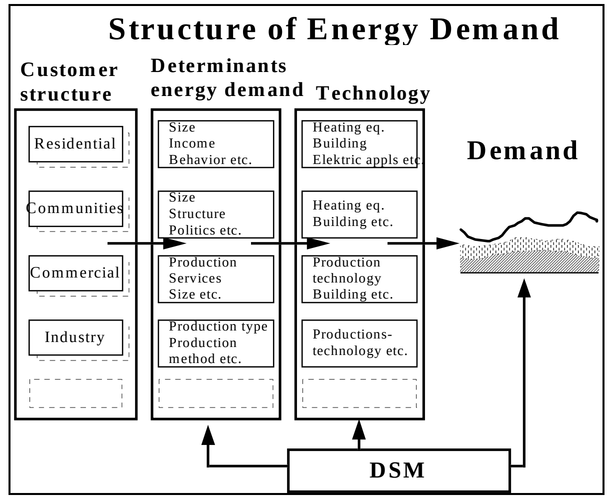

Figure 3

The second evaluation step consists of a Multiple Criteria Analysis (MCA) of the available alternative DSM programs or designs. It enables the incorporation of multiple objectives and criteria in the evaluation. The MCA results in a relative ranking of the alternatives. The results from the energy-environment-economics evaluation can be directly used in the MCA evaluation.

The Energy-Environment-Economy Evaluation

The Modeling Framework

The Modular Energy System Analysis and Planning Environment (MESAP) is a tool for integrated energy and environmental planning and can be used for a wide range of analyses. It has been developed at the Institute of Energy Economics and the Rational use of Energy (IER) at Stuttgart University (9). MESAP integrates different modular energy planning tools through a central database system. MESAP is selected as the framework for DSM evaluation because of its:

- flexibility in time, regional scale and the level of detail .
- suitability to the mathematical methodologies available for analysis, in particular simulation and optimisation.
- standardised open data interface for modelling and information systems.
- user-friendly data entry, consistency checking, analysis and reporting.

Standardisation of the data structure is achieved through the representation of any energy and environmental system in a network diagram.

A Model of the Demand-side System and DSM

The basis of the tool for DSM-evaluation is a model of the energy end-use system that the DSM program will affect. Figure 3 shows the general structure of the model of energy demand, including the way energy end use is influenced by DSM. One can distinguish three levels: the customer structure, the determinants of energy demand and the technology level. By entering the customer structure, for instance the number of households or size of population, the energy demand and emissions levels can be calculated.

DSM programs can be included in the model as well. DSM affects the determinants of energy demands, e.g by changing the utilization of end-use technologies, or the end-use technologies themselves, e.g. by promoting energy efficient refrigerators.

In figure 4, an example of a demand structure and a modelled DSM program is given (promotion of efficient lighting). The impacts of the program can be calculated in comparison with the reference case without DSM. The DSM program is characterised by the following variables in particular:

- Specific changes in energy demand of the end-use.
- Fixed and variable technology costs.
- Fixed and variable DSM costs.
- Number of participants and share of free riders/drivers.

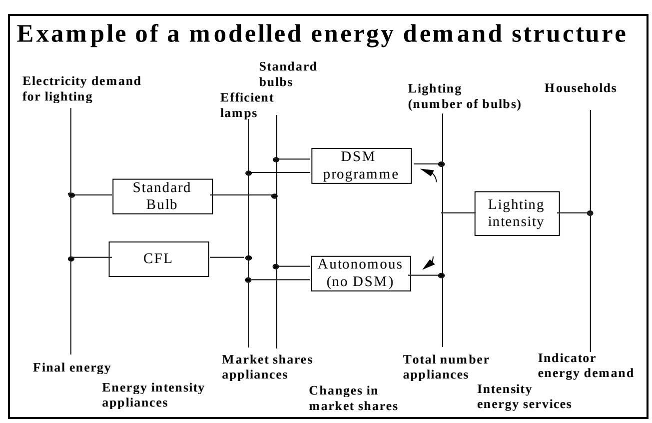

Figure 4

The following variables are calculated by the model:

- Total impact on energy demand, either in yearly values or as load shapes.
- Total impacts on emissions, in particular CO_2.
- Total DSM program costs.
- Total technology costs.
- Lost or gained revenues on the basis of pre-defined rates.
- Avoided production costs on the basis of a predefined fixed cost structure.

On the basis of these results, the cost-effectiveness of energy conservation and emission reduction are calculated. In addition, the standard benefit-cost ratios can be built.

Links with Models for Supply-side Planning and IRP

The MESAP analysis and planning framework is being further developed to provide energy utilities with a set of tools for energy planning, including the model for DSM evaluation, which is described in the paper at hand (10,11). The set of tools further includes simulation models for energy demand analysis, optimisation models (supply-side planning, integrated resource planning), and databases (energy technologies, end-use and customer load shapes, DSM programs).

The approach using a common modelling and data format secures the direct link between the models. For example, a model of the demand-side, including DSM, which has been developed for DSM-evaluation, can be directly linked to a supply-side model, for instance developed for supply-side planning, in order to carry out IRP analysis by optimising the total energy system.

The User Interface

The methodology for the evaluation described in the previous sections, which is based on energy system modelling, seems perhaps complicated and therefore contradictory to the design requirement to keep the use of the tool simple. Therefore, an user interface will be designed that allows the user to enter specific data quickly and easily and carry out the analysis in a ‘press the button and get results’ way. To this purpose, a reference end-use structure and reference database for DSM programs will be provided. The user enters utility-specific parameters only, like number of households, to obtain an estimate of the utility end-use structure and end-use demand. In the next step, a specific DSM program from the reference database can be selected and the characterisation adjusted, for instance by entering the expected or realised number of participants. Impacts on energy demand, emissions and the related costs and benefits can then be calculated. The user then can choose to extend the evaluation with a multiple criteria analysis to achieve an overall ranking. The modelling interface remains available for those users that wish to model the demand structure themselves and have the expertise to do.

Multiple Criteria Analysis

Multiple Objectives and Criteria

At most utilities, multiple objectives are incorporated in DSM planning and, consequently, in DSM evaluation. For each objective, one or more evaluation criteria can be established. This results in an often very heterogeneous list of criteria. Table 1 gives an example.

Often the objectives and the corresponding criteria conflict and, consequently, trade-offs exist. This means that contributing to one objective will have an negative effect on another, for example the reduction of CO_2-emissions versus cost reduction.

In the previous section, a methodology for the assessment of the energy, environment and economy DSM impacts based on energy system modelling was described. The assessment covers a wide range of the criteria, that are important for DSM evaluation, e.g. energy savings, CO_2-emissions and costs. However, many more criteria could be included in DSM evaluation that can not be assessed using this analytical approach, e.g. the contribution to the improvement of the company’s image. They need to be assessed by the planner or decision maker himself.

Table 1: Example of a Criteria List

Objective	Criterion
Minimize utility’s costs	Program costs Avoided production costs Change in revenues
Optimize strategic benefits	Long-term customer retention Confidence building Improving utility’s image Opening new fields of business
Minimize customer’s costs	Change in energy bill Technology costs Transaction costs
Optimize customer’s satisfaction	Quality of service Improving comfort Production increase Providing information
Improve environment	Energy savings Reduction of CO_2 emissions Reduction of other impacts Raising environmental awareness
Satisfy politicians	Contribution to energy and environmental policy objectives Creation of new jobs
Minimize risks	Reliability of data Implementation effort required

The Advantages of Multiple Criteria Analysis

An approach is required that integrates the DSM impacts for the individual criteria and results one single ranking of the alternatives. For this, Multiple Criteria Analysis (MCA) can be applied. MCA does not attempt to reduce the criteria to the same unit, but uses the trade-offs between the criteria, which are assessed by the planner or decision maker, to weight the criteria. The advantages of MCA are (12):

- the trade-offs, which are partly subjective, are made explicit.
- MCA doesn't just rank the alternatives on basis of predefined objectives and priorities, but aims to support the decision making process itself, including the establishment of those objectives and priorities. In practice, at the start of the DSM design or screening process, planners or decision makers often have no clear idea of the objectives they pursue and the priorities and trade-offs.
- MCA helps decision makers make more consistent and rational evaluations.

MCA therefore is an adequate method to support the multiple criteria decision making process in DSM planning and evaluation by energy utilities.

The Implementation of MCA for DSM Evaluation

Below, a nine-step approach to MCA in DSM evaluation, based on an approach by Hobbs and Horn (12), is described, and illustrated with a simple example:

1. *Alternatives.* The identification and characterisation of the alternative DSM programs or designs are established by the user or decisionmaker.

For example, an utility has in a DSM screening process the choice between three alternative DSM programs:

- promotion of condensing boilers,
- load management in industry, and
- promotion of efficient refrigeration using financial incentives.

2. *Objectives*. The objectives to be pursued with DSM are established by the user or decision maker.

In the example, the utility decides cost reduction, environmental protection and improving strategic customer relations are the main objectives.

3. *Criteria and units*. The criteria and units that are used to assess the contribution of DSM to the objectives are established.

In the example, the total DSM costs, the avoided CO_2-emissions and the improvement of the image of the utility are chosen as the criteria

4. *Impact estimation*. The impact of the alternative programs on the criteria is assessed. Part of the impacts (energy savings, emission reduction, costs) are calculated using the energy-environment-economics evaluation tool. The impacts of other criteria, e.g. the improvement of image of the company, are assessed by the user.

In the example, the following impact matrix is established:

Table 2. Example of an Impact Matrix

	DSM costs (DM)	**avoided CO_2 emissions (t/a)**	**Image improvement (5 point scale)**
Condensing boilers	50,000	1000	high
Load management	-100,000 (benefit)	0	none
Efficient refrigerators	20,000	2500	small

5. *Value scaling of impacts*. The scaling of the range of values for the different criteria to a linear zero (worst value) to one (best value) scale.

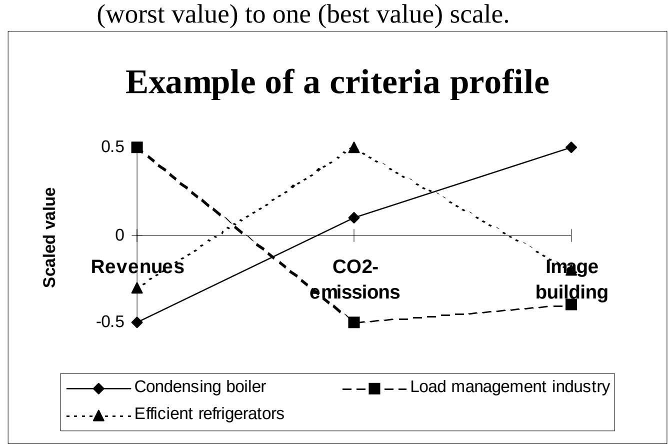

Figure 2

6. *Criteria profile*. The establishment of an average 'zero-impact' or 'neutral' value within the range for each criteria. The impacts are scaled by dividing the difference to the neutral value by the neutral value itself. In this way, a so-called 'Criteria Profile' can be drawn, which visualises the relative impacts of the alternatives. In figure 5, an example is given.
7. *Weighting of criteria*. A wide range of methods for picking criteria weights is available. In the ratio method, the stakeholder is asked if an improvement from the worst to the best value of one criteria is to be preferred compared to the worst to best improvement of the others.

Table 3 illustrates this for the example. In the fourth column the user enters the relative preference of improving the value of one criterion form worst to best in comparison to the equal improvement of the other criteria. Other approaches with different weighting procedures exist, but here the most simple and transparent one is shown.

Table 3: User Entry of Relative Preferences

Criteria	Worst value	Best value	Relative preference of improvement worst to best
Costs	50,000 DM	-100,000 DM	50%
Avoided CO_2 emissions	0	2500 t/a	30%
Image improvement	none	large	20%

8. *Evaluation*. On the basis of the trade-offs, specified by the user, the scaled criteria are weighted and added up to yield the total value of a DSM program.

For the example, the results are shown in table 4. Because of the relative high weight given to the reduction of costs, the load management program, which has negative costs, is the best program from the view point of the decision maker, although the program's scores on the other two criteria are very low.

Table 4: Example Results of MCA

Program	Weighted scaled impacts			Total value
	Costs	CO_2	Image	
Condensing boilers	0.0	0.12	0.14	0.26
Load management	0.5	0.0	0.02	0.52
Efficient refrigerators	0.1	0.3	0.06	0.46

9. *Iteration*. The user probably wants to change the weighting and see how this will affect the ranking of the alternatives in order to gain insight in the influence of the weighting.

The approach described above can be applied using deterministic impact values. However, it is useful, given the large differences in uncertainty between the various impacts, to incorporate user-defined uncertainty in the analyses. Instead of the result 'program A is better than program B', this would, for example, lead to the result 'It is certain/very likely/slightly likely that program A is better than B'.

Outlook

Although the future of DSM in Germany is uncertain, it can be expected that the role of evaluation to improve the effectiveness and efficiency of DSM will increase. As a result, there will arise a demand for simple, easy to use tools that can support utilities in the planning of DSM programs and the ex-post evaluation. The combination of the energy system modelling for the estimation of the energy, environmental and economic impacts with multiple criteria analysis to include other criteria in the evaluation seems an promising approach. However, the suitability is yet to be proven in the evaluation practice of German energy utilities.

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