International Energy Agency

Annex 22

Energy Efficient Communities

Energy Conservation in Buildings and Community Systems Programme

INTERNATIONAL ENERGY AGENCY

ENERGY CONSERVATION IN BUILDINGS AND COMMUNITIES

PROGRAMME

Annex 22

Energy Efficient Communities

Final report

July 1994

This Final Report documents results of cooperative work performed under the IEA programme for Energy Conservation in Buildings and Community Systems, Annex 22: *Energy Efficient Communities.* The information contained herein does not supersede any requirements or advices given in any national or international codes or regulations, neither is its suitability for any particular application guaranteed. No responsibility is accepted for any inaccuracies resulting from the use of this publication.

Principal authors:

R. JANK, VSE AG, Saarbrücken, GERMANY
J. JOHNSSON, CHALMERS TEKNISKA HÖGSKOLA, Institutionen för Energiteknik, Avdelningen för Energisystemteknik and PROFU AB, both in Gothenburg, SWEDEN
S. RATH-NAGEL, IC CONSULT GMBH, Aachen, GERMANY

Source for additional copies:

Forschungszentrum Jülich
Projektträger Biologie, Energie, Ökologie - BEO
A. LeMariè, J. Gehrmann
Postfach 1913
D-52405 Jülich
Tel. 02461-61-0

PREFACE

The International Energy Agency's Implementing Agreement for a Programme of Research and Development on Energy Conservation in Buildings and Community Systems was established in Paris on March 16, 1977, to conduct cooperative research, development, demonstrations and exchanges of information regarding the general objective of an internationally required sustainable energy supply system. This IEA-work is to be done by undertaking a series of "Annexes" which are established to coalesce the knowledge gained in research performed by participating countries on a particular topic.

Since 1977, 28 Annexes have been commenced by all or a subset of the 18 countries which have undersigned that Implementing Agreement. Only three of these Annexes were so far devoted to the second part of the agreement's title, community systems:

Annex 2:	Ekistics and Advanced Community Energy Systems
Annex 6:	Energy Systems and Design of Community Systems
Annex 7:	Local Energy Planning.

All of them have already been finished almost 15 years ago. In addition, only a few participating countries have attended those early Annexes. Since that time, energy supply of communities and the potentials to improve energy efficiencies, to tap new energy resources and to reduce energy demands have gained increasing interest in municipality administrations. In addition, environmental issues came into the center of interest during the eighties. Due to these developments, in a number of countries major efforts have been undertaken to develop and apply the instrument of *Local Energy Planning* (LEP) to a tool by which an integrated planning of entire community systems would be possible. In fact, LEP can today be considered as a kind of "meta-planning" instrument which integrates the knowledge and experiences of various planning disciplines to enable the urban management to simultaneously optimize the whole municipal organisation under a variety of given goals. Its potential to improve the urban environmental situation is, however, by far not exhausted today. Even under the more confined aspect of *urban energy planning* one must state, that claims according to the reduction potentials of energy consumption and reality still diverge widely at present, even though major differences in development and application of LEP in different IEA-countries are observed.

For these reasons, in 1989 a proposal for a new attempt has been brought about by several IEA-countries to assess the state-of-the-art of LEP and to review methods which have been developed and experiences which have been made in that field during recent years. The result of this proposal was to create a new Annex 22: *"Energy Efficient Communities"*, by which an evaluation of the international experiences with that instrument should be accomplished and conclusions should be drawn from those experiences with respect to an improved future LEP-utilization.

Four countries have decided in 1990 to participate in this Annex 22, Belgium, Germany, Italy and Turkey, followed one year later by two additional countries, France and Sweden. The project started in 1991 under the lead of Germany (operating agent of Annex 22 and lead country for two of the four Subtasks) and Belgium (lead country for Subtask D) and later Sweden (lead country for Subtask A). The project was carried out mainly by elaborating "National Reports" covering each of the Subtasks by the lead country, supplemented by additional information on those Subtasks requested by the lead countries from the other participating countries. The information was exchanged during six workshops organized by the Operating Agent which were attended by the Annex experts from the participating countries. Based upon these National Reports, the information was evaluated for the Final Report of Annex 22, which is provided herewith. It is a result of contributions and fruitful discussions amongst the experts listed in the following table.

I gratefully acknowledge the cooperation of these persons, in particular of the representatives of the lead countries who have shared the main responsibility and burden of work. In particular, I want to emphasize the cooperation of *John Johnsson* from Sweden, *Jo van Assche* from Belgium and *Stefan Rath-Nagel* and *Günther Korb* from Germany, whose contributions were of decisive value for the execution of this Annex 22. I do hope that our results will enhance further interest and developments in community systems planning, which in my opinion will be of enormous importance if the objectives of a future sustainable world shall be achieved in an efficient way.

Saarbrücken, March 1994
Reinhard Jank
(Operating Agent, Annex 22)

Experts participating in Annex 22:

Name	Affiliation	Address
Verbruggen, Aviel, Prof.	University of Antwerp UFSIA-SESO Studiecentrum voor Economisch en Sociaal Onderzoek	Prinsstraat 13 B-2000 Antwerp Tel..: 0032-3-22 041 73 Fax . 0032-3-23 081 90
van Assche, Jo	Studiecentrum STEM TECHNOLOGIE ENERGIE MILIEU	Gitschotellei 138 B-2600 Berchem Tel. 0032-3-2710892 Fax 0032-3-27101524
Korb, Günther Dütz, Armand	B.&S.U. GmbH	Alt-Moabit 105 D-10559 Berlin Tel.: 030-390706-54 Fax: 030-390706-31
Roeder, Matthias	peb GmbH	Seler Weg 33 D-12169 Berlin 41 Tel.: 030-7958 073 Fax: 030-795 30 94
Jank, Reinhard	Vereinigte Saar-Elektrizitäts AG (VSE)	D-66121 Saarbrücken Heinrich-Böcking-Str. 10-14 Tel.: 0681-607-565 Fax: 0681-607-566
Rath-Nagel, Stefan Elsenberger, Ulrich Westermann, Martin	IC Consult GmbH	Auf der Hüls 197a D-52068 Aachen Tel.: 0241-169 001 Fax: 0241-169007
Lavagno, Evasio, Prof.	Dipartimento di Energetica Politecnico di Torino	Politecnico di Torino Corso Duca degli Abruzzi 24 I-10129 Torino Tel.: 0039-11-564 4429 Fax: 0039-11-564 4499
Tan, Melih Omurtay, Dogan	Ankara Greater City Municipality Belko Ankara Coal and Supply Materials Distribution Company	Mesnevi Sokak 27 Asagi Ayranci Ankara Tel.: 0090-312-440-79 49/10 Fax: 0090-312-440-78 67
Wene, Clas-Otto, Prof. Josephson, Anna	Energy Systems Technology Division Chalmers University of Technology	Chalmers University of Technology S-41296 Göteborg Tel.: 0046-31-77 21455 Fax: 0046-31-77 235 92
Johnsson, John	Profu AB	Nordostpassagen 61B S-41311 Göteborg, Tel. 0046-31428220 Fax 0046-31242638
Troche, Jean-Louis	RE-Sources	8, Place Jean-Baptiste-Clement F-75018 Paris Tel.:0033-1-42 570 212 Fax: 0033-1-42 236 465

Reports written in the course of Annex 22:

For every Subtask a "National Report" has been elaborated by the lead country covering the main issues of the subject under discussion and complimentary reports were then prepared by the participating countries. This work, expressing the specific national experience of each participant, was the basis for the evaluation of the Annex results by the lead countries and the Operating Agent which is summarized in this Final Report which is the only Annex 22 Report which is intended for publication. Copies of the various National Reports have been passed on to Kernforschungszentrum Jülich (KFA), which is the German representative within the IEA organization's Executive Committees. Further copies of these internal reports are available upon request by KFA, as well as reprints of the Annex 22 Final Report.

In addition to the Annex 22 Final Report, the following reports have been passed on to KFA:

- ***Subtask A: Software Tools in Energy Planning***
  (National Report of the lead country Sweden with a *software tools inventory* and evaluations of the contributions of the participating countries Belgium and Germany to Subtask A; *49 pages, Appendix 150 pages*)

- ***Subtask B: Models for the Calculation of Environmental Aspects***
  (National Report of the lead country Germany, including a comprehensive bibliography; *179 pages*)

- ***Subtask C: Means to Represent and Advertise Planning Solutions***
  (National Report of the lead country Germany, *121 pages*)

- ***Subtask D: Institutional Elements in the Implementation of Local Energy Planning Concepts***
  (National report of the lead country Belgium, *47 pages*)

- ***Energy Efficient Communities: National Report for France***
  (National Report of the participating country France, covering Subtasks B and C, *31 pages*)

- ***Energy Efficient Communities: National Report for Italy***
  (National Report of the participating country Italy, covering Subtasks A, B, C and D, *65 pages*)

- ***Energy Efficient Communities: National Report for Turkey***
  (National Report of the participating country Turkey, covering Subtask B, *17 pages*)

- ***Subtask D: Implementation of Integrated Planning Procedures***
  (National Report of the participating country Germany, covering Subtask D, *26 pages*)

Annex 22: Energy Efficient Communities - Final Report Summary

R. Jank, Operating Agent
Vereinigte Saar Elektrizitäts AG, Saarbrücken

1. Background

Since 1977, 28 Annexes have been commenced by all or a subset of the 18 countries which have undersigned the IEA-Implementing Agreement on Buildings and Community Systems. Only three of these Annexes were so far devoted to Community Systems. All of them have already been finished almost 15 years ago. Since that time, energy supply of communities and the potentials to improve energy efficiencies, to tap new energy resources and to reduce energy demands have gained increasing interest in municipality administrations. In addition, environmental issues came into the center of interest during the eighties. Therefore, major efforts have been undertaken in a number of countries to develop and apply the instrument of *Local Energy Planning* (LEP) to a tool by which an integrated planning of entire community systems would be possible, making use of the substantial progress which has been made at the "microscopic" level of individual buildings. In fact, LEP can today be considered as a kind of "meta-planning" instrument which integrates the knowledge and experiences of various planning disciplines to enable the urban management for simultaneous optimization of the whole municipal system under a variety of given goals. Its potential to improve the urban environmental situation is, however, by far not exhausted today: energy consumption reduction potentials and reality still diverge widely.

Environmental aspects of the energy supply of "community systems" are increasingly decisive for assessment and comparison of different supply options. Whereas economic optimization of the energy supply of *individual buildings* as well as of *regional supply areas* is the goal of traditional planning procedures, LEP is an interdisciplinary field of town-planning and energy supply engineering, developed and applied during the last 15 years and recently characterized by an extension to "integrated solutions", where the system as a whole is optimized rather than single components of it, using a variety of different optimization criteria.

LEP was developed quite independently within several countries. From the very beginning LEP was a means for practicioners rather than for scientists. Therefore, communication and exchange of experiences between planners in different countries was quite weak. Since the increase of reqirements to LEP has led to a growing complexity of the planning process on the one hand, and growing interest from countries having so far less experiences in that field on the other, Annex 22 was conceived by which national experiences with LEP should be summarized and an exchange of these experiences between the participating countries should be managed.

In the present situation of dynamic and diverse development of LEP, the task of Annex 22 has been defined to

- compare data, methods and approaches applied within the participating countries and evaluate the results with special consideration of transferability
- develop a summary of those informations which are of particularly practical usefulness for the individual planner of a concrete LEP-project.

The LEP-process consists in general of two main components, which interact with each other in manifold ways:

i) the actual process of planning and design

and

ii) the transfer of the results to the various groups involved to implement the energy plan.

According to this and the project objectives stated above, the work was structured into four subtasks, with Subtasks A and B closely related to i) and Subtasks C and D to ii):

Subtask A	*Software Tools in Energy Planning*
Subtask B	*Models for the Calculation of Environmental Aspects*
Subtask C	*Means to Represent, demonstrate and Advertise Planning Solutions*
Subtask D	*Implementation of Integrated Planning Procedures.*

The following countries have participated in Annex 22: Belgium, France, Germany, Italy, Sweden and Turkey, with EU and OECD as observer. The lead countries for the different subtasks, being responsible for preparation and coordination of the work, were *Sweden* for Subtask A, *Germany* for Subtasks B and C and *Belgium* for Subtask D.

2. Subtask A: Software Tools in Energy Planning

One of the main objectives of Annex 22 was to collect information on existing computer-assisted instruments in LEP, which had been developed within several countries which were specifically active in this field during recent years. Several models for the analysis of municipal energy systems have been developed during the last decade. These models originate from universities and research institutes and from the consultancy sector and the energy industry as well. The models differ widely in detail and scope, where the more detailed models are used for the analysis of subsystems of the municipal energy system and the models of less detail, but of wider scope are used for the analysis of the entire system. LEP-software tools in the context of Subtask A are understood as *computer-aided instruments, which are used by either urban planners, design engineers for "technical infrastructure" or urban decision makers within the LEP-process or during the implementation of an LEP-conception*. By this understanding, "macro-tools" for energy planning at the national or even regional level are excluded as well as "micro-tools" for optimization or simulation of objects below the level of detail usually considered in LEP-projects (such as tools for detailed network design or simulation software for buildings like TRNSYS, BLAST, DOE-2, LogoCAD etc.).

2.1 Categorization of LEP-software tools

With respect to the different existing software tools, some *categories of distinction* can be conceived:

(1) Energy system design tools according to their scope:

"single purpose" calculation tools	result in an optimization of defined single components of the energy system (e.g. of a heat pump, a solar collector array, a cogeneration plant, etc.) according to given goals
"horizontal" calculation tools	consider (and optimize) the whole chain of energy transformations (or a part of it) from city-gate to end-use

"vertical" calculation tools — consider an "intersection" of two or more energy supply systems (e.g. gas vs. district heating-optimization, different types of cogeneration heating plants, ...)

"integrated" calculation tools — use comprehensive models for the simultaneous optimization of supply and demand side measures

(2) "Auxiliary tools" according to their fields of application:

"mapping" tools — process *geographical information* (such as emission catasters, heating maps etc.) for grafical presentations or for the use in calculations for energy distribution system design ("geographical information systems": *GIS*)

"ecologic" tools — provide *environmental information* (such as calculation of immissions from given emission data which themselves are calculated by other "ecologic" tools)

data bases — allow for generally accepted *inputs of data* into energy system design tools (such as statistical climatic data ("test reference year": *TRY*), building statistics, customer statistics of utilities,...)

evaluation tools — provide means to evaluate *results* of energy system design tools (e.g. cost/benefit-analyses, environmental assessment analyses etc.)

urban planning tools — support planning of the physical environment within a community (land use planning devices, traffic planning; digitized city catasters)

grafical presentation tools — provide *means to present* LEP-results to decision makers or to the public

For each of the above categories some or even many different software tools have been developed and most of them are available to the practicioner *in principle*. During the work on Subtask A, comprehensive data on existing sofware tools were only available from Sweden and Germany. Almost 200 such tools have been found in these two countries. Within the other three participating countries in Subtask A, the application of computer aided LEP is obviousy much less common.

2.2 The Comprehensive Linear Programming Model MARKAL

One of the most important tools found is MARKAL, a comprehensive LEP-model which is capable to optimize the entire energy system of a municipality under defined optimizing objectives. It is therefore described with more detail here.

MARKAL was developed in a multinational co-operation within the framework of IEA. The model was originally designed for studies of the national energy system but was in the mid 80'ies adjusted to the municipal level by Chalmers University of Technology, Energy System Technology Division, in Gothenburg, Sweden.

MARKAL is a dynamic linear programming (LP) model. It is of specific interest because of its capacity to simultaneously describe the access to energy resources, the transport and distribution of energy, large-scale and small-scale energy conversion and energy saving. This property makes it possible to study the interaction and competition between all the parts of the municipal energy system from a technical and economical viewpoint. MARKAL can also handle environmental factors. Different environmental standards can be set for the energy system. The model allows the implementation of cost-benefit analyses or environmental/energy studies. MARKAL is a *prescriptive* model in the sense that the solution it provides is a technical energy system that meets a specific target in the best way, for example, minimized total system cost under a given development of the system environment. The results are therefore not forecasts.

The first example of a project in Sweden using a computer-based model as a tool to analyse the entire community energy system was in Jönköping in 1980, where the MARKAL model was used. Development of the MARKAL model in mid 80's made it possible to handle different types of emission constraints and that model has since then been used as a tool for municipal energy planning in about 20 projects. The municipalities differ in both size (Värnamo 30.000 - Gothenburg 400.000 inhabitants) and settlement type. In all cases the model has been used interactively in cooperation with the local politicians and organisations involved [1].

2.3 Main conclusions on Subtask A

The enormous diversity of existing tools which are in principle available to the planner is to be opposed to the growing diversity of tasks of LEP, which today are not only cost-minimizing energy supply design projects, but have to satisfy much more ambitious goals: integration of demand and supply side measures (*"Integrated Resource Planning"*) and integration of environmental requirements or boundary conditions into the planning and decision process, possibly with quantified results for different options in accordance with the given system of goals.

These increasing ambitions and requirements to LEP result into a certain "scientification" of the LEP-process. The availability of suited software tools for his purposes will in principle enable the traditional planner to fulfill the increasing requirements to LEP with the desired quality. This presupposes, however, a certain standardization of methods and data bases, which today is at its very beginning.

We can observe at present a transition from "traditional LEP", which on the basis of optimization or design calculations for single, confined parts of the energy system tried to optimize the system as a whole by either iteration or experience, to comprehensive, *simultaneously* optimizing approaches using modern methods of systems analysis which so far still are not or very scarcely applied in LEP. If one searches for the "optimal combination of measures" (minimal costs, minimal primary energy use, minimal emissions, minimal environmental impacts, ...) as the result of an LEP-project, only such a comprehensive approach will allow for a consistent and transparent solution.

This development is justified because urban or utility decisions as a result of LEP-proposals require complex and long-term decisions with large investments and appreciable risks. Since in general a number of different options are possible, with possible interactions, and since the necessary assessments have to consider a whole set of goals with possible conflicts (between goals and amongst affected groups as well), comprehensive models such as MARKAL can best support and objectivize the decisions to be taken. In addition, the use of such models which easily allow for supplementary informations by changing some parameters and posing "what-if-questions", will enable a learning process amongst different actors involved in LEP, thereby supporting its acceptance which is necessary for a successful implementation. Later changes in general or local frame conditions not foreseen during the LEP-process can be considered quite easily when they appear.

From the participating countries in Subtask A, only in Sweden and in Germany such comprehensive models as described above are under development or already applied at the LEP-level. Comparable developments are known from universities in Finland and Denmark, which, however, are not participating countries in Annex 22. It is only Sweden where a version of MARKAL was redesigned for LEP-purposes and applied to a number of Swedish communities.

Any application of this model for a defined LEP-project requires a large amount of new input data describing the specific application case. It is the generation of this information input to the model, where the interface to many of the other tools mentioned above would be essential: the results of these tools, such as specific cost functions for distribution networks or for energy saving measures, climatic conditions which define the demand for heating and cooling, emission factors or cogeneration credits, provide the necessary informations for the comprehensive optimization model. On the other hand, the calculation results of the model create input to other tools such as immission calculations, environmental assessments, cost/benefit-analyses with respect to the system of goals etc.

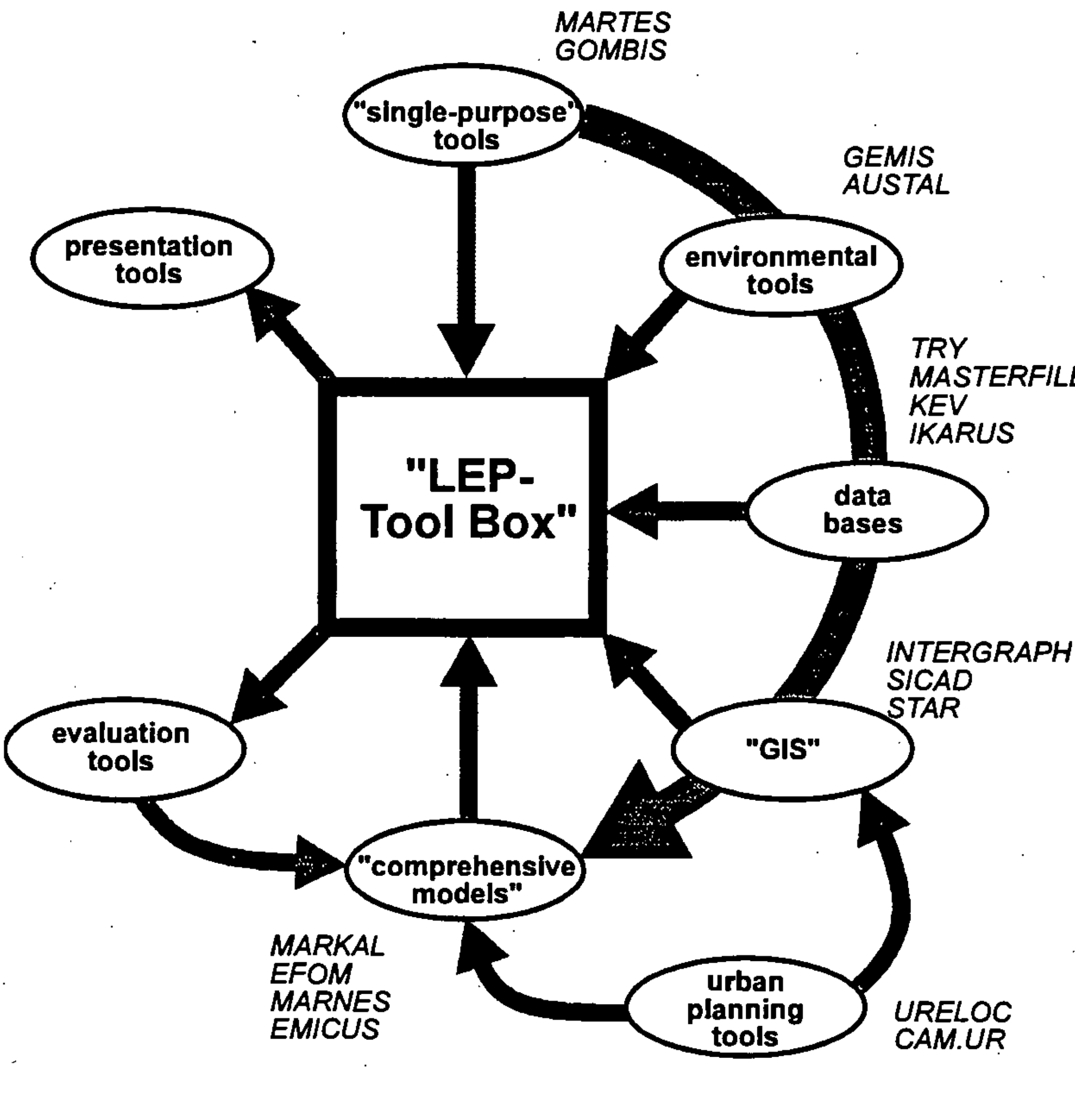

Fig. 1: The LEP-toolbox", which in principle is available to the planner. Some existing commercial or scientific software tools for different categories are indicated.

According to the discussions within the Subtask A working group, one cannot expect that there ever will be an overall comprehensive LEP-expert system which will provide a ready LEP-solution when it only was fed with the correct input data: not one single model - or a small number of such models - will ever provide a sufficient means to evaluate a realistic LEP-project. On the contrary, future LEP-experts must have sufficient insights in methods and knowledge of available software tools that they are able to handle them as separate tools which provide reliable and actual sources of information for the specific requirements given in their concrete LEP-project: the expert chooses his own "expert system" to be adapted in his specific case, consisting of a number of different software tools suited for the individual application (fig. 1). The comprehensive model is used in this context as a central software tool which serves as a means to describe in a general way different "futures" in dependence from different assumptions on developments or boundary conditions.

The extent to which this model describes details of single parts of the energy system is, however, limited. This is the regime of the above mentioned "single purpose" calculation tools and data bases, such as GEMIS 2.0, which answer questions with much greater detail and resolution. The planner will use a number of such individual tools which generate partial results to be used for the development of LEP proposals either in a traditional way or by using an integrated comprehensive model describing simultaneously the overall system of energy demand and supply. Fig. 2 shows a schematic illustration of this approach, where data inputs from data bases and first results from specialized "single purpose tools" are processed by a comprehensive simulation model which produces certain outputs. The results may be fed back into an iteration step to generate a change of input data, eventually after interaction with decision makers.

Because of the interdisciplinary character of the tasks within the LEP-process, the availability of professional software tools will contribute to an enormous improvement of the quality of the planning results. This presupposes a broad knowledge of existing tools, the methods used therein and the data and other informations used by them. The present situation is quite distant from that goal: existing software tools for energy planning are often badly documented, insufficiently marketed, offer no or insufficient support for data input or presentation of results etc. In other words, many of the existing tools do not keep the standards of software engineering which today should be required from professional software, they rather concentrate to the immediate technical-economical problem to be solved. Since the planner has to use a whole "family" of software tools, there is an urgent need for consistent tools which use consistent input data and provide defined interfaces for data exchange.

In addition, at present a certain "quality gap" has to be observed: the scientific methods of systems analysis must be the basis of future LEP-methods, making use of most actual data bases on energy systems and environmental informations as well as of simulation and scenario techniques, linear (or non-linear) programming methods for optimization calculations under given restrictions, methods of operations research or decision theory in complex systems until methods of General Systems Theory. At present, such methods are hardly ever used in the context of LEP. As a consequence, one can say that whereas partial solutions and tools have been developed and quite broadly documented and published in the past ten or fifteen years of LEP-applications, still a long way has to be gone to provide fully consistent and scientifically supported instruments for the supply of professional LEP-solutions. Along this way, a certain "convergence process" has to take place between LEP and urban planning including the special field of traffic planning, which will have to be considered simultaneously if really optimal and lasting, that is *sustainable* solutions shall be found for the future development of communities.

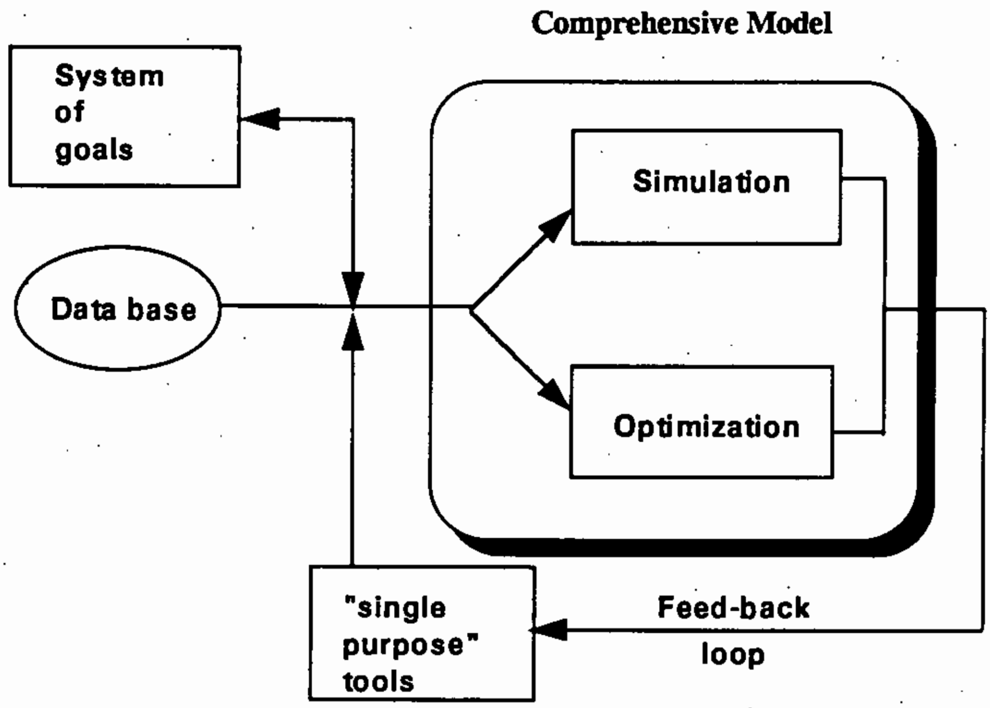

Fig. 2: Principle of approach to LEP using support of existing software tools and a "comprehensive model": For a given scenario the whole energy system (of a community) is simulated and according to given goals optimized. In one or more iterative steps subsets of the whole system are recalculated using "single purpose" tools and the results are fed back to formulate a new scenario.

3. Subtask B: Models for the Calculation of Environmental Aspects

In accordance with the necessary move from pollution control to pollution prevention, environmental effects have to be increasingly considered already during the planning process. The objective of Subtask B was to provide an overview of actual data and instruments available to local planners who have to solve practical planning problems. These tools shall be applicable for evaluation and comparison of environmental impacts of different alternatives or strategies considered in local energy planning. Since integration of environmental aspects into the process of local energy planning involves widespread and rapidly developing interdisciplinary knowledge, very often the practical problem arises, how and where to gather actual information to answer specific questions in the context of energy use and its environmental impacts, combined with economic evaluations. To the traditional planner, this generally surmounts the scope of his educational background, which is oriented to specialized planning processes rather than comprehensive *integrated* considerations. This statement is true in general for architects, urban planners and engineers as well. Since planning budgets are restricted, a way must be found to evaluate meaningful answers without the help of specialized and expensive scientists. It was the aim of Subtask B to show the present "state of the art" of the inclusion of environmental considerations in local energy planning by the planner, using the best available data to achieve comprehensive and consistent results.

3.1 Content of Subtask B

The "national report" of the lead country Germany for Subtask B was the basis of the final report evaluation and consists of four parts:

Part I: *Systems energy efficiency*

In this basic evaluation characteristic data on energy systems with respect to their energy efficiency are identified, including in particular bivalent systems such as cogeneration or heat pump systems, whose design depends, among other criteria, also from the energy-price levels given at the time of planning or forecasted over the life-time of the energy system investment. When comparing different supply systems, input data which result from the national energy supply structure, such as the fuel mix for electricity production, are needed.

Part II: *Legal requirements and basic informations on the environmental impact of energy systems*

In the LEP-process an agreement has to be found as to the "environmental properties" of the different energy systems to be considered. These properties can vary largely between different countries, due to different environmental requirements, different technologies used, different properties of fuels etc., which are of essential influence to emission factors. Part II gives an overview on actual data on these issues which are to be used as a basic input to any environmental comparison.

Part III: *Methods to compare environmental impacts of energy systems*This is the most ambitious part of the work on Subtask B, since it aims to integrate the more "one-dimensional" approach of simple quantitative comparisons or optimizations, for instance with respect to economics, with complex environmental assessment procedures. These procedures intend to achieve an increasingly broader approach to the problem of assessment of environmental impacts and will presumably be applied also in LEP-projects in the future.

Part IV: *Environmental monitoring and information systems*

This part is focussed to an overview over national environmental monitoring programmes and networks as well as to computer-based environmental information systems which make spatial related handling, processing and presentation of large sets of environmental data possible. While single environmental data are already considered in LEP-projects, it is predictable that such modern information systems for environmental data will be used in the future. It is therefore of interest to assess the present and future possibilities in this field which may have effects for the future practical planning process.

3.2 Environmental impacts

The broadening of the scope of environmental evaluation has consequently led to a vertical and horizontal expansion of the energy systems to be considered. To give a comprehensive valuation of the available energy options, the technologies under consideration, generally

fossil based energy supply
energy conservation
renewable energies and
nuclear energy

have to be investigated according to their complete fuel chain on the one hand and to their life-cycle impacts during the operation of the technology used on the other. Relevant environmental emissions and burdens to be considered are then

- *atmospheric emissions*

  SO_2, NO_x, particulates,
  CO, H_nC_m, nitrous oxides, heavy metals, radio isotopes
  CO_2 and other green house gases

- *solid wastes*

  bottom ash, gypsum, fly ash
  mine spoil
  waste water sludge

- *emissions to surface or groundwater*

  suspended solids, organic compounds, heavy metals
  acidity, sulphate, chlorides
  radio isotopes
  heat

- *other burdens*

  water consumption, land use
  accidents, mining subsidence
  visual intrusion, noise.

These environmental burdens produce a wide range of impacts, which can be classified as follows:

- *human health impacts*

  mortality
  morbidity

- *biological impacts*

  agriculture and forestry
  terrestrial ecosystems/wild-life habitat
  aquatic systems, fisheries

- *non-biological impacts*

  materials damage
  water supply
  land use
  perceived noise
  visual impact.

In principle, these impacts cause external costs to the energy system. Valuation techniques to assess these externalities depend to a large extent upon the relationship of the considered impact to existing markets. However, these impacts are so different, that a general judgement in terms of external costs is in most cases very difficult. As long as there exist regulatory standards (such as immission limits), quantifications are possible at least in principle. Many of the impacts mentioned above are of a qualitative nature and not quantifiable at all. Others are very difficult to quantify - at least to an acceptable degree of confidence. Obviously, in that complicated situation there is a strong need to offer some help to the practitioner which may help him in assessing energy options within his concrete LEP-project.

3.3 Valuation methods

In theory, there is a very elegant method to arrive at a quantification of externalities: the "external costs eqilibrium principle". This principle requires that expensive measures for pollution abatement should enable commensurate societal benefits in return: the cleaner the environment, the more expensive the further abatement will be. At some point, the next increment of emission abatement may not be worth the costs to society, which has also alternative uses for their real resources - the equilibrium external costs (fig. 3). In other words, the societal welfare is then maximized, when the marginal costs of pollution control are in balance with its marginal benefits.

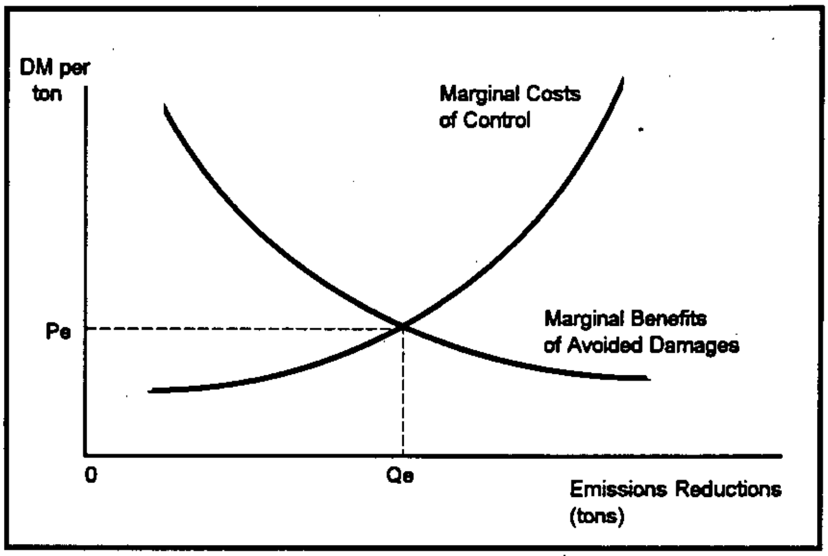

Fig. 3: Equilibrium external costs of pollution abatement [2]

Unfortunately, many of those benefits (or avoided damages) cannot be quantified, therefore surrogate approaches have to be developed, which may consider only subsets of the general impacts mentioned above. The most prominent approaches which have been developed by economic theory are according to present practice [2]:

- *the damage function approach*

  (external costs equal to the damage caused)

- *the abatement cost approach*

  (the costs of reducing emissions are by definition attached to the external costs of the avoided emission)

- *the target approach*

  (establishes physical/mandatory constraints on energy system selection with the objective of finding the option that provides energy services at the lowest costs consistent with those constraints, set at the point of emission or deposition; emission abatement strategies are then developed within that physical/mandatory constraints)

- *the revealed preference method*

  (with insufficient informations on damages or abatement costs, the costs of achieving compliance with legislated standards can be considered a societal "revealed preference" value)

- *the hedonic pricing approach*

  (uses market prices to infer prices of non-priced goods, e.g. wages of workers exposed to enhanced risk compared to "normal" workers)

- *the willingness-to-pay approach*

  (also called "contingent valuation"; determines the value assigned by individuals to avoid or be compensated for an environmental impact by evaluation of interviews, surveys or opinion polls)

- *the critical-volume approach*

  (suited for product eco-profiles rather than energy systems: uses the volume of air or water necessary to dilute the raw emissions to a legally accepted level).

All of the approaches mentioned above have there niches of application. In the LEP-case, if the consideration of environmental impacts is not a dominating issue, it will often be sufficient to confine the analysis to a target approach accompanied by a cost-effectiveness analysis. Here, it is assumed that by achieving the limits given by environmental legislation the environmental impacts have been reduced to an extent which is in general accepted by the society and has not to be quantified further. Within the existing legal framework, it is then the task of the planner to find the most cost-efficient solution.

This approach has the merit to significantly simplify the task of considering environmental impacts and to enable unambigous results. It has, on the other hand, the disadvantage that local peculiarities, which can be quite important in considering environmental impacts, are ignored. This is the reason why more complex approaches are frequently required also in LEP, such as environmental impact assessments. For such a comprehensive approach, *life-cycle analysis* (LCA) seems to play a key role at present in the scientific discussion to quantify the emissions/burdens of energy systems (and generic product assessment as well).

LCA consists of two stages (fig. 4):

- *life-cycle inventory* - quantifies flows of energy, raw materials and residuals required or released throughout the life-cycle of an "energy service"
- *life-cycle impact analysis* - values the effects of the environmental burdens identified in the inventory (using one of the approaches mentioned above) in order to interpret the results of stage 1 and to give answers to policy questions.

Stage 1 is usually considered as "objective": data are accumulated on a verifiable basis and no valuation takes place (with the exception that in this stage it is already decided which impacts are considered and which are not). Stage 2 is the actual impact assessment step.

With no surprise, the implementation of this second step is far from being generally accepted within the scientific community. Even if there is, for some impacts, an undisputed understanding of their mathematical evaluation, quite unprecise results will be achieved in general due to appreciable data errors. For example, calculate the external costs of one single immission impact from an energy transformation process. This involves a series of multiplications: emission rate times transfer coefficient times exposure factor times exposure-response factor times a monetary value. Besides the fact that in this calculation it is assumed that all processes are linear (which may be quite wrong), the five coefficients may be known more or less precisely; due to error propagation the result will in general have an appreciable uncertainty.

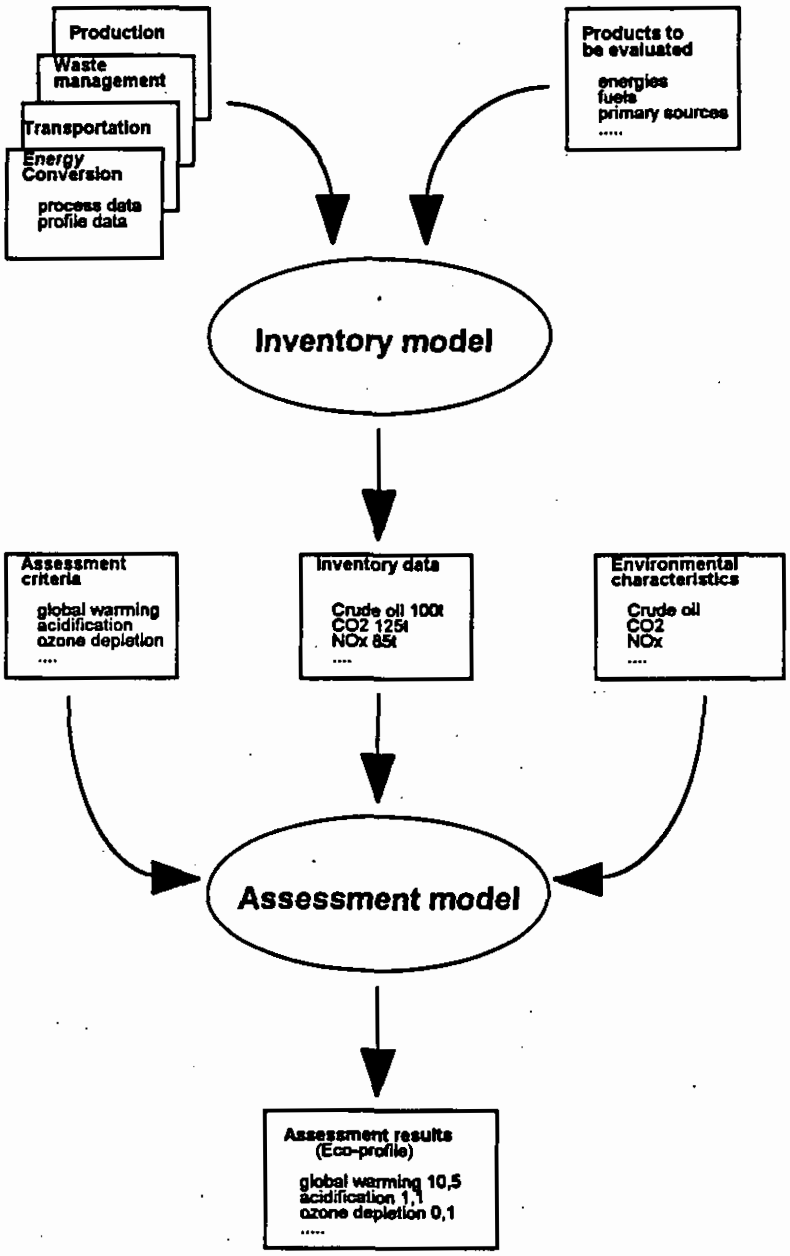

Fig. 4: Principle of a holistic environmental impact assessment [3]

For stage 2, again different methods are applicable in principle, as provided by economic theory, such as

- cost-benefit-analysis
- cost-effectiveness analysis
- use-value analysis (also called benefit value analysis)
- ecological risk analysis.

A possible development for the future could be the combination of LCA (stage 1, which produces the quantified inputs) with a *use-value analysis* (assigns "use values" or "benefits" to the achievement of defined goals by different energy system options using transparent algorithms [4]) of the results of the first stage of LCA as valuation model for stage 2. This approach would meet scientific requirements to verifiability and rigorousness. However, quite a bit of mathematics would be involved with that method [5] by which transparency and credibility is lost within the process of LEP, where many different decision makers at the local level are involved (creditibility dilemma of expert systems). Whereas such a method certainly would have its scientific merits, it seems to be hardly applicable at the front of LEP-practice at present.

3.4 Practical Approach to Assess Environmental Impacts in LEP

For the practicioner, what is really necessary is an approach which is balanced between *accuracy* of the assessment of environmental impacts, *practicability* and *public transparency*. According to these requirements, as a result of Annex 22 - workshop discussions the following "rules of thumb" may be useful at the present "state-of-the-art":

(1) Consider only *relevant impacts* (where the energy system is the dominating factor for the impacted eco-system). Debate only issues that can be adressed meaningfully.

(2) Distinguish between *quantifiable* emissions/burdens and *non-quantifiable* burdens.

(3) Consider national targets according to actual environmental legislation.

(4) Distinguish between *global* and *local* impacts.

(5) Do not aggregate over several indicators or criteria expressed in different measurement units ("multi-score eco-profiles"), since this would hide facts and conclusions.

(6) Consider direct costs and external costs independently without aggregation.

(7) Make sensitivity considerations to discuss the robustness of the interpretations.

(8) Give assessments and interpretations of results.

(9) Leave the decision maker with some decision power, based on his own system of goals, and present as neutral and transparent judgement of impacts as possible.

(10) Involve the decision maker into the whole process continously.

Applying these rules, quantifiable burdens of energy systems which in general should be considered in LEP are

- atmosperic emissions:
  "classical" pollutants: SO_2, NO_x, CO, particles; eventually also halogens, heavy metals
  green-house gases: CO_2, CH_4, CO, N_2O, NMVOC
- soil immissions (particle matter, acid rain)
- temperature rise of surface water, water consumption
- solid waste.

(Accident risk assessment is also quantifiable in principle, but this quantity is of a quite different quality, since it considers probabilities rather than impacts. This issue, however, is in general of minor relevance in LEP-practice.)

Qualitative aspects of energy systems are in general dominated by the consequences of primary energy extraction, though local effects such as demand of land area, noise (both of them with quantitative and qualitative aspects) or visual intrusion may in specific cases also have their weight in the assessment of alternatives.

4. Subtask C: Means to Represent, Demonstrate and Advertise Planning Solutions

One of the main issues in LEP is the transfer of planning results from the planning and engineering level into the level of public acceptance of a municipal energy plan. The actors participating in the approval processes are manifold and so are their aims and targets. Examples of the several actors include political decision makers, administrations, utilities, energy consumers and various interest groups. One of the most important output from the planning process is therefore to find ways of harmonization of the different actor's interests, including learning and conflict resolution. It is consequently very important to illustrate and edit communal energy planning results in the appropiate forms, i.e. to "sell" the results of LEP to the concerned actors within the decision process. Many municipalities are in fact putting considerable efforts into the "marketing" of energy projects. Various means have consequently been developed specifically to represent, demonstrate and advertise planning solutions accordingly.

A comprehensive evaluation of the these means to disseminate informations on LEP to achieve a widespread application of this planning instrument does not exist in either of the participating countries. For an assessment of the value and effectiveness of the enumerated examples of information media and means the following main criteria are used:

- expected impacts on energy conservation
- volume of the target group addressed with the aspect of information dissemination
- anticipated multiplier effect
- relevant costs required for the realization of the measures.

The assessment is summarized in table 1.

While discussing all those different efforts with respect to the results achieved, it has turned out so far that an evaluation of support and dissemination programs for energy conservation and their respective cost/benefit-yields has rarely ever been made. Conclusions from German experiences indicate, that a *combination of measures*, tailored to specific target groups, can be generally expected to be most effective. A broad information campaign alone, for example, will have little effect. It should be accompanied by specific "on-the-spot" consulting, combined with financial programmes for measures which have proven to be economic, for instance, in order to surmount the implementation barrier of energy saving measures which generally have to compete with other possibilities of investment. The advisory process should preferably be organized by a public institution or an association. By this, in general, optimal public relation channels are accessible as well as support in organisation and management problems. Qualified and free-of-interest service which is normally best accepted by the target group is provided by this approach.

A very good example for such an integrated approach is given by the Swiss "Impulse program", by which outstanding and very useful teaching material for energy conservation in the building sector has been prepared in co-operation between universities, industries, consultants and the Swiss association of tradesmen. This program was not subject of our investigation, but it has turned out that within the Annex 22 participating countries no efforts of comparable quality have been carried out. It is this integrated approach of combined and specifically tailored measures, which can be expected to be adapted most efficiently by the target groups, while at the same time the percentage of free-riders is kept low. In contrary, isolated measures, such as some single, mono-oriented energy conservation programmes, may turn out to be of quite doubtful success in terms of their cost/benefit-ratio. As it was experienced with the above mentioned "Impulse-Programme", in order to arrive efficiently at the desired behavioral changes and environmental improvements and to support the implementation of the LEP-plan as the essential aim of LEP, a bundle of measures is necessary. These measures have to be elaborated and implemented on different levels (national, regional and local) and by different actors (administrations, communities and utilities).

Measures/Institutions	Adressed Target Group	Multiplier Effect	Cost	Effects on Energy Conservation	Extent of Application in Participating country	
Information and Advisory Campaigns	high	high	small	small	Sweden Belgium France Germany	medium small medium high
Specific Consulting and Qualification Measures						
Energy Conservation Programmes	small	small	medium	high	Sweden Belgium France Germany	medium small medium high
Demonstration Projects	high	medium	high	small	Sweden Belgium France Germany	medium small small medium
information Systems	high	high	high	high	Sweden Belgium France Germany	medium small high high
Energy Agencies	small	medium	small	medium	Sweden Belgium France Germany	medium medium small high
Experience Exchange	small	medium	small	small	Sweden Belgium France Germany	medium small medium medium
Specific Institutions at the local level						
Energy Officer, Energy Coordination Conference	small	small	small	high	Sweden Belgium France Germany	medium medium medium high
Energy Councils	small	high	small	small	Sweden Belgium France Germany	medium small medium high

Table 1: Assessment of the efficiency of dissemination activities and the extent of their application within the participating countries

5. Subtask D: Implementation of Integrated Planning Procedures

The decisive aim of LEP is the implementation of the resulting urban energy plan by a consequent and steady municipal energy policy. It has turned out, however, that there are large differences within the participating countries according to the existence and implementation of such a municipal energy policy, which are assigned by the lead country of Subtask D, Belgium, to structural differences within the legal and economic frame of energy supply and the role municipalities have therein. These differences are discussed in the evaluation of Subtask D and conclusions are drawn as to the possibilities of municipalities to develop their own activities to achieve a sustainable energy supply system under differing legal and structural conditions.

It was generally agreed upon by the Annex 22 experts that there are indeed energy saving potentials in the local energy supply in all participating countries which could be exploited more effectively if there was an integrated LEP-conception and concerted efforts at the local level to implement it. It was also agreed that the management of the municipalities should in general be the main actor in developing LEP, but, independent from the legal structure of the national (electric) energy supply, that it was important to involve the utility being responsible for the local supply into that process of finding an optimized use of energy. The municipality shall play an active role in

- inclusion of all relevant groups
- conceiving a steady urban energy policy which is oriented to the long-term objectives of national energy policy and with clear priorities and quantified goals at the local level
- exerting influence, if possible, to the actual boundary conditions to support those goals, such as adaptation to general urban planning or declaration of district beating priority areas
- designing an autonomous program of projects and other measures to minimize the energy consumption of municipal buildings and establishing a continous energy management for them
- establishing a long-term municipal energy plan in cooperation with the existing utility as a basis of an integrated energy policy which is oriented to economic and ecologic goals as well
- creating a position or institution which is responsible for the control of the implementation of this conception.

The inclusion of the local (or regional) energy suppliers was considered to be crucial for such a program, since only then sufficient technical, financial and data resources for that program would be available. To avoid possible goal conflicts of the utility, incentives should be negotiated such as long-term co-operation contracts and extension of its energy services, accompanied by defined obligations of the utility to support the development and implementation of the municipal energy plan. With such a strategy, which however presupposes the principal willingness of the utility to develop itself towards an energy service company rather than a traditional supplier of kilowatthours, legal and structural differences of the national energy structure of the participating countries could be balanced out at the level of municipal energy demand and supply. Regardless to the national structure of energy legislation, LEP could then be considered as an equally successful instrument towards a sustainable supply of energy.

6. One Successful Example: The City of Mannheim

Finally, the example of the city of Mannheim should be mentioned, where a municipal energy policy was already introduced as early as in the late fifties, when the erection of a large hard coal CHP-plant was planned at the premises of the city and it was decided to construct a large district heating network to make maximal use of the cogeneration potential. This decision was due to economic and ecologic reasons as well, since by cheap low temperature heat from cogeneration plants, compared to the quite high levels of electricity and fuel oil prices at that time, the substitution of individual coal ovens could be expected from that plan. Coal ovens then still had a major share of the heating supply and were responsible for much of the atmospheric pollution in Mannheim in the post-war years.

Whereas the local utility had the sole responsibility for that project until the seventies, it was then decided to support the utility by a municipal energy policy which had clear goals and priorities to establish an integrated plan where the former support of district heating was substituted by a well balanced strategy of gas and district heating extension and support of demand side energy saving measures, accompanied by a regular inclusion of the investment programs for gas and district heating into every actualization of city planning.

The result of this long-term policy can be seen in fig. 5. Of particular interest in this figure is the considerable time which is needed to see measurable changes of the situation and the fact, that only after starting a really integrated energy policy including efforts to save energy a real "phase change" in energy consumption patterns could be achieved.

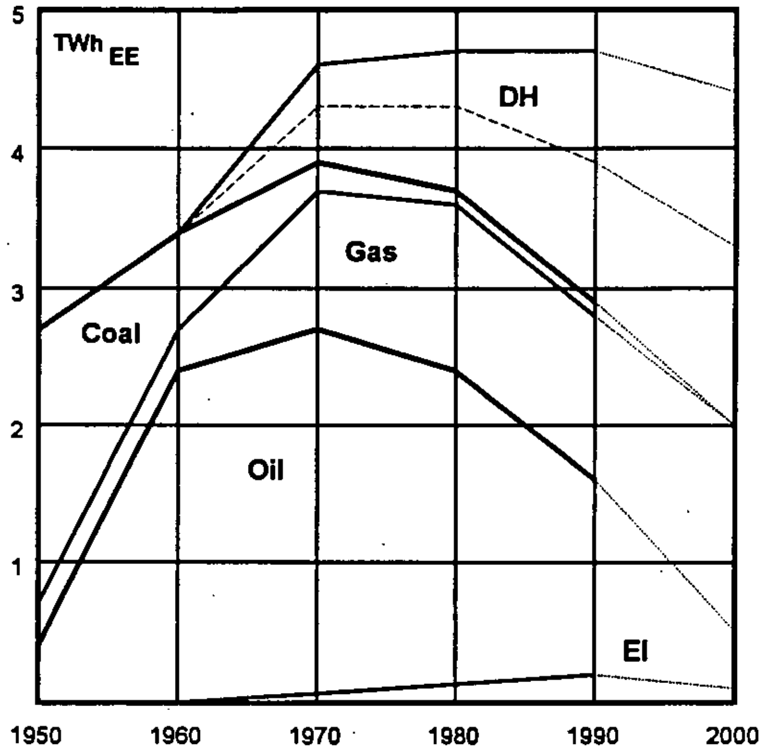

Fig 5: End-energy demand [TWh_{EE}] for space heating and hot-water supply 1950 - 2000 in Mannheim (dotted line in district heating (DH-) sector corresponds to an average an average specific primary energy consumption of β_{DH} = 0,65 MWh_{PE}/MWh_{th} for the supply of heat by combined heat and power). El ... electric direct heating (night storage).

TABLE OF CONTENT

PART I

SUMMARY ON LOCAL ENERGY PLANNING (LEP)

PART II

RESULTS ON SUBTASK A: SOFTWARE TOOLS IN ENERGY PLANNING

PART III

RESULTS ON SUBTASK B: MODELS FOR THE CALCULATION OF ENVIRONMENTAL ASPECTS

PART IV

RESULTS ON SUBTASK C: MEANS TO REPRESENT, DEMONSTRATE AND ADVERTISE PLANNING SOLUTIONS

PART V

RESULTS ON SUBTASK D: IMPLEMENTATION OF INTEGRATED PLANNING PROCEDURES

Annex 22 - Energy Efficient Communities

Part I

Local Energy Planning (LEP)

1-1 Introduction

Since the first energy (price) crisis in 1973 rather similar patterns of energy policies in many countries of the European Community could be observed: after an initial period of enforced regulations, mainly concerned with building codes or speed limits, specific schemes of financial incentives for energy-related investments, such as subsidies or tax reductions, followed as an additional approach in the late seventies. These policies were considered as quite successful in achieving the prevailing objectives of energy policy in that period: *oil-substitution* and *energy conservation*. As an example, the average consumption of heating-oil in one-family houses in West-Germany fell from some 35 - 40 ltr/m^2·yr in 1970 to about 18 - 25 ltr/m^2·yr in 1982. Today, according to the latest legal code for *new* buildings, coming into force in 1995, a consumption of less than 10 ltr/m^2·yr can be expected.

During the eighties, the national concern for energy conservation gradually declined in many industrialized countries, due to oil over-supply and falling energy prices. On the other hand, the effects of growing environmental pollution, such as vast damages of forests and aquatic systems and increasing concentrations of pollutants in nature, caused similar reactions in environmental policy as ten years before in energy policy: stringent environmental regulations and standards were set during the eighties, which from today's sight have proven to be quite successful in reducing atmospheric pollution.

Recently, another turn of political priorities has come about, caused by the global threat of climate changes, if the ever increasing emissions of CO_2 and other greenhouse gases will not be reduced successfully. In contrast to the issues of the 70ies and 80ies, this single issue presents a new challenge for the industrialized nations, since the traditional pattern of political reaction may turn out to be much less effective here: the means of new regulations and standards seem to be quite exhausted already, while the market is presenting the wrong signals to the consumers.

In this situation, where national energy and environmental policy often is the subject of controversial debates, the communities will have to play an important role: integrated measures to save energy and optimize energy services can be successfully achieved preferably at the level of the community. However, finding solutions at this level is a rather complicated process, with many different options and decision makers involved. It has turned out in practice, that optimizing local energy services (not merely energy supply) is a task which requires specific knowledge and experiences which differ from traditional patterns of planning. A new instrument had to be developed to solve this task, *"local energy planning" (LEP),* as a means to design "energy efficient cities".

This was recognized already at the end of the seventies in some countries, in particular in countries with traditionally decentralized (political) decision structures, such as Sweden, Denmark or Germany. In those countries this new instrument of LEP was developed and applied since then in many practical cases. In countries with more centralized decision structures the cities are equally close to the problems, but more distant to decisions. But also there, a development to local system optimization can be observed, though perhaps with some delay.

However, LEP was developed quite independently within the countries mentioned above, due to different boundary conditions and also due to the fact, that LEP from the very beginning was a means for practicioners rather than for scientists. Therefore, communication and exchange of experiences between planners in different countries was quite weak. Since the increase of reqirements to LEP has led to a growing complexity of the planning process on the one hand, and growing interest from countries having so far less experiences in that field on the other, Annex 22 was designed by which national experiences with LEP should be summarized and an exchange of these experiences between the participating countries should be managed.

Environmental aspects of the energy supply of "community systems" are increasingly decisive for assessment and comparison of different supply options - at least at the local level. Whereas economic optimization of the energy supply of *individual buildings* as well as of *regional supply areas* is the goal of traditional planning procedures, LEP is an interdisciplinary field of town-planning and energy supply engineering, developed and applied during the last 15 years and very soon characterized by an extension to "integrated solutions", where the system as a whole is optimized rather than single components of it, using a variety of different optimization criteria.

The growing importance of environmental issues has complicated the task appreciably: Whereas under defined boundary conditions normally rather unquestionable (traditional) solutions are developed, the discussion of environmental effects is in general much more complex and their results are rather often disputable, according to the background and goals of experts and decision makers involved. While it is unclear, if there ever will be a unique solution to this problem, much efforts should be devoted at least to verify those data, informations and methods, which are indisputable for the time being and to distinguish them from issues which still are under discussion amongst the scientific community.

In this situation of a dynamic and diverse development of the instrument LEP, the task of Annex 22 has been defined to

- compare data, methods and approaches applied within the participating countries and evaluate the results with special consideration of transferability

- develop a summary of those informations which are of particularly practical usefulness for the individual planner within a concrete LEP-project.

The LEP-process consists in general of two main components, which interact with each other in manifold ways:

i) the actual process of planning and design

and

ii) the transfer of the results to the various groups involved to implement the conception.

According to this and the project objectives stated above, the work was structured into four subtasks, with Subtasks A and B closely related to i) and Subtasks C and D to ii):

Subtask A	*Software Tools in Energy Planning*
Subtask B	*Models for the Calculation of Environmental Aspects*
Subtask C	*Means to Represent, demonstrate and Advertise Planning Solutions*

Subtask D *Implementation of Integrated Planning Procedures.*

The following countries have participated in Annex 22: Belgium, France, Germany, Italy, Sweden and Turkey, with EU and OECD as observer. The lead countries for the different subtasks, being responsible for preparation and coordination of the work, were Sweden for Subtask A, Germany for Subtasks B and C and Belgium for Subtask D.

1-2 Local Energy Planning

1-2.1 Definition of LEP

During the development of experiences with LEP, three major changes, related to approach, methods, instruments and objectives have come about:

Approach

LEP has turned out to be an open process with many decision makers and interested groups involved, rather than a well defined single project. In particular, implementation strategies for the resulting conception became subject of increasing relevance.

Methods and Instruments

With the introduction of "integrated planning procedures", the number of options to be studied and data to be processed has strongly increased. Furthermore, new methods such as Demand Side Management (DSM) and Least Cost Planning (LCP) have been introduced by different participants of the process. In parallel, software tools have been developed allowing for a new quality standard even for smaller communities, if used.

LEP Objectives

Whereas the substitution of oil was the most important objective some 15 years ago, environmental quality and environmental performance indicators have now emerged as important decision criteria. Through this development, the complexity of the LEP-process has strongly increased.

Discussions among the participants of Annex 22 have shown that there can be quite different opinions on the definition of LEP, dependent on national or local supply structures and legal responsibilities of local administrations. Therefore, the following proposal to define LEP is to be considered as a "working definition" which is based on the experiences within countries with traditionally decentralized organisation of the public administration in general and of energy supply in particular, but which should also be applicable in countries with more centralized planning traditions. In every individual case, this definition has to be reconsidered according to the given task and its actual boundary conditions.

LEP-Objective

The objective of an LEP-project is to develop a conception to find environmentally benign and cost-efficient solutions for the supply of a defined area with (low temperature heating) energy. The conception is oriented to a general system of goals and subgoals derived therefrom, which are to be defined at the outset of the project under interaction amongst the relevant groups and decision makers affected by the LEP-conception. This system of goals shall be optimally achieved through the implementation of the LEP-conception. The system of goals can vary between different municipalities and different countries according to local or national conditions and needs. (Table 1-1 shows an example for a general system of goals to be agreed with between decision makers and planners.)

The LEP-planner has to find a well-balanced consensual solution amongst the relevant groups. His proposals shall serve as a basis of decisions within the urban management and for possible investors into local energy supply structures or energy saving measures as well and provides them with informations on immediate or future consequences of their decisions.

General content of LEP

Using data on the existing situation of energy demand and supply within the LEP-area and its environmental conditions, logically consistent measures are to be developed (according, for example, to the scheme shown in fig. 1-1) to achieve the given system of goals by a strategy of decisions and measures considering the actual legal requirements and the latest technology. During the planning process, the actual situation of the investigated area is analyzed with respect to possible weaknesses, problems and improvement potentials. Short-term and medium-term activities are to be defined which are suited to achieve the given goals in the best possible way. The planner has to consider the most actually available technologies and all principally possible means for improvements, such as

- shifting of primary energies
- energy conversion technologies
- end-of-pipe technologies for emission abatement
- process improvements
- waste heat utilization
- control technologies
- energy conservation
- regenerative energy potentials
- organisational and behavioural measures,

whereas conservation (= demand side) measures are to be preferred to supply-side measures in general.

The plan consists of a general "frame-conception" and a consistent set of short-term measures to remove acute weaknesses or to realize given potentials. The conception adresses all groups affected by these proposals. It provides - where possible quantified - informations concerning the extent to which the given goals can be achieved or will be failed.

Subject of LEP

The subject of LEP is a defined "administration area" (town, agglomeration area or county) and the *low-temperature heat supply* of the public, private and commercial sectors herein. The industrial sector is only considered as far as solutions are discussed which adress more than one company or enterprise, as, for example, waste heat utilization projects. High temperature heat supply is generally *not* subject to LEP, as well as electricity supply, if not connected with direct heating or cogeneration. Moreover, LEP is not a marketing concept of supply companies or an internal utility optimization program such as demand side management nor does it consider the traffic sector.

System of Goals	Methods and tools to measure the contribution to goals	Measures, indicators
Cost-effectiveness of energy supply	Economic analyses and optimization, sensitivity analyses, scenario techniques	Internal and external costs, prices
Energy saving	Urban energy balances, methods of analysing energy use performance, energy demand indicators	Relative and absolute energy consumption, time-dependent energy demand development, comparison to similar energy users
Augmented use of regenerative energies	Consideration of potentials and optimization options	Relative use of regenerative energy as compared to conventional energy sources
Environmental friendliness	Emission balances, immission calculations, life-cycle analysis, environmental impact assessment (EIA)	Comparison to actual standards or requirements of environmental legislation, external costs, qualitative comparisons
Security of supply	Import balances	Shares of imported energies from different countries, share of primary energies with short-ranged availability
Social acceptancy	Economic analyses and impact to social indicators; social surveys	Prices, social costs, flexibility, safety, comprehensibility; agreement with given goals
Compatibility with the goals of regional and urban planning and generic goals of national economy	Qualitative description and comparison of options according to their contribution to urban and national planning goals	Specific demand indicators; growth effects, effects to balance of payment

Table 1: A possible system of goals of LEP and their verification

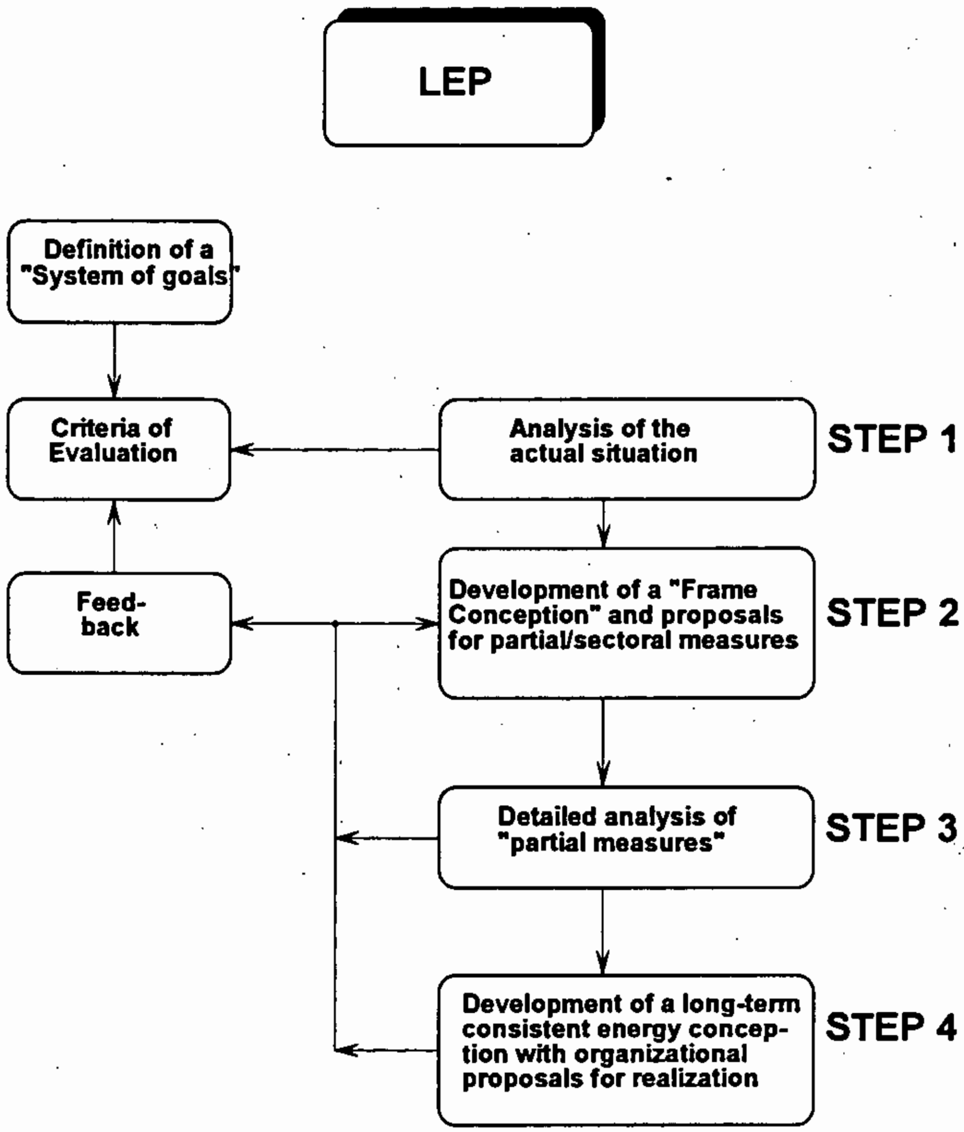

Fig. 1-1: Structure of LEP working steps

Responsibility for LEP

As explained above, in the case of countries with decentralized decision structures the development of "local energy conceptions" belongs to the competence of the local administration which is responsible for urban development and/or environment in cooperation with independent experts, involved utilities and other institutions affected by it.

Once developed, the conception shall be revised and actualized regularly, due to changing conditions and goals. One instrument of regular actualization is the "communal energy report" which shall be edited annually by the community and may establish a controlling instrument for an "urban energy management programme".

The definition of LEP given above is oriented to practical experiences in countries with high urban decision autonomy, such as Sweden or Germany. In this case, the result of an LEP-project can be the object of a continous controlling and updating process by the urban management. In countries with less autonomous urban administrative competences there is still the possibility to develop an urban energy plan in accordance with much of the definition given above. In that case, however, the urban administration has less power to enforce the implementation of the LEP-conception. However, as it is demonstrated for example in France, by exercising indirect influences by the urban management, for example by dissemination of information, by consequent application of the planning results in all urban decisions and by its inclusion into urban development planning, short-term and long-term improvements of the energy situation can be achieved also in that legal framework. As it is the case in France with ADEME, by the development of urban or regional energy plans with the help of this national institution, using factual advice, organisational support and investment subsidy programs as well a similar approach is possible: With the existing efforts to introduce urban energy analyses ("analyse ènergètique sur l'urbanisme") and the new french conception of urban environmental plans ("plans municipeaux de 'lenvironnement"), a similar pathway is gone in France than it was in Sweden or Germany. Since these French efforts are to be integrated into urban and regional planning and also linked with traffic and transportation planning, this approach is even more comprehensive - the answer of a centralized decision structure. These efforts being rather at the beginning in France, it will be interesting to observe and compare the results achieved under such different national boundary conditions.

1-2.2 Schematic approach to develop a local energy plan

Derived from various discussions during the Annex 22 workshops, despite of quite different conditions and differences at the level of detailed LEP-considerations in the participating countries of Annex 22, the following *general approach* to LEP is applied apparently in most LEP-projects:

- **Step 1:**
  Analysis of the actual situation according to existing weaknesses and improvement potentials

- **Step 2:**
  Development of a long-term *"frame conception"* for the whole area under consideration and, on the basis of the outcome of step 1, identification of short-term high-priority measures from a selected part of the entire catalogue of measures (*"partial measures"*)

- **Step 3:**
  Detailed analysis of the partial measures and feed-back with the "general system of LEP-goals" as defined in step 1

- **Step 4:**
  Final definition of a long-term plan for the area of consideration which optimally achieves the given goals and development of proposals to implement the conception

In accordance with common experiences in actual LEP-projects [I-1], these four steps have to be accompanied by "procedural" measures, such as conflict resolution, learning processes etc. with the groups affected by the results of LEP. A "follow-up step" has to be the continous control and feed back of the implementation process(es) which is a permanent task for the urban and utility managers..

Figs. 1-2 to 1-4 show more detailed some single tasks that are connected with the LEP steps mentioned above.

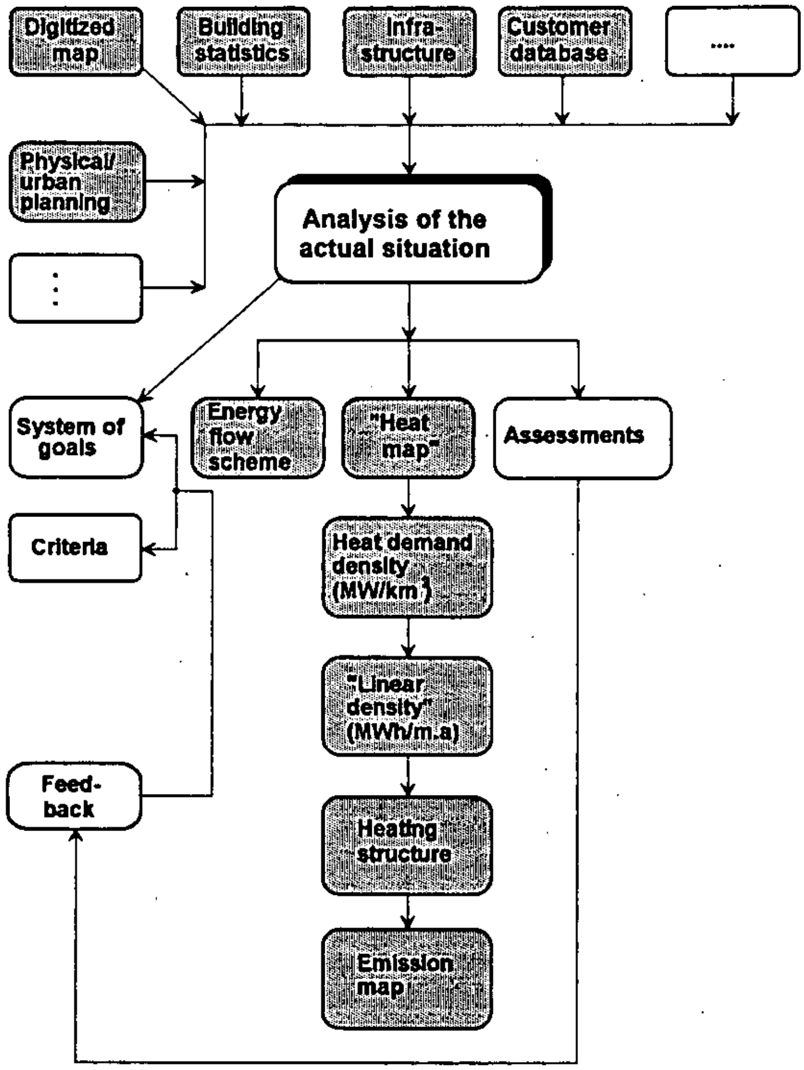

Fig. 1-2: Step 1 of LEP

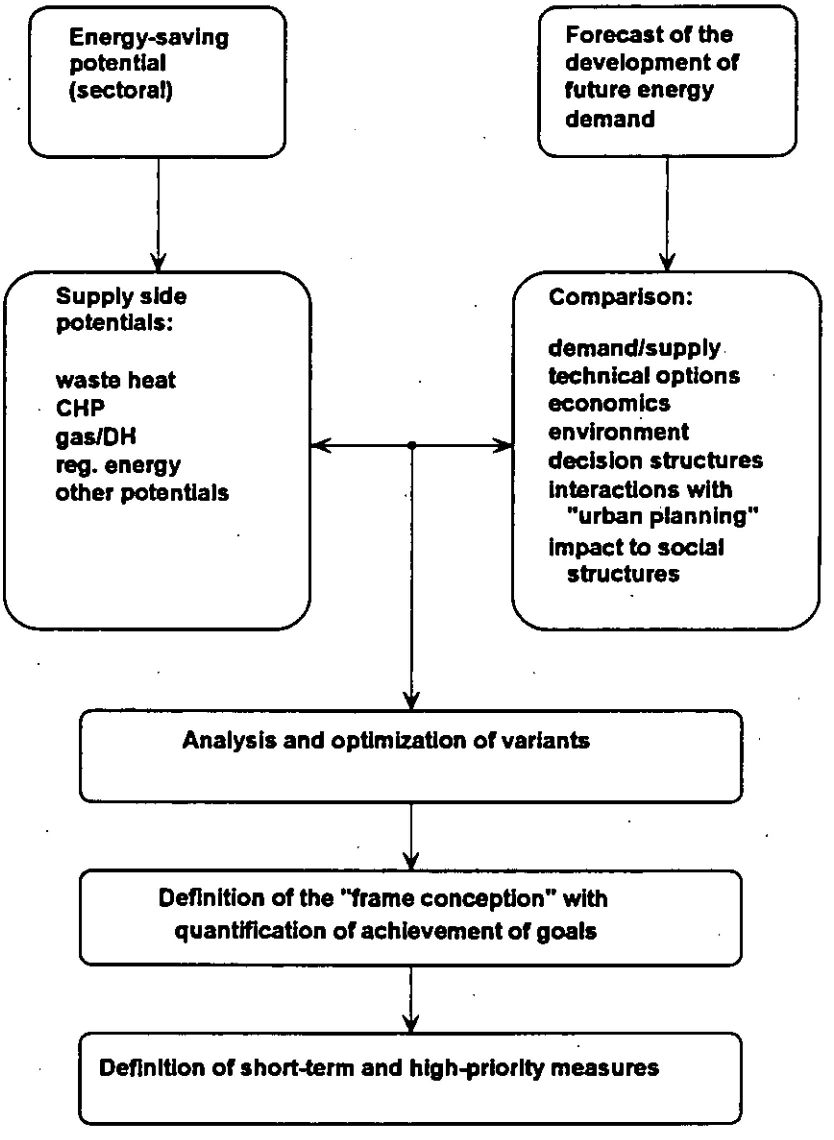

Fig. 1-3: LEP-Step 2, "Frame Conception"

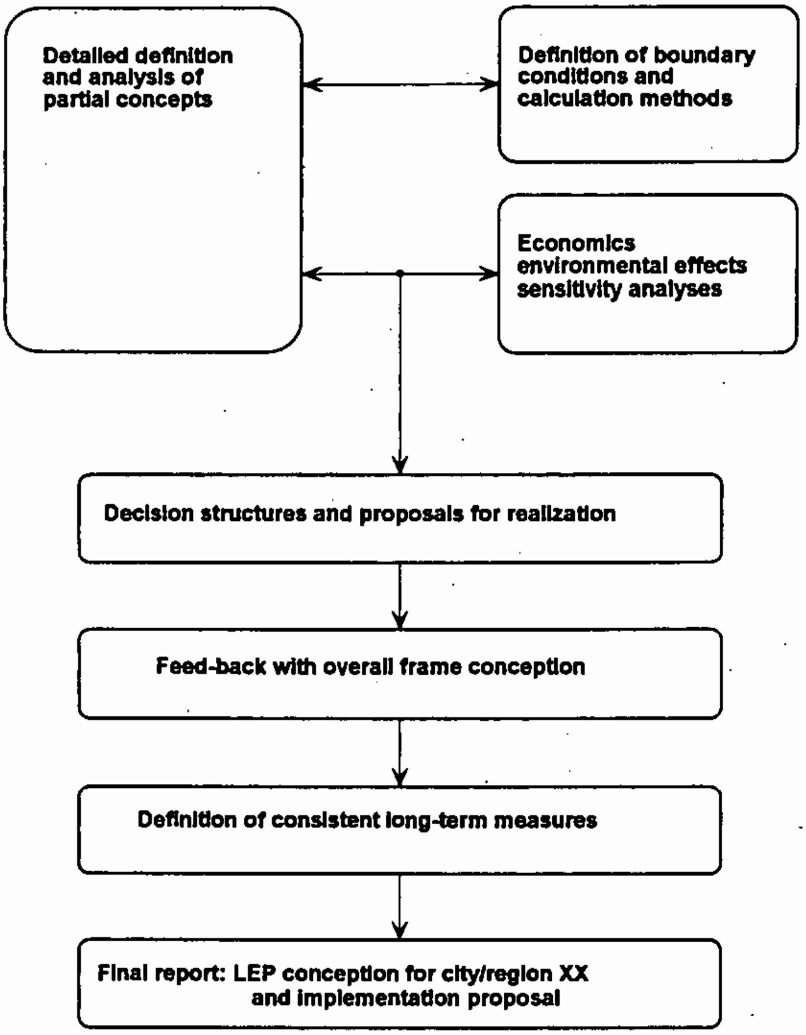

Fig. 1-4: LEP-Step 3, "Long-term Conception"

As mentioned, the lions share of the work in Annex 22 was carried out by the lead countries for the individual subtasks. They prepared "National Reports" for their individual subtasks, including a comprehensive review on the given topic and its treatment within the lead country. These National Reports of the lead countries were the basis for further discussion and exchange of experiences among the participating countries. The Final Report on Annex 22 reflects these discussions and presents overall conclusions and recommendations.

1-3 National reports on Subtasks A to D: Objectives

1-3.1 Subtask A: Software Tools in Energy Planning

One of the main objectives of Annex 22 was to collect information on existing computer-assisted instruments in LEP, which had been developed within a couple of countries being specifically active in this field during the recent years. Since only five countries were participating in Subtask A (Belgium, Germany, Italy, Turkey and Sweden as "lead country") which in addition represented quite different levels of software application and LEP-efforts as well, the results of Subtask A cannot really be comprehensive: countries such as U.S., Canada, Denmark, Finland or The Netherlands with comparably highly developed traditions in both fields could certainly contribute additional information, insights and experiences with LEP-software tools. It would be a success of Annex 22, if the work developed within this Annex would trigger additional international efforts to provide users with information about existing tools and to stimulate additional cooperation amongst LEP-software developers and users.

During the last decade several mathematical models for the analysis of municipal energy systems have been developed. These models originate from universities and research institutes and from the consultancy sector and the energy industry as well. The models differ widely in detail and scope, where the more detailed models are used for the analysis of subsystems of the municipal energy system and the models of less detail, but of wider scope are used for the analysis of the entire system. Models have also been developed for studies of the interaction between activities outside the energy system, such as the connection between industrial siting, housing, transport and energy systems (urban/physical planning).

LEP-software tools in the context of Subtask A are understood as *computer-aided instruments, which are used by either urban planners, design engineers for "technical infrastructure" or urban decision makers within the LEP-process or during the implementation of an LEP-conception.* Within this understanding, "macro-tools" for energy planning at the national or even regional level are excluded as well as "micro-tools" for optimization or simulation of objects below the level of detail usually considered in LEP-projects (such as tools for detailed network design or simulation software for buildings like TRNSYS, BLAST, DOE-2, LogoCAD etc.).

In the evaluation of LEP-software tools first the present relevance of such tools in LEP is discussed and it is tried to classify the large number of different applications. The emphasis lies on the *use* of computer based energy system models. The models themselves are presented in three sections (chapter 2-4 to 2-6). Sections 1 and 2 are of a more technical character. The emphasis of section 1 lies on an *inventory* of models, with a discussion of models for different parts of the technical energy system, and section 2 expands this perspective by including models for urban/physical planning. In sections 1 and 2 examples of different models are discussed. These examples are taken from the Swedish and German models due to a wider use of such models in these countries and a lack of more details from the other participating countries. In section 3 a number of "auxiliary tools" from the German inventory are presented. These models are software instruments providing data inputs or supporting procedures for the energy models presented in sections 1 and 2.

Finally, in chapter 2-7 conclusions are drawn about the present use of energy planning models and the outlook for the future.

1-3.2 Subtask B: Models for the Calculation of Environmental Aspects

In accordance with the necessary move from pollution control to pollution prevention, environmental effects have to be increasingly considered already during the planning process. The objective of Subtask B is to provide an overview of actual data and instruments available to local planners who have to solve practical planning problems. These tools shall be applicable for evaluation and comparison of environmental impacts of different alternatives or strategies considered in local energy planning. Since integration of environmental aspects into the process of local energy planning involves widespread and rapidly developing interdisciplinary knowledge, very often the practical problem arises, how and where to gather actual information to answer specific questions in the context of energy use and its environmental impacts, combined with economic evaluations. To the traditional planner, this generally surmounts the scope of his educational background, which is oriented to specialized planning processes rather than comprehensive *integrated* considerations. This statement is true in general for architects, urban planners and engineers as well. Since planning budgets are restricted, a way must be found to evaluate meaningful answers without the help of specialized and expensive scientists. It is the aim of subtask B to show the present "state of the art" of the inclusion of environmental considerations in local energy planning by the planner, using the best available data to achieve comprehensive and consistent results.

The "national report" of the lead country Germany for subtask B consists of four parts:

Part I: *"Systems energy efficiency"*

In this basic evaluation characteristic data on energy systems with respect to their energy efficiency are identified, including in particular bivalent systems such as cogeneration or heat pump systems, whose design depends, among other criteria, also from the energy-price levels given at the time of planning or forecasted over the life-time of the energy system investment. When comparing different supply systems, input data which result from the national energy supply structure, such as the fuel mix for electricity production, are needed. Such data are considered in this part I.

Part II: *"Legal requirements and basic informations on the environmental impact of energy systems"*

In the LEP-process an agreement has to be found as to the "environmental properties" of the different energy systems to be considered. These properties can vary largely between different countries, due to different environmental requirements, different technologies used, different properties of fuels etc., which are of essential influence to emission factors. Part II gives an overview on actual data on these issues which are to be used within the lead country as a basic input to any environmental comparison.

Part III: *"Methods to compare environmental impacts of energy systems"*

This is the most ambitious part of the work on Subtask B, since it aims to integrate the more "one-dimensional" approach of simple quantitative comparisons or optimizations, for instance with respect to economics, with complex environmental assessment procedures. These procedures intend to achieve an increasingly broader approach to the problem of assessment of environmental impacts and will presumably be applied also in LEP-projects in the future.

Part IV: "Environmental monitoring and information systems"

This part is focussed to an overview over national environmental monitoring programmes and networks as well as to computer-based environmental information systems which make spatial related handling, processing and presentation of large sets of environmental data possible. While single environmental data are already considered in LEP-projects, it is predictable that such modern information systems for environmental data will be used in the future. It is therefore of interest to assess the present and future possibilities in this field which may have effects for the future practical planning process.

1-3.3 Subtask C: Means to Represent, demonstrate and Advertise Planning Solutions

One of the main issues in LEP is the transfer of planning results from the planning and engineering level into the level of public acceptance of a municipal energy plan. The actors participating in the approval processes are manifold and so are their aims and targets. Examples of the several actors include political decision makers, administrations, utilities, energy consumers and various interest groups. One of the most important output from the planning process is therefore to find ways of harmonization of the different actor´s interests, including learning and conflict resolution. It is consequently very important to illustrate and edit communal energy concepts in the appropiate forms, i.e. to "sell" the results of energy planning to the concerned parties or actors within the decision process. Various municipalities in Germany are in fact putting considerable efforts into the "marketing" of energy projects. Several instruments or means have consequently been developed specifically to represent, demonstrate and advertise planning solutions accordingly.

The aims of Subtask C are to systematically illustrate and evaluate the information and the dissemination means in the context of LEP. The evaluation therefore considers information media as well as institutional arrangements. It would however neither be possible nor worthwhile to produce an extended list of all German institutions dealing with LEP and their respective way of representing, demonstrating and advertising planning solutions. The national study report rather focuses on a representative number of examples and assesses the experiences made with these.

It is quite reasonable to present instead existing information media and institutional arrangements in a systematic way and to characterize and measure their effectiveness. A quantitative assessment of the different means of information collection, transfer and dissemination according to energy related criteria, such as the achieved level of energy conservation, however is not feasible due to lacking information from special project-related evaluation studies. Only for parts, as for example the Working Programme of the Federal Authorities of Germany with its 25 LEP field studies (accomplished 1980 - 1985) or the more recent LEP support programmes of Saarland and North-Rhine Westfalia, relevant cross section analyses with different topical orientations are available.

1-3.4 Subtask D: Implementation of Integrated Planning Procedures

The decisive aim of LEP is the implementation of the resulting energy conception by a consequent and steady municipal energy policy. It has turned out, however, that there are large differences within the participating countries according to the existance and implementation of such a municipal energy policy, which are assigned by the lead country of Subtask D, Belgium, to structural differences within the legal and economic frame of energy supply and the role municipalities have therein. These differences are discussed in the evaluation of Subtask D and conclusions are drawn as to the possibilities of municipalities to develop own activities to achieve a sustainable energy supply system within differing legal and structural preconditions.

Annex 22 - Energy Efficient Communities

Part II

Results on SUBTASK A: Software Tools in Energy Planning

2-1 Introduction

Individual software tools, as discussed in Subtask A, which have numerously been developed by scientific institutions, technical consultants, urban planners or utilities, can be assigned to almost any of the steps of LEP as described above (see gray boxes in fig. 1-2 as example). Such tools are in most cases of decisive value for the precision, quality and consistency of work of the LEP-planner. The question arises, if such tools are known to other planners and if they are available for potentially interested users, thereby avoiding appreciable own efforts in developing such aids or providing such users with materials and abilities, which they otherwise could not have been able to rely upon.

It would be a very interesting and challenging task to describe methods, procedures and data bases of the discovered individual tools and evaluate and compare their practical usefulness. Due to restricted budgets this task could not be carried out in Annex 22. The job had to be rather restricted to the evaluation of an inventory of existing software tools within the participating countries, which in addition, due to a lack of information from the other participating countries, had to be further restricted to Sweden, Belgium and Germany and some examples from Italy and Turkey. Despite of these restrictions, a surprising large number of software tools has been discovered, which shows that there is obviously a large demand for such tools. The evaluation has, on the other hand, shown that the market is quite imperfect because of the intransparency by which the offer of LEP software tools is characterized.

2-2 LEP and software tools - an attempt to a classification

Software tools as instruments for LEP are existing and partially generally available in most participating countries. Whereas the development of LEP-software tools in the narrow sense (design tools for components of the energy system) has only very recently become a field of professionalized commercial activities, "auxiliary tools" like data bases and graphical or environmental information systems, which were developed independently from LEP, present already a high standard of quality (in terms of software engineering). However, the potential benefits of LEP-software tools are by far not generally realized by LEP practitioners at present. Today, a transition phase can be observed, where an increasing number of planners begin to use professional software. With increasing information on and demand for such tools, increasing development efforts will be triggered which make use of the powerful computing capacities in modern PC's as well as of modern methods of systems analysis. In the long range, one can expect that LEP-software tools will be of very important value for the development of the desired transparency of LEP-decisions in a complex environment of objectives and decision structures within communities. It will, however, still be quite a long way to this goal.

With respect to the different existing software tools, some *categories of distinction* can be conceived:

(1) Energy system design tools according to their scope:

"single purpose" calculation tools	result in an optimization of defined single components of the energy system (e.g. of a heat pump, a solar collector array, a cogeneration plant, etc.) according to given goals
"horizontal" calculation tools	consider (and optimize) the whole chain of energy transformations (or a part of it) from city-gate to end-use
"vertical" calculation tools	consider an "intersection" of two or more energy supply systems (e.g. gas vs. district heating-optimization, different types of cogeneration heating plants, ...)
"integrated" calculation tools	use comprehensive models for the simultaneous optimization of supply and demand side measures

(2) **"Auxiliary tools" according to their fields of application:**

"mapping" tools	process *geographical information* (such as emission catasters, heating maps etc.) for grafical presentations or for the use in calculations for energy distribution system design ("geographical information systems": *GIS*)
"ecologic" tools	provide *environmental information* (such as calculation of immissions from given emission data which themselves are calculated by other "ecologic" tools)
data bases	allow for generally accepted *inputs of data* into energy system design tools (such as statistical climatic data ("test reference year": *TRY*), building statistics, customer statistics of utilities,...)
evaluation tools	provide means to evaluate *results* of energy system design tools (e.g. cost/benefit-analyses, environmental assessment analyses etc.)
urban planning tools	support planning of the physical environment within a community (land use planning devices, traffic planning; digitized city catasters)
grafical presentation tools	provide *means to present* LEP-results to decision makers or to the public

For each of the above mentioned categories some or even many different software tools have been developed and most of them are available for the practicioner *in principle*.

2-3 Calculation Models in the Process of Local Energy Planning

Why are models of the municipal energy system needed?

Designing computer models is a time-consuming effort. Therefore, a model is more valuable if it has a generic structure that allows it to be used for different energy systems. Most of the structure is determined by the characteristics of different energy technologies, but a model must also possess flexibility in order to include local conditions.

Models can be used to solve technical problems as well as to improve the planning process. Here, we identify four reasons for the use of models; two of them are related to the technical properties of the energy system, complexity and uncertainty, and two to the planning process, learning and cooperation:

Complexity

A municipal energy system is a complex structure consisting of various technologies and subsystems. Futhermore, the energy system is expected to satisfy several conflicting objectives such as those for cost-efficiency and low emissions. In a top-down approach using a model with a wide scope but less detail, synergies can be identified for the cost-efficient development of different subsectors as well as for meeting multiple targets. Examples are combined heat and power generation for supply of both electricity and heat, and energy conservation for the simultaneous reduction of multiple pollutants. Such integrated solutions cannot be identified if a bottom-up approach is used, where each technology or subsystem is modelled separately.

However, one single component of the municipal energy system may in fact constitute a highly complex system of its own, e.g., an individual building. Models of such subsystems may therefore be necessary to test the feasibility of the results obtained from the aggregated model of the entire municipal energy system. With such an approach the development of the overall municipal energy plan will be both technically and economically feasible and in line with overall targets for the entire system.

Uncertainty

The choice of new technology and the utilisation of existing technologies are to a large extent determined by developments in the system environment. Four sets of uncertainty factors can be identified (see also fig. 2-3):

- ***Energy demand:***
  Different consumer categories require energy in different quantities, of different qualities and with different load characteristics. The development of each category determines the energy demand of the entire system.

- ***Energy sources:***
  Energy sources can be tapped within the system boundaries or bought on the international market. The availability of domestic sources and present and predicted prices of internationally traded energy carriers are therefore determinants for the choice of technology mix to supply the demand.

- ***Research and development:***
  The cost and properties of new energy technologies, as well as the time at which they will become available also affect the present choice of energy technology.

- ***The Physical environment:***
  All activities within the technical energy system have an impact on the physical environment in the form of land use, noise, emissions, etc. On-going research steadily reveals new compounds to be dangerous, and questions the existing consensus on compounds believed to be dangerous.

These uncertainties can be found in the environment of all types of technical energy systems. The software models fulfil two functions in the work of developing methods to handle uncertainty:

- ***Sensitivity analyses:***
  The models can be used to study the effects on the technical energy system of different developments in the system environment (scenario analysis). They ensure consistency between different scenarios.

- ***Effective and robust systems:***
  The objective of energy planning is to develop energy systems which are both cost-effective end robust. Here, a system is robust if measures are taken (at a certain cost) prior to the resolution of uncertainty to make possible a smooth adaptation to changes in the system environment. Studies of other types of uncertainty, such as sudden changes in trends *during* the planning period, are also required.

The handling of uncertainty is one of the most important objectives for the development of methods.

The learning process

A model has the capability to answer questions, but also to generate new questions. The success of the learning process is dependent of the awareness of the user of the necessary conditions for a learning process to get underway. If the model is not available to the management of the system and external analysts are used, the work must be set up for providing information resources continuously by the external analyst to the administrator or decision-makers in the (municipal) organizations.

When a comprehensive model is used, many organizations will be affected by its results. It is then possible, as shown in fig. 2-1, to distinguish two important control points which are directly related to the learning process:

- ***Pilot study:***
  The work begins with a pilot study with limited data acquisition. One of the two targets for the pilot study is of a technical nature. It is important to verify that the models to be used can handle the designated technical issues. The second target concerns the planning process. Here, it is important to explain the methodology and initiate a dialogue between the analysts and those involved in or affected by the planning concerns ("handshaking" operation). This part of the project can of course be more or less extensive, depending of the comlexity of the system (and the model), the number of organisations involved and the background of the participating representatives.

- ***Base case:***
  The main phase starts with the structuring of a base case, which requires extensive collection and evaluation of data. The quality of the study is determined here. It is important not to leave this phase in the work before the data and base case have been evaluated and analysed by reference and work groups. In practice this may

imply that the rate at which the general studies can be implemented is determined not by the time it takes to collect data and process of the results of the models, but by the learning process for the participating actors.

(An alternative title to this chapter could have been *"Experts make models. Models make experts."*)

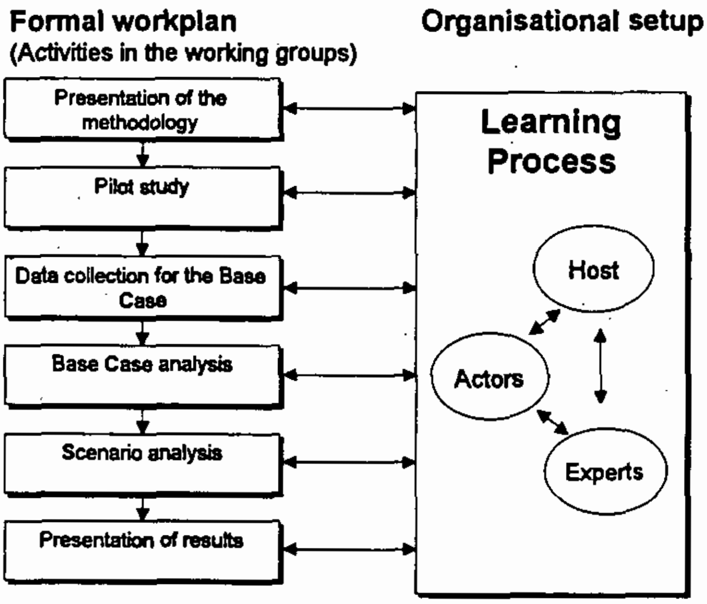

Fig. 2-1: The planning process

Interaction between different organizations

To derive benefits from coordinated efforts, it is often necessary to overlap the boundaries between different organizations. Many of the models which are discussed here cut through such boundaries. Examples of procedures requiring cooperation over organizational boundaries both within and outside of the municipality are the co-production of heat and electricity or the use of industrial waste heat in the municipal district heating network. Problems often arise when the planning process requires cooperation between different organisations, even if the technical conditions are conducive to cooperation. A frequent dispute concerns the allocation of expected benefits acquired from synergetic measures.

Two cases are discussed below which may contribute to a solution to the problem of the distribution of benefits:

- ***The flow of information:***
  The flow of information between organizations and the surrounding environment is considerable, but the information received can be either incorrect or misinterpreted. Errors of this kind often concern new factors in the environment, which the organization has not yet acquired the capacity to handle. The debate on the environment is a case in point. A model can improve the flow of information, and help the individual organization to interpret it. The model initiates a learning process at the organizational level.

- ***Culture for conflict solving:***
  Individual organizations have both the culture and the methods to formulate and solve internal conflicts. These methods are often inadequate for solving conflicts ***between*** organizations. For example, arguments like "A saved kWh is always cheaper than a produced kWh" or, "The more kWh we deliver the cheaper they will be" do not contribute to achieve an effective solution to the problem of balancing energy supply and conservation. What is required in this situation is a completely new perspective which considers the entire system. An effective balance can be achieved by calculating the total cost for the entire technical system but this concept ("Least-Cost-Planning" method, LCP) normally is alien to the organizations controlling the different technical subsystems. The problem becomes even worse if one has to take into consideration the possibility of energy conservation to reduce emissions or uncertainties in the system environment. The problem of finding a balance between saving and supply cannot be solved with subsystem models. A common "language" based on the perspective of the entire system is necessary for solving such conflicts between organizations. A conceptual analyst would call the new language a "meta-language", since it becomes logically superior to the internal languages of the organizations.

A system model in which the technical systems of different organizations are included as subsystems provides the basis for a language at the system level. This structure enables the analyst to show how the benefits from synergies arise, and gives an extra platform for discussion between the involved organisations about their allocation.

Concluding remarks

Computer-based energy system models have often been criticized being too complicated to be used in the planning process. It has also been said that they can be used to rationalize decisions which have already been made or to isolate the decision-maker from important aspects of planning such as uncertainty. Our main arguments in defence of the system models are the following:

- The complexity of the models reflects the increased complexity both in the system and in the planning situation. Rising energy prices (or the expectation of it) have powerfully increased the number of technical alternatives which must be examined. Moreover the number of factors which must be taken into consideration has also increased. The present issues in integrated resource planning encompass not only energy supply but also demand side management of energy use and management of environmental risks.

- In the future we can expect greater requirements for cooperative measures in the energy and environmental fields. The computer-based energy system models will then become important tools for efficient planning. Stringent requirements must be set, however, on the use of models.

- To ensure the learning process, the models must be used interactively. All concerned parties must be engaged in the work with the models from the beginning. Discussion in work and reference groups about methods, data acquisition and results must be continuous. As more aspects of the technical energy system are studied, more organizations become involved. Models which consider large parts of the system can therefore considerably improve the flow of information within all involved parties.

Coordination requires, however, interaction between different organizations, focusing to the actual planning process. An important question for the further development of computer models, particularly those which handle complete or large parts of the technical energy system, is therefore how models can effectively be integrated into the planning process. There is a hidden conflict here. Optimum solutions are the objective of technical work. The learning process, flow of information and culture of conflict resolution are the real objectives of interaction between the actors and organizations. If the requirement for optimising is subordinated to the learning process, "socially ineffective solutions" may result because of unsufficient acceptance: the most perfect technical solutions are impracticable without cooperation of the system's interested parties.

2-4 System Engineering Models: Analyzing the Technical Energy System

A model is a simplified picture of the real word. It is used as a tool eithar to create a better understanding of how "reality" functions (*descriptive model*), e.g. if certain conditions are changed, or to make the real word more efficient (*prescriptive model*), e.g. make specific technical modifications. Which parts of reality are actually reproduced in the different energy models? What can they be used for?

The range of available computer-based energy models is extensive. The majority of the models describe parts of the municipal energy system, such as the heating alternatives for a building or the composition of the production units in a district heating plant. Only a few cover the entire municipal energy system.

The environmental aspect is becoming more and more important in local energy planning. In most cases it is calculations of atmospheric emissions which is included in the models that include "an environmental dimension". The three most studied compounds are SO_2, NO_x and CO_2. Analysis of emissions is generally included in the models for:

- the entire or major part of the technical energy system,
- large-scale conversion systems, and
- in some cases analysing the energy supply and energy conservation in buildings.

A conceptual model for the municipal energy system

The technical solutions for the energy system include technologies for:

- ***Energy conversion***, (both large scale and small-scale), e.g., combined heat and power plants and individual oil burners
- ***Distribution***, e.g., district heating, electricity and gas

- Techniques for ***energy saving*** at the consumer level

- The technology for the exploitation of ***energy carriers***, if there are exploitable natural resources, such as peat bogs and biomass, within the energy system.

Fig. 2-2 illustrates examples of the technical energy system.

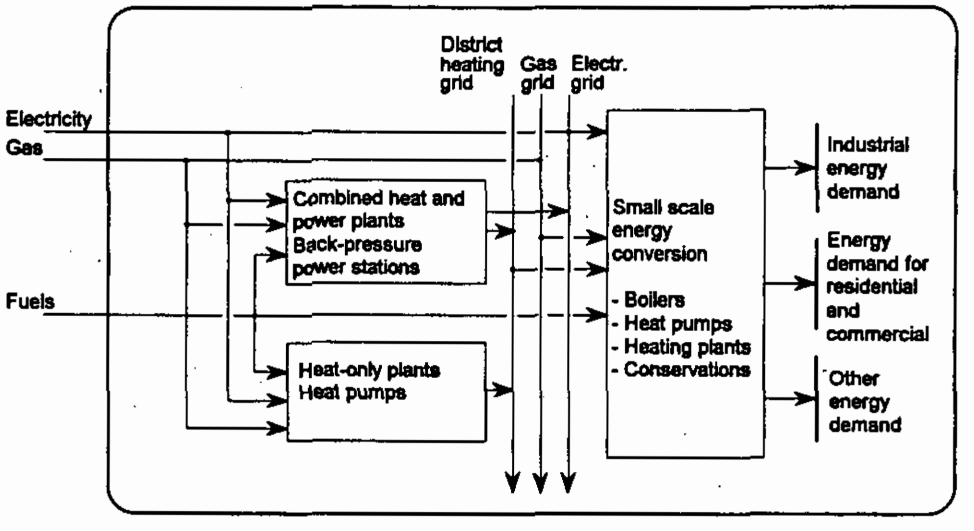

Fig. 2-2: Schematic diagram of a local technical energy system

Already at this stage we must make certain practical limitations. By definition the technical energy system also includes the technical part of the transport system. The municipality has little influence over this part of the transport system (except for the public transport system), and transport therefore plays a very small role in the models which have been developed so far. This is a deficit of existing comprehensive models, which with the availability of powerful mapping systems and their increasing use for municipal land-surveying should be considered more thoroughly in the future. The transport system is, however, examined in more detail in the models which consider energy and physical planning (see Section 2-5.2).

The building and commercial sector, particularly their heating systems, play a major role in the models for the technical energy system of the municipalities discussed here. Only few of the models consider the industrial sector, but several examine alternative supply systems for different industries, and several include also the possibility of analyzing the use of waste heat from industry for the district heating system.

Even after these limitations a municipal energy system, or parts of it, can still be structured in quite a large number of ways. Another complication is that the structuring of one part of the system influences the structuring of other parts. By representing the system by a computer-based model, it is possible to examine how the system should be structured under different conditions, or how a change in one part of the system affects another part. What then determines how the technical energy system should be structured? There are several factors outside of the system, i.e. the technical system environment, which influence the choice of technology. In order to discuss these external factors we must broaden the system description. We do this with the help of the simplified diagram in fig. 2-3.

The technical energy system links together the different available energy sources with the energy demand. Energy sources may be available both on the markets outside of the municipality (oil, coal, firm power, etc.) and within the municipality (e.g. peat bogs, waterfalls and biomass). Energy demand arises in different sectors of society. Demand, which can vary over time, can be for different qualities of energy. Examples of this are "low-temperature heating" in smaller urban areas in the municipality, and process heating in heavier industries.

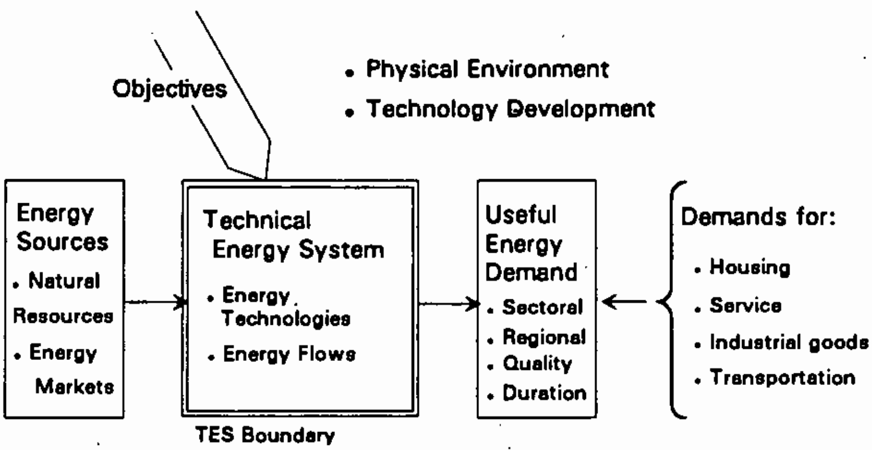

Fig. 2-3: The Technical Energy System (TES) and its surroundings

Apart from the demand for energy and the energy sources available, two other factors in the system environment affect the design of an efficient technical energy system, the technology available and the restrictions given by the physical environment. To construct the "best possible" technical energy system in view of an existing demand for energy and access to a certain set of energy sources, various other factors must be known. The limits for technically feasible solutions are set by the technologies available for energy production, conversion, distribution and conservation, by the possibilities for developing these technologies and by thair social acceptance. In addition, there are also restrictions caused by the physical environment. Today environmental requirements (e.g. the release of dangerous substances) are often assigned to separate components in the system. Legal limits are established for emissions from individual components of the technical system(s) rather than for the total discharge from the system. If environmental restrictions are formulated in this way, requirements are primarily set for the characteristics of the technology or the fuels which can be used as components of the entire system.

To construct an "optimal" technical energy system several other system characteristics must be known, beginning with the definition of "optimal". Most models assume economic criteria, that is, they attempt to meet the energy demand as cost-efficient as possible. In reality, and in certain models, additional restrictions and standards must be accounted for related to the physical environment. Finally, the techniques available for the conversion, distribution and conservation of energy must be taken into consideration.

In the following discussion only models for the municipal technical energy system are considered. Some attempt to cover the entire system and others only a part of it. The technical energy system is established by the technologies for the conversion of energy in its various forms, e.g. large-scale, in the form of municipal heating plants, or small-scale, in the form of individual heating devices, techniques for the distribution of municipal heating, electricity and gas, and techniques for end-use consumer conservations.

2-4.1 Models for the Entire or Major Part of the Technical Energy System

The models are categorized on the basis of the descriptions in fig. 2-2. The first model group includes those which handle the total technical system. The other groups include models which represent the different subsystem of the technical energy system. Below a review of some examples from each group is given. All models are described in more detail in the annex of the Swedish report on Subtask A.

MARKAL is the most prominent example of a comprehensive energy system model. The model was originally designed in the early eighties for studies of national energy systems. Adjustment to the municipal level has been made during recent years in Sweden.

MARKAL is a dynamic linear programming (LP) model for the simultaneous optimisation of the entire energy system. The model is of specific interest because of its capacity to simultaneously describe the access to natural energy resources, the transport and distribution of energy, large-scale and small-scale energy conversion and energy saving, see also section 2-4.6..

Another LP-model used in Sweden is MODEST, developed in 1992, which functions similar to the MARKAL model. The main difference between these two models is that MODEST is a *static* model (optimising every year in isolation from the others) whereas MARKAL is dynamic (optimising over an entire, extended period). On the other hand, MODEST provides more detailed resolution of load curves. The MODEST model has been used in a number of Swedish energy planning projects.

Examples of this type of models which have been used in Germany are GEMIS and IKARUS. GEMIS (or its English version TEMIS) is an effective instrument to calculate the "total" environmental effects of energy systems based on a data base which contents characteristic data of the national energy system. It has been developed by the ÖKO-Institute in 1989. Because of its convenience to be handled by LEP-planners without special knowledge it has already been used in a number of regional and municipal energy plans in Germany and several other countries. There are, however, today no examples of municipal energy projects using comprehensive optimizing models such as MARKAL in Germany.

The IKARUS-project, which stands for "Instruments to Reduce Energy-Induced Greenhouse-Gas Emissions", was started in 1990 with the objective to support the discussion on national energy strategies for the reduction of CO_2-emissions by simulation and optimisation. The model consists of two parts: 1) database and information system and 2) simulation and optimisation tools. It shall be generally available in 1994 as PC-tool. One of the large benefits of IKARUS will be that it provides data to the LEP-planner which are readily prepared for use, well documented and of general acceptance.

An example of a model which considers horizontal cross sections of the energy system is the Swedish model HEATMAP. It is a simulation model for analysis and design of the district heating or cooling system. The model includes both production units and heat production and distribution. The model uses a CAD-programme to describe the location of the heat distribution. Even if it is an Swedish model it has never been used in Sweden.

The total number of these models in the inventory is 23.

2-4.2 Models for Large Scale Energy Systems

Models which describe the vertical cross section of the energy system have been divided into four groups. These are models for large-scale energy conversion, distribution, small-scale energy conversion and energy saving measures, including models for forecasting energy requirements.

The Swedish MARTES model is an example of a model for the study of large-scale energy conversion. It is a detailed simulation model for district heating production. The production of district heating is simulated day by day for up to ten years. MARTES uses marginal cost ordering to select the most appropriate operating strategy on the basis of a number of given production units and calculates the economic and environmental consequences. Despite the fact that operating strategies are sketched the model is primarily a planning instrument for studies of production alternatives. The model is used in a large number of municipalities, e.g. Stockholm, Göteborg, Malmö, and Uppsala.

Another model of the same type is GOMBIS (used in Germany), which was developed in cooperation between a utility and a software developer. It simulates and optimises cogeneration plants and their integrated operation with a peak load facility, with or without thermal storage. It allows a detailed cost/benefit-analysis including the financial balances of the utility which either operates the plant or serves as a sink to surplus electricity from that plant.

In recent years the models for large-scale conversion planning have become the most frequent used, at least in Sweden. The degree of scope and detail differs among the models within a broad spectrum.

The total number of such models in the inventory is 38.

2-4.3 Energy Distribution Models

Because energy suppliers and utilities have to handle a large amount of grid, facility and customer data, many database applications and Geographical Information Systems (GIS) have been developed during the last 15 years to provide the graphical representation and visualization of these data. Today energy suppliers, utilities and urban administrations are frequent users of such systems. As GIS-instruments are still expensive, their use by traditional planners will be restricted yet. At present, low cost GIS-systems adapted for powerful PC´s are under development. This will have major consequences for the LEP-approaches.

Most of the energy distribution models contains some type of GIS-system. The sophistication of the systems varies considerably. There are a number of such models in Sweden which have been used extensively. An example of an electricity model is SWEDNET, a model for the technical-economical planning of the electricity network at both high and low voltage levels. On the district heating side two examples are LICHEAT and TBMENY. With these models it is possible to design the district heating network and calculate costs and heat losses. EASYNET and GASENOK are models for dimensioning gas networks in a municipality or conurbation. The models optimise the routes for laying the gas network on the basis of market conditions. EASYNET and GASENOK have been used in a great number of municipalities and conurbations.

Examples of energy distribution models used in Germany are NIPS, BETRIS and PEGASUS. NIPS is an alphanumeric database containing technical information about electricity, gas, district heating and watergrid facilities, and customer information (contracts, house connections, installations, etc). NIPS provides the basic data for: 1) technical-economic planning, calculation and optimising of the gas and district heating networks, 2) expansion of district heating and gas supply, and 3) grid-facilities maintenance.

BETRIS is an energy supply facility information system with a modular design. It integrates marketing and energy distribution information. There are different modules for market information system, facility information system and strategic planning, and the model communicates with external mapping tools.

PEGASUS is a PC-based design tool for gas networks, which is frequently used by German gas distributors. The model has a GIS-interface.

The total number of these models in the inventory is 27.

2-4.4 Models for Analyzing the Energy Supply and Energy Conservation in Buildings

The models for small-scale energy conversion and energy conservation is one of the largest groups of models. One example among the Swedish models is ERAD. It is the most frequently used energy-balance model and it optimises the saving and heating alternatives for one building or a group of buildings using a high degree of detail.

This type of models is frequently used also in Germany. Some examples: ENEM calculates the heating system of a single building including atmospheric pollutant estimations. THERMOTECT (developed by RWE Energie AG) investigates the results of different energy conservation measures for a building including dynamic passive solar gains. ENERGIE calculates and compares heating systems with different fuels and provides data on economics and emission balances.

The total number of such models in the inventory is 31.

2-4.5 Models for Energy Demand Calculations and Energy Conservation Assessments

There are several models that calculate/estimate the future energy requirements within all sectors; heating in housing, domestic electricity, electricity within industries, etc. The models have been split into two groups, one with models that only calculates energy demand in a single building and one with models that also calculate the energy demand in a whole area of a community.

One example from the first group is ENORM, which is used in most Swedish communities to analyse the energy demand in new houses. The model is used in building construction to determine if a new building will conform to energy regulations and in the processing the application for a building permit. There are also a lot of German models in this group of models. They range from simple static software tools, e.g. STATBIL or ENBIL, to building analysis programs which simulate the hourly thermal behaviour of a building during a fictive year, such as BLAST or TRNSYS, which needs experts know how in application but is internationally one of the most frequently used tools for building simulation.

An example from the other group is the Swedish HOVA model that calculates the energy requirements for heating and hot water in dwelling houses and offices on the basis of building statistics for an area, municipality, or region. Appropriate input data are statistics from the General Registers Office. HOVA also calculates the energy saving potential and cost for the buildings. Different conservation measures are also combined into more manageable "packages".

The energy demand is also calculated by some of the models for small-scale conversion and energy conservation and in some of the models for physical planning.

In the U.S.A. many models have been developed to study the impact of different demand side management (DSM-) measures. Much of this development has been sponsored by Electric Power Research Institute, EPRI. This type of models are not yet widely used in Europe. There are, however, a few German models which are similar to some of the DSM-models developed in the U.S.A., e.g. "Energie-know-how".

Three examples from the large number of such DSM-models developed in the U.S.A. are LOADSIM, COMPASS and DSM-MANAGER, which are frequently used by US-utilities. One of the most recent developed tools (by EPRI) is the MARKET-MANAGER. It is an energy analysis system based on ASHRAE databases, climate data and manufacturers information for the evaluation of the complete energy system of a building.

LOADSIM simulates the load shape of controllable appliances within individual households with varying types of supervision. It develops hourly load profiles with accompanying indoor temperature and humidity levels for each day.

COMPASS was developed to perform rapid integrated analyses of DSM programs. Rather than focusing narrowly on end-use impacts, market penetration projections, or load-shape changes, COMPASS makes it possible to look at DSM programs in an integrated context.

The total number of these models in the inventory is 42.

2-4.6 The Comprehensive Linear Programming Model MARKAL: an Outline

MARKAL is a dynamic linear programming (LP) model for the simultaneous optimisation of the entire energy system. The model is of specific interest because of its capacity to simultaneously describe the access to natural energy resources, the transport and distribution of energy, large-scale and small-scale energy conversion and energy saving. This property makes it possible to study the interaction and competition between all the parts of the municipal energy system from a technical and economic standpoint. MARKAL can also handle environmental factors. Different environmental standards can be set for the energy system. The model allows the implementation of cost-benefit analysis or environ-mental/energy studies. MARKAL is a *prescriptive* model in the sense that the solution it provides is a technical energy system that meets a specific target in the best way, e.g., minimized total system cost under a given development of the system environment. The results are therefore not forecasts.

The first example of a project in Sweden using a computer-based model as a tool to analyse the entire community energy system was in Jönköping in 1980, where the MARKAL model was used. Development of the MARKAL model in mid 80's made it possible to handle different types of emission constraints and that model has since then been used as a tool for municipal energy planning in about 20 projects. The municipalities in question differ in both size (Värnamo 30.000 - Göteborg 400.000 inhabitants) and building composition. In all cases the model has been used interactively in cooperation with the local politicians and organisations involved.

2-5 Models for integrated Land Use and Energy Planning

Since the '70s a number of municipal plans in the communities have dealt with energy related issues. These plans can be divided into two different groups according to planning tradition, planning methods and planning perspective:

- physical planning
- planning of technical systems, e.g. energy planning

Tools for the latter traditions are the energy systems engineering models discussed in the previous section. The tools for the first tradition are described in this section. The purpose of both physical and technical planning is largely to specify development of the infra-structure. Although the infrastructure may be said to integrate systems and components subject to both types of planning, these systems and objects can nevertheless be treated separately in the planning process. In fact, physical and energy planning have traditionally been carried out as parallel and rather independent processes, interacting with each other only in an iterarive way: the results of one planning process can be seen as input and restrictions to the other planning process and vice versa. There are some advocates of a closer integration between physical and technical planning, but most of those involved in the planning process are of the opinion that the parallel approach is the most effective way to work.

There are two main groups of models for physical planning that include an energy perspective, models for calculating the heating/cooling demand and models for the transport system. In eddition, some models handle both energy/cooling demand and transport.

2-5.1 Models for the Calculation of Heating and Cooling Demand

Energy has not been of major concern to physical planning in recent years, because few housing areas have been newly built, at least in Sweden. The developed planning tools (mainly non-computerized) have therefore not been fully used and the number of computerized models is low.

The Swedish URELOC model is an example of a model that uses a GIS-system to describe the community in geographical terms. URELOC also includes the transport system, see also section 2-5.3.

The total number of models in the inventory is 9.

2-5.2 Transport Models

Since the '60s the number of trips by private cars in industrialized countries has increased by 200% and more, whereas the public transport system in most communities has remained fairly constant. Swedish municipalities have less influence over planning and decision making that affect the overall transport system and its behaviour. Even so there are a number of models used in Swedish communities. The transport models handle questions ranging from the consequences of the location of main roads to those of new traffic lightening. Most of the transport models were not originally built to handle energy and emissions questions but adaptations have been made in recent years.

The connection between engineering models and physical planning models is most evident on the strategic level, in a broad decision context, e.g. in the planning process for a new area with residential and commercial buildings. It is also possible to find connections between the two concepts (traditions) on the operational level, e.g. the ESO-MAX model, which analyses the transport system for an only partly storable fuel (e.g. biomass) used in the technical energy system. Comparable models on the tactical level are not to be found today, but it is possible to imagine a model which connects the short-term planning in the energy system to a transport model for a non-storable and partly storable fuel.

The total number of models in the inventory is 13.

2-5.3 Combined Heating/Cooling and Transport Models

The combined models have only one representative in Sweden, URELOC, which handles the energy issues related to a location (local climate, exploitation cost, etc) of new and existing housing and the transport which location makes necessary. The model also calculates the emissions of SO_2, NO_x and CO_2 from both energy conversion and transport. The model describes the whole community as squares of 500x500 meters for which detailed calculations of the energy demand for heating and transport are made. The model also takes different energy conversion technologies and local emissions restrictions into account.

No models of this type has been identified in the other countries.

Since the construction of the Swedish building stock has largely been completed and will probably not require renewal for the next 50-100 years, models like URELOC are primary used to describe the current situation or to analyse changes in the transport system and their effects. In countries with a less mature building stock the model would be of much larger importance to physical planning.

There was only found one such model for the inventory.

2-6 Other Models

In the German National Report a slightly different classification of the models has been used. Most of the models have been "reclassified" in this paper to fit into the classification used here. There are, however, a number of models which cannot be included in our classification and these models are presented in this section. The "auxiliary tools" - as mentioned earlier - are software tools providing data or supporting special procedures such as evaluation, calculation of environmental effects, presentation etc.

The total number of such models in the inventory is 26.

2-7 Conclusions

The enormous diversity of tools described above which are in principle available to the planner is to be opposed to the growing diversity of tasks of LEP, which today are not only cost-minimizing energy supply design projects, but have to satisfy much more ambitious goals: integration of demand and supply side measures (*"Integrated Resource Planning"*) and integration of environmental requirements or boundary conditions into the planning and decision process, possibly with quantified results for different options in accordance with the given system of goals.

These increasing ambitions and requirements to LEP result into a certain "scientification" of the LEP-process. The availability of suited software tools for his purposes will in principle enable the traditional planner to fulfill the increasing requirements to LEP with the desired quality. This presupposes, however, a certain standardization of methods and data bases, which at present is at its very beginning.

According to the discussions with the Annex 22 workshop participants, we can observe at present a transition from "traditional LEP", which on the basis of optimization or design calculations for single, confined parts of the energy system tried to optimize the system as a whole by either iteration or experience, to comprehensive, *simultaneously* optimizing approaches using modern methods of systems analysis which so far still are not or very scarcely applied in LEP. If one searches for the "optimal combination of measures" (minimal costs, minimal primary energy use, minimal emissions, minimal environmental impacts, ...) as the result of an LEP-project, only such a comprehensive approach will allow for a consistent and transparent solution.

This development is justified because urban or utility decisions as a result of LEP-proposals require complex and long-term decisions with large investments and appreciable risks. Since in general a number of different options are possible, with possible interactions, and since the necessary assessments have to consider a whole set of goals or objectives with possible conflicts (between goals and amongst affected groups as well), comprehensive models such as MARKAL can best support and objectivize the decisions to be taken. In addition, the use of such models which easily allow for supplementary informations by changing some parameters and posing "what-if-questions", will enable a learning process amongst different actors involved in LEP, thereby supporting its acceptance which is necessary for a successful implementation. Later changes in general or local frame conditions not foreseen during the LEP-process can be considered quite easily when they appear.

From the participating countries in Subtask A, only in Sweden and in Germany such comprehensive models as described above are under development or already applied at the LEP-level. Comparable developments are known from universities in Finland and Denmark, which, however, are not participating countries in Annex 22. It is only Sweden where a version of MARKAL (a fully comprehensive "Linear Programming" model originally developed for use at national level) was redesigned for LEP-purposes and applied to a number of Swedish communities.

Any application of this model for a defined LEP-project requires a large amount of new input data describing the specific application case. It is the generation of this information input to the model, where the interface to many of the other tools mentioned above would be essential: the results of these tools, such as specific cost functions for distribution networks or for energy saving measures, climatic conditions which define the demand for heating and cooling, emission factors or cogeneration credits, provide the necessary informations for the comprehensive optimization model. On the other hand, the calculation results of the model create input to other tools such as immission calculations, environmental assessments, cost/benefit-analyses according to the system of goals etc.

According to the discussions within the Subtask A working group, one cannot expect that there ever will be an overall comprehensive LEP-expert system which will provide a ready LEP-solution when it only was fed with the correct input data: Not one single model - or a small number of such models - will ever provide a sufficient means to evaluate a realistic LEP-project. On the contrary, future LEP-experts must have sufficient insights in methods and knowledge of available software tools that they are able to handle them as separate tools and models which provide reliable and actual sources of information for the specific requirements given in their concrete LEP-project (fig. 2-4): The expert chooses his own "expert system" to be adapted in his specific case, consisting of a number of different software tools suited for the individual application.

The comprehensive model is used in this context as a central software tool which serves as a means to describe in a general way different "futures" in dependence from different assumptions on developments or boundary conditions. The extent to which this model describes details of single parts of the energy system is, however, limited. This is the regime of the above mentioned "single purpose" calculation tools which answer questions with much greater detail and resolution. The planner will use a number of such individual tools which generate partial results to be used for the development of LEP proposals either in a traditional way or by using a integrated comprehensive model describing simultaneously the overall system of energy demand and supply. Fig. 2-5 shows a schematic illustration of this *approach, where data inputs from data bases and first results from specialized "single* purpose tools" are processed by a comprehensive simulation model which produces certain outputs. The results may be fed back in an iteration step to generate a change of input data, perhaps after interaction with decision makers.

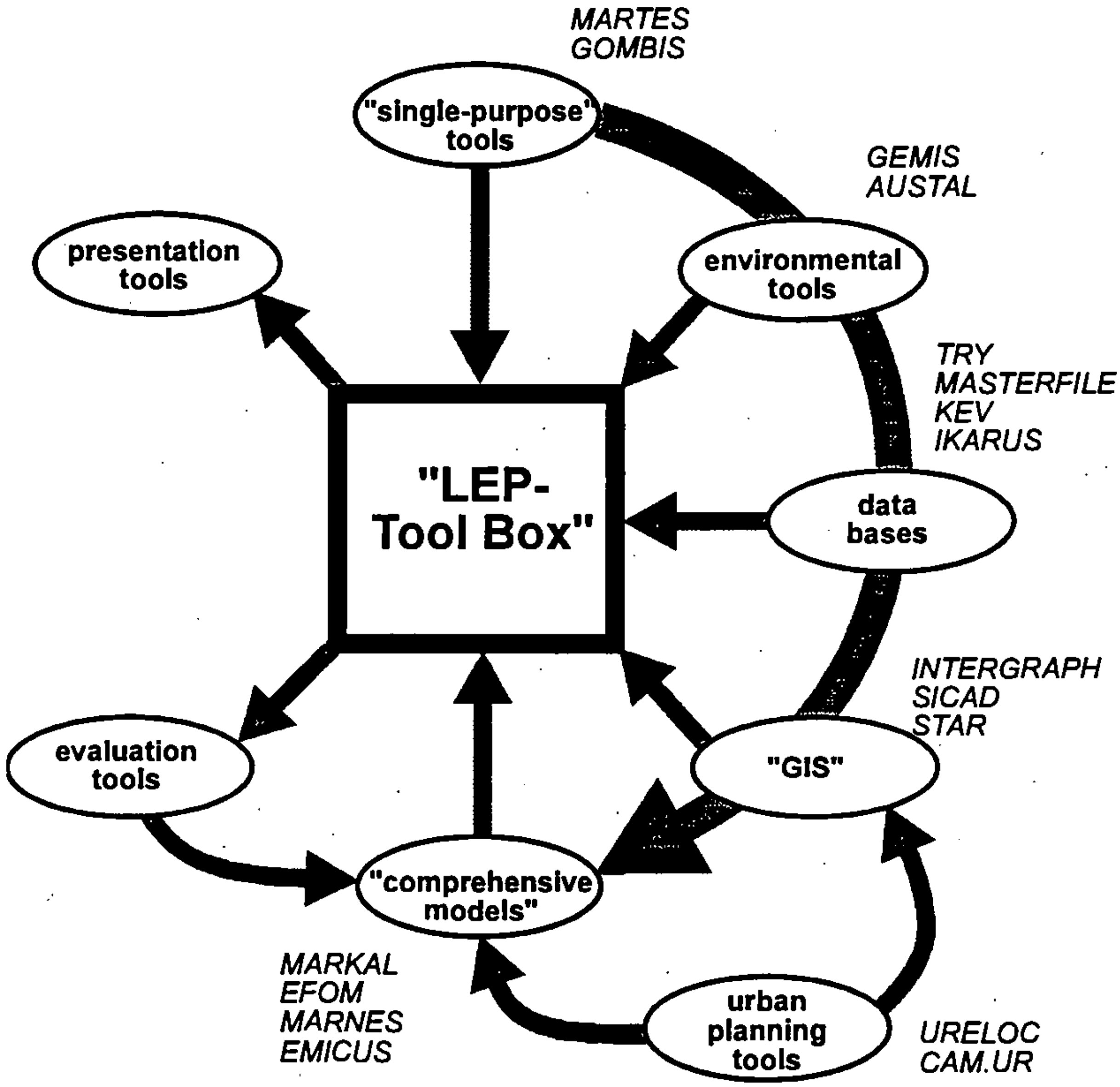

Fig. 2-4: The LEP-toolbox", which in principle is available to the planner. Some existing commercial or scientific software tools for different categories (see text) are indicated.

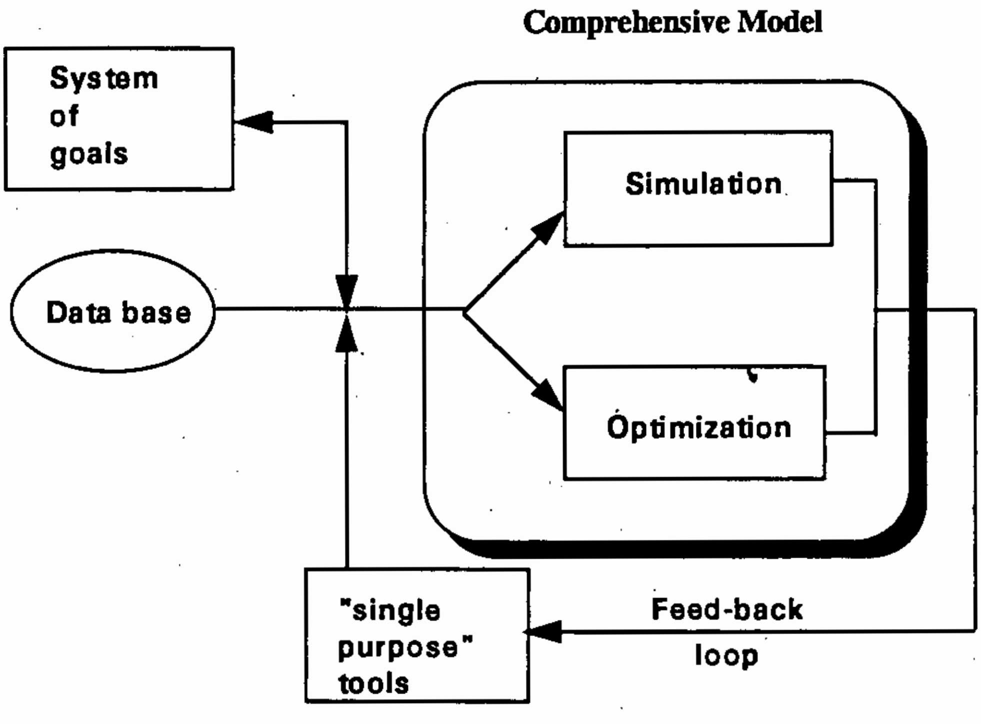

Fig. 2-5: Principle of approach to LEP using support of existing software tools and a "comprehensive model": For a given scenario the whole energy system (of a community) is simulated and according to given goals optimized. In one or more iterative steps subsets of the whole system are recalculated using "single purpose" tools and the results are fed back to formulate a new scenario.

Because of the interdisciplinary character of the tasks within the LEP-process, the availability of professional software tools will contribute to an enormous improvement of the quality of the planning results. This presupposes a broad knowledge of existing tools, the methods used therein and the data and other informations used by them. The present situation is quite distant from that goal: existing software tools for energy planning are often badly documented, insufficiently marketed, offer no or insufficient aids for data input or presentation of results etc. In other words, many of the existing tools do not keep the standards of software engineering which today should be required from professional software, they rather concentrate to the immediate technical-economical problem to be solved. Since the planner has to use a whole "family" of software tools, there is an urgent need for consistent tools which use consistent input data and provide defined interfaces for data exchange.

In addition, at present a certain "quality gap" has to be observed: the scientific methods of systems analysis must be the basis of future LEP-methods, making use of most actual data bases on energy systems and environmental informations as well as of simulation and scenario techniques, linear (or non-linear) programming methods for optimization calculations under given restrictions, methods of operations research or decision theory in complex systems until methods of General Systems Theory. At present, such methods are used only within some of the "comprehensive" models mentioned in section 4 and 5 and hardly ever used in the context of LEP. As a consequence, one can say that whereas partial solutions and tools have been developed and quite broadly documented and published in the past ten or fifteen years of LEP-applications, still a long way has to be gone to provide fully consistent and scientifically supported instruments for the supply of professional LEP-solutions. Along this way, a certain "convergence process" has to take place between LEP and urban planning including the special field of traffic planning, which will have to be considered together if really optimal and lasting, that is *sustainable* solutions shall be found for the future development of communities.

The number of LEP-models which are available in the studied countries varies a lot. It may partly be a consequence of the "energy planning environment". The important role of the municipalities regarding local energy planning in Sweden and Germany has probably stimulated the development of software tools for this planning task and therefore there are considerably more models available in these countries than in Belgium, Italy and Turkey where the role of the municipalities as an energy planning actor is much weaker.

The conditions of information available about the present energy demand and conversion technologies vary widely between the countries. In Sweden, energy information databases including energy demand and technologies for every building in the country, make it easy to develop a heat map. In most other countries this part of a project is often a very time-consuming first part of a energy planning project. The methods and models for this heat mapping work will be further developed in the future based on the wide-spread availability of GIS systems. The introduction of GIS-based system in local energy planning will mainly stimulate those part of the planning process that has a "geographical dimension", mainly all kinds of distribution (electricity, gas and district heating), transports and physical planning.

The future development of local energy planning is subject to both a "technology push" and a "problem pull". Examples of the "technology push" are the development of geographical information systems, GIS, in addition with the availability of digitized municipal maps, and other advanced computer software which will allow for a new planning quality. The major "problem pulls" are the need to further include environmental considerations in energy planning and the trend towards deregulation of the energy supply sector.

Deregulation and enhanced competition within the energy sector will lead to a situation where an increasing amount of the planning task will be transferred from local authorities to the energy utilities. The character of the planning may shift from local energy planning, LEP, to integrated resource planning, IRP, and the planning will above all be used for the company's strategic planning. This will probably not reduce the demand for energy planning models, but it may influence the design of the models. The energy planning may become more fragmentary with new organizations involved in the planning and this will increase the need for OR - (operations research) approaches to modelling.

The need for improved models in the energy planning process is basically a function of the uncertainties in the environment of the energy system. One strategy to handle uncertainties may be increased cooperation between communities (local systems) on a regional level. We also need to develop methods to analyse such types of cooperation. Thus, to support the decision maker and give him insights into the consequences for the energy system, interesting areas for the future model development will be:

- Environmental consequences
- Calculation of social costs (externalities)
- Deregulation of the energy sector
- Cooperation between communities (or local systems) on a regional level
- Security of supply.

(Some of these issues are treated within Subtask B.)

In addition to the discussions about the features of the models, it is important to be aware of the process in which the model is used. Especially when a comprehensive model is used, many organizations will be affected by its results. Together with the model results, the most important part of the planning is the learning process amongst the involved people and organisations. To ensure the learning process, the model must be used interactively. All concerned parties must be engaged in the work with the models from the very beginning. Discussions in work- and reference-groups about methods, data acquisition and results must be continuous.

Models are for insights, not for numbers!

Annex 22 - Energy Efficient Communities

Part III

Results on Subtask B: Models for the Calculation of Environmental Aspects

3-1 Introduction

As mentioned in part I, the consideration of environmental aspects has gained an increasing relevance in LEP. The objective of Subtask B is to discuss methods that treat environmental impacts of energy systems within LEP-projects which are at present in use within the participating countries.

In correspondence with the transition from traditional single-score planning to the consideration of entire energy systems, methods have been developed which meet the more complex requirements of systems analysis. In *economic optimization*, this resulted in Least Cost Planning (LCP) rather than in independent optimization of single components. Similarly, considering *environmental issues* we see a transition to environmental impact analysis, incorporating also features of facility siting analysis, rather than a one-dimensional comparison of single environmental aspects. The difficulty here is given by the task to make energy systems of often quite different structures comparable with respect to their environmental impacts to allow for the decision makers to get informations on the economic and environmental consequences of decisions for specific options.

3-2 Environmental impacts

The broadening of scope of environmental evaluation has consequently led to a vertical and horizontal expansion of the energy systems to be considered. To give a comprehensive valuation of the available energy options, the technologies under consideration, generally

fossil based energy supply
energy conservation
renewable energies and
nuclear energy

have to be investigated according to their complete fuel chain on the one hand and to their life-cycle impacts during the operation of the technology used on the other. Relevant environmental emissions and burdens to be considered are then generally

- *atmospheric emissions*

  SO_2, NO_x, particulates,
  CO, H_nC_m, nitrous oxides, heavy metals, radio isotopes
  CO_2 and other green house gases

- *emissions to surface or groundwater*

  suspended solids, organic compounds, heavy metals
  acidity, sulphate, chlorides
  radio isotopes
  heat

- *solid wastes*

  bottom ash, gypsum, fly ash
  mine spoil
  waste water sludge

- *other burdens*

  water consumption, land use
  accidents, mining subsidence
  visual intrusion, noise.

These environmental burdens produce a wide range of impacts, which can be classified as follows:

- *human health impacts*

  mortality
  morbidity

- *biological impacts*

  agriculture and forestry
  terrestrial ecosystems/wild-life habitat
  aquatic systems, fisheries

- *non-biological impacts*

  materials damage
  water supply
  land use
  perceived noise
  visual impact.

In principle, these impacts cause external costs to the energy system. Valuation techniques to assess these externalities depend to a large extent upon the relationship of the considered impact to existing markets. However, these impacts are so different, that a general judgement in terms of external costs is in most cases very difficult. As long as there exist regulatory standards (such as immission limits), quantifications are possible at least in principle. Many of the impacts mentioned above are of a qualitative nature and not quantifiable at all. Others are very difficult to quantify - at least to an acceptable degree of confidence. In general practice, quantified impacts are valued higher than non-quantified ones. Nonetheless, non-quantified impacts can be quite important and should not be ignored.

Obviously, in that complicated situation there is a strong need to offer some help to the practitioner which may help him in assessing energy options within his concrete LEP-project.

3-3 Valuation methods

In theory, there is a very elegant method to arrive at a quantification of externalities: the "external costs eqilibrium principle". This principle requires that expensive measures for pollution abatement should enable commensurate societal benefits in return. The cleaner the environment, the more expensive will be the further abatement. At some point, the next increment of emission abatement may not be worth the costs to society, which has also alternative uses for their real resources - the equilibrium external costs (fig. 3-1). In other words, the societal welfare is then maximized, when the marginal costs of pollution control are in balance with its marginal benefits.

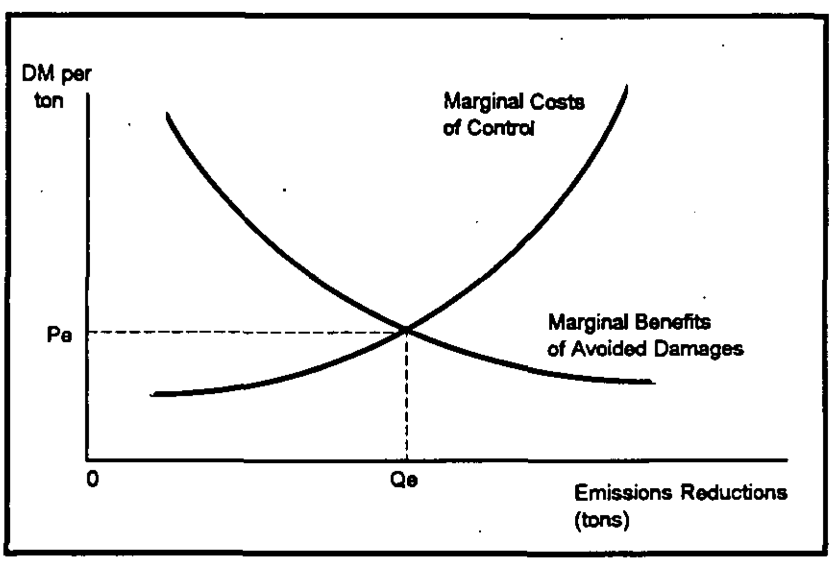

Fig. 3-1: Equilibrium external costs of pollution abatement

Unfortunately, we cannot quantify many of those benefits (or avoided damages), therefore surrogate approaches have to be developed, which may consider subsets of the general impacts mentioned above only. The most prominent approaches which have been developed by economic theory are according to present practice:

- *the damage function approach*
  (external costs equal to the damage caused)
- *the abatement cost approach*
  (the costs of reducing emissions are by definition attached to the external costs of the avoided emission)
- *the target approach*
  (establishes physical/mandatory constraints on energy system selection with the objective of finding the option that provides energy services at the lowest costs consistent with those constraints, set at the point of emission or deposition; emission abatement strategies are then developed within that physical/mandatory constraints)
- *the revealed preference method*
  (with insufficient informations on damages or abatement costs, the costs of achieving compliance with legislated standards can be considered a societal "revealed preference" value)
- *the hedonic pricing approach*
  (uses market prices to infer prices of non-priced goods, e.g. wages of workers exposed to enhanced risk compared to "normal" workers)
- *the willingness-to-pay approach*
  (also called "contingent valuation"; determines the value assigned by individuals to avoid or be compensated for an environmental impact by making interviews, surveys or opinion polls)
- *the critical-volume approach*
  (suited for product eco-profiles rather than energy systems: uses the volume of air or water necessary to dilute the raw emissions to a legally accepted level).

All of the approaches mentioned above have there niches of application. In the LEP-case, if the consideration of environmental impacts is not a dominating issue, it will often be sufficient to confine the analysis to a target approach accompanied by a cost-effectiveness analysis. Here, it is assumed that by achieving the limits given by the environmental legislation the environmental impacts have been reduced to an extent which is in general accepted by the society and has not to be quantified further. Within the existing legal framework, it is then the task of the planner to find the most cost-efficient solution.

This approach has the merit to significantly simplify the task of considering environmental impacts and to enable unambigous results. It has, on the other hand, the disadvantage that local peculiarities, which can be quite important in considering environmental impacts, are ignored. This is the reason why more complex approaches are frequently required also in LEP, such as environmental impact assessments.

For such a comprehensive approach, *life-cycle analysis* (LCA) seems to play a key role at present in the scientific discussion to quantify the emissions/burdens of energy systems (and generic product assessment as well) [III-1]. The results will in the general case have to be supplemented by a qualitative assessment of remaining intangible environmental issues.

LCA consists of two stages (fig. 3-2):

- *life-cycle inventory* - quantifies flows of energy, raw materials and residuals required or released throughout the life-cycle of an "energy service"
- *life-cycle impact analysis* - values the effects of the environmental burdens identified in the inventory (using one of the approaches mentioned above) in order to interpret the results of stage 1 and to give answers to policy questions.

Stage 1 is usually considered as "objective": data are accumulated on a verifiable basis and no valuation takes place (with the exception that in this stage it is already decided which impacts are considered and which are not). Stage 2 is the actual impact assessment step.

With no surprise, the implementation of this second step is far from being generally accepted within the scientific community. Even if there is, for some impacts, an undisputed understanding of their mathematical evaluation, quite unprecise results will be achieved in general due to appreciable data errors. For example, calculate the external costs of one single immission impact from an energy transformation process. This involves a series of multiplications: emission rate times transfer coefficient times exposure factor times exposure-response factor times a monetary value. Besides the fact that in this calculation it is assumed that all processes are linear (which may be quite wrong), the five coefficients may be known more or less precise; due to error propagation the result will in general have an appreciable uncertainty anyway.

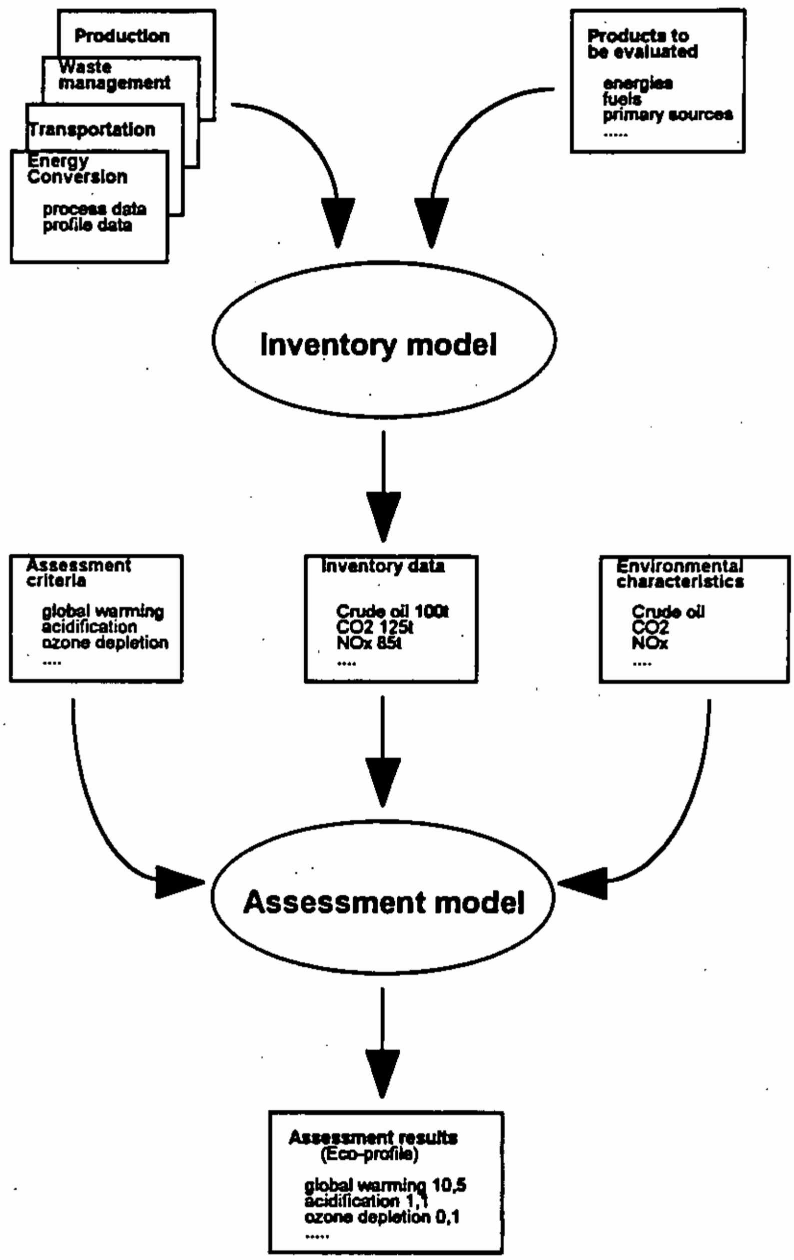

Fig. 3-2: Principle of a holistic environmental impact assessment

For stage 2, again different methods are applicable in principle, as provided by economic theory, such as

- cost-benefit-analysis
- cost-effectiveness analysis
- use-value analysis (or benefit value analysis)
- ecological risk analysis,

(see national report on Subtask B for further details).

A possible development for the future could be the combination of LCA (stage 1, which produces the quantified inputs) with a *use-value analysis* (assigns "use values" or "benefits" to the achievement of defined goals by different energy system options using transparent algorithms) of the results of the first stage of LCA as valuation model for stage 2 [III-2]. This approach would meet scientific requirements to verifiability and rigorousness. However, quite a bit of mathematics would be involved with that method by which transparency and credibility is lost within the process of LEP, where many different decision makers at the local level are involved (creditibility dilemma of expert systems). Whereas such a method certainly would have its scientific merits, it seems to be hardly applicable at the front of LEP-practice at present.

Further inputs may be expected from the present work on the consideration of environmental costs in national accounting systems: the need to institute national resource accounting and for depreciation of natural resource assets has been recognized recently by several countries, such as Canada, The Netherlands, Japan or Germany. This work is coordinated by UNEP and should, after completion, hopefully lead to the introduction of a broadly accepted assessment methodology.

3-4 Practical Approach to Assess Environmental Impacts in LEP

For the practicioner, what is really necessary is an approach which is balanced between *accuracy* of the assessment of environmental impacts, *practicability* and *public transparency*. According to these requirements, the following "rules of thumb" may be useful at the present "state-of-the-art":

(1) Consider only *relevant impacts* (where the energy system is the dominating factor for the impacted eco-system). Debate only issues that can be adressed meaningfully.

(2) Distinguish between *quantifiable* emissions/burdens and *non-quantifiable* burdens.

(3) Consider national targets according to actual environmental legislation

(4) Distinguish between *global* and *local* impacts.

(5) Do not aggregate over several indicators or criteria expressed in different measurement units ("multi-score eco-profiles"), since this would hide facts and conclusions.

(6) Consider direct costs and external costs independently without aggregation.

(7) Make sensitivity considerations to discuss the robustness of the interpretations.

(8) Give assessments and interpretations of results.

(9) Leave the decision maker with some decision power, based on his own system of goals, and present as neutral and transparent judgement of impacts as possible.

(10) Involve the decision maker into the whole process continously.

Applying these rules, quantifiable burdens of energy systems which should be considered in LEP are in general

- atmosperic emissions:

  "classical" pollutants: SO_2, NO_x, CO, particles; eventually also halogens, heavy metals
  green-house gases: CO_2, CH_4, CO, N_2O, NMVOC

- soil immissions (particle matter, acid rain)

- temperature rise of surface water, water consumption

- solid waste.

Accident risk assessment is also quantifiable in principle, but this quantity is of a quite different quality, since it considers probabilities rather than impacts. This issue, however, is in general of minor relevance in LEP-practice.

Qualitative aspects of energy systems are in general dominated by the consequences of primary energy extraction, though local effects such as demand of land area, noise (both of them with quantitative and qualitative aspects) or visual intrusion may in specific cases also have their weight in the assessment of alternatives.

3-5 Availability of Data

In a real LEP-project, with restricted resources of time and money, the job has to be done in a quite straightforward manner without possibilities to include scientific investigations. The practicioner has to have at his hand the sources of methods, instruments, tools and data which should be directly usable for his concrete project.

As discussed in detail in Subtask A, a large number of software tools has been developed in recent years which in principle are readily available for practice. For the inclusion of environmental aspects in LEP, in accordance with the practical approach recommended above, after deciding for the method how to elaborate environmental assessments the question of the availability of data arises. Again it turns out that there are numerous sources of data available, which have been developed in recent years by different institutions. In Europe, the most prominent sources are at present (see also [III-3]):

- *CORINE* and *CORINAIR* (a data base of the European Union)
- *EDB* ("environmental data base"; United Nations Environment Program UNEP and Risö National Laboratory, DK)
- *IKARUS* (KFA Jülich; in the final stage of development)
- CADDET (IEA data base on experiences with energy technologies, TNO/Sittard, The Netherlands and Chalmers University, Gothenburg)
- MASTERFILE (a database available in Sweden describing almost all existing Swedish buildings according to the newest census data)
- *GEMIS 2.0* (Öko-Institut Darmstadt/Freiburg).

Among these sources, GEMIS 2.0 can play a key role for practicioners at present for numerous reasons [III-4]:

- It is offered at a price which every practical planner can afford; in fact, this software can even be regarded as a kind of "public domain" software.

- The software is very well documented in accompanying studies and annexes.

- Due to its already widespread use a continous scientific discussion takes place, which ensures regular actualization and updating of the data base.

- There is, at least in Germany, quite a broad consensus about assumptions and results of GEMIS 2.0.

- The software includes a data base and a calculation model as well to carry through a life-cycle analysis for the energy service option under consideration. It provides results which can rather directly be used for a concrete project.

- The software allows for individual adjustments due to special cases or differing circumstances.

- Together with the calculation of results, the use of this software creates theoretical and methodological insights for the user by which he achieves some security that his results may withstand also critical debates.

- The data base of GEMIS is also continously developed for application within other countries (then under the name TEMIS) with differing conditions. In particular, it is also used for North America, which further ensures its scientific actuality.

The approach recommended in chapter 3-4 can be carried through under the help of GEMIS, using data as described at length in the national report for Subtask B. In the most recent version of GEMIS 2.0, in addition to environmental data also data on costs of energy systems are available, which in the practical project have to be examined critically but allow for a first guess in comparing different options of energy supply.

3-6 Conclusions

In LEP, it is the field of environmental impacts and their minimization where the responsibility of the society is involved rather than private companies to implement an overall strategy of setting up a sustainable energy system. One pre-requisite for this is to possess suitable data and calculation models that will allow for the right decisions to be taken.

Ideally, energy-environmental planning will be comprehensive, adressing all pollutants, all pathways and all effects for each stage of the energy transformation cycle. This comprehensive requirement would, however, mean that the planner would be ahead of the current state of scientific understanding and beyond the currently available data. Therefore, a more pragmatical procedure is necessary which makes maximal use of the available knowledge and is in the same time applicable for practice. In chapter 3-4 it is described how such a practical approach can be developed and which data are necessary and available to find meaningful answers to concrete environmental issues as a basis for the decisions to be taken. Recommendations as to the best available practice (at present) have been given according to the work on Subtask B and the discussions hereon amongst the participating countries.

Once an energy plan has been developed and decided, the next responsibility is to monitor its implementation and to amend it continously, as needed. For this, the continuing participation of the public is essential, as described in part I and in Subtask D. According to the LEP-experiences made in recent years in some of the participating countries, this is best achieved with a high degree of decentralisation for energy systems decisions. To enable this, among such consensual and participatory decision circumstances, low-level aggregation of results on environmental impacts is preferred, on which different decision-makers can rely upon in drawing their own conclusions. Ways to provide such results on the basis of present knowledge are described above. It is, however, very important to keep in mind, that in assessing environmental impacts and drawing conclusions on that we still are facing many uncertainties, part of which may be disclosed by appropriate sensitivity analyses. For those pollutants whose pathways or impacts are not or poorly known it is important that their emissions are accounted for at least at the beginning of the pathway to ensure that they finally are considered at all at least in a qualitative way.

3-7 Some Special Aspects

The national report on Subtask B gives a review to methods and existing data on environmental effects of energy supply. These informations are intended to provide the practical planner with a usable background on environmental questions without having to make a lenghty search for material and data to be used.

In general, *methods* to describe environmental impacts are independent from geographic locations. Differences in *results* stem from different climatic conditions, for example, or from different fuel properties etc. A major dispute, however, is caused by the treatment of co-generation. This technology, which certainly allows for appreciably savings of primary energy, if compared with separated generation of heat and electricity (from thermal power plants), has also some disadvantages, such as increase of local energy consumption, economic problems, and increased dependency from gas or fuel oil. The assessment of co-generation advantages depends from the "environment" of the national energy supply structure and can be quite different in countries where electricity supply is based predominantly on fossil sources, such as Italy, or on nuclear and hydro energy, such as France: *While there is a necessity of optimizing urban energy supply on the basis of local energy planning independently from the country, LEP-results may quite intensively be influenced by the existing national supply structure!*

In the following, some important aspects in the consideration of environmental aspects are summarized. For more details the reader is referred to the national report on Subtask B.

3-7.1 Global warming (or greenhouse-gas) potential

The main contribution (roughly 50 %) of the man-made global warming potential stems, according to present knowledge, from CO_2. Whereas CO_2-emissions can easily be calculated from the carbon content of fuels, other gases with global warming effects are more complicated to consider, since their emission factors and warming potentials depend from combustion processes and atmospheric conditions and, moreover, from the number of years to be considered in the calculation of the warming effect. For these reasons, there are a number of uncertainties in assessing greenhouse - gas potentials. The following table shows some values on the global warming potential of gases which are emitted by combustion processes, indicated as "equivalent warming factors" (EWF) as compared to CO_2 (which has, per definition, a value of EWF = 1).

Table 3-7.1: Equivalent warming factors (EWF) of greenhouse gases generated by the combustion of fossil fuels (according to GEMIS 2.0)

	Time of integration (years)		
	20	100	500
CO_2	1	1	1
CH_4	71	25	11
CO	7	3	2
NMVOC*)	31	11	6
$NO_{x(2)}$	30	8	3
N_2O	250	270	170

*) non-methane volatile organic compounds

Due to the high EWF-values of some gases it is necessary not to neglect them in comparing different supply options. In contrast to economic calculations, due to the long response time of the atmosphere a longer time of integration is necessary in considering warming effects, e.g 100 years.

The next table shows emission factors of some key pollutants and the CO_2-equivalent emissions of different fuels considering the whole fuel chain from the well head (or coal mine) over fuel processing and transport to the end user, as calculated for German conditions, according to GEMIS 2.0. These values can well be used, at least as a first approximation, also in other countries.

Table 3-7.2: Emission factors of fuel chains from extraction until end use (without combustion) according to GEMIS 2.0, data for Germany

		imported hard coal USA	imported hard coal Poland	imported hard coal Russia	lignite Germany	fuel oil import mix	gas	nuclear energy Germany	biomass Germany
SO_2	g/MWh_{PE}	340	140	210	8	580	22	16	50
$NO_{x(2)}$	g/MWh_{PE}	420	170	200	4	180	50	30	400
PM	g/MWh_{PE}	25	40	30	1	40	4	3	30
CO_2	kg/MWh_{PE}	24	40	60	6	90	14	7	35
CO_2 equiv. (100)*)	kg/MWh_{PE}	40	100	95	6	100	90	8	38
η_{PE}**)	MWh_{PE}/MWh_{PE}	0,92	0,88	0,82	0,98	0,77	0,92	0,97	0,82

*) integration time 100 years

**) average primary energy consumption of fuel chain until end use of primary energy in Germany

The values given in table 3-7.2 have to be added to the emission factors of the actually considered combustion process to achieve the overall "fuel chain emissions". It has to be considered, however, that these emissions do not occur at the location of the combustion, but represent "global" emissions. It should be noted from these data, that emissions caused by other gases than CO_2 can contribute appreciable to the warming potential, and that emissions which are connected with extraction, processing and transport of primary energy cannot be neglected in the whole fuel chain balance.

3-7.2 Treatment of cogeneration

Formulas and graphs to calculate energy saving potentials of different cogeneration technologies have been derived in the national report of Subtask B. Since the application potential of cogeneration is of central interest in most LEP-projects, a short summary on this issue is given below.

3-7.2.1 Primary Energy Performance of Cogeneration Processes

A useful measure for the performance of a cogeneration process is the *"specific fuel consumption" β* which is necessary to provide one unit of useful heat [MWh_{PE}/MWh_{th}]. While for the normal boiler process β is just the inverse of the efficiency, for the cogeneration process a "comparison process" has to be introduced. Usually, cogeneration has to be compared with separated generation of heat (with a boiler) and electricity (with the condensing power plant whose electric output is substituted by the cogeneration process). In that case, the performance of the cogeneration process, β_{cog}, is given by

$$\beta_{cog} = \frac{(1+s)}{\eta_u} - \frac{s}{\eta_{el}} \quad [MWh_{PE}/MWh_{th}]$$

where

s	...	ratio of electric to thermal output of the cogeneration plant [MWh_{el}/MWh_{th}],
η_u	...	ratio of thermal plus electric (= useful energy) output from the cogeneration plant over its primary energy input [(MWh_{el}+MWh_{th})/MWh_{PE}] and
η_{el}	...	electric efficiency of the "comparison process" (the efficiency of that conden sing power plant whose electric output is substituted by the cogeneration process; typical value: η_{el} = 0,37 for a mean size hard coal power plant).

Depending from the electricity supply structure of the country, the cogeneration plant will substitute in general electricity from mean load power plants, either large hard coal, oil or gas fueled condensing power plants. Table 3-7.3 shows reasonable values for η_{el}.

Table 3-7.3: Typical electric efficiencies [%] of possible "comparison power plants"

	existing average	new	near future
hard coal	35	38	44
fuel oil	36,5	40	48
gas	38	42	51

Cogeneration plants are usually operated according to the heating demand. Because of their high investment costs compared to boilers, the cogeneration unit is usually designed for the base load heating demand to achieve long operating times. The specific fuel consumption $\beta_{cog}{}^{sys}$ of such a supply system consisting of a cogeneration unit "cog" and a peak load boiler "PL" is given by

$$\beta_{cog}{}^{sys} = p_{cog} \cdot \beta_{cog} + p_{PL} \cdot \beta_{PL},$$

where p_{cog} and p_{PL} are the shares of the cogeneration unit and of the peak load boiler of the annual heat supply - in typical, well designed district heating systems p_{cog} = 0.85 and p_{PL} = 0.15 - and β_{PL} is the specific fuel consumption of the peak load boiler, PL (typically 1,20 MWh_{PE}/MWh_{th}).

Under German conditions, small cogeneration plants are usually designed for about 30 % of the winter peak thermal load, whereas medium or large CHP plants supply about 50 % of the peak load. By this, some 70 % of the annual heating demand are supplied by cogeneration or about 85 % in the case of larger CHP plants. For LEP-purposes, such a rough estimate will in general suffice as first approximation. Similar figures will hold in general also for the other participating countries. For more detailed calculations, a simulation of the heating (and electricity) demand on a hourly basis is necessary, using calculation tools as described in Subtask A.

If thermal losses l_{th} of the district heating grid which is served by the combined heat/power-plant and the electricity demand d_{el} for water transport (both in [%], typical values 8 and 3 %), are also considered, the following formula for the system performance β_{cogDH} of cogeneration district heating results, as compared with heat supply by decentralized boilers:

$$\beta_{cog}DH = p_{cog} \cdot \left[\frac{1+s}{\eta_u} \cdot \left(1+\frac{l_{th}}{100}\right) - \frac{s - \dfrac{d_{el}}{100 \cdot p_{cog}}}{\eta_{el}} \right] + p_{PL} \cdot \beta_{PL} \cdot \left(1+\frac{l_{th}}{100}\right)$$

with good approximation.

Fig 3-7.3 shows the dependancy of $\beta_{cog}{}^{DH}$ from the electricity/heat-ratio s (see national report of Subtask B for further details).

From fig. 3-7.3 it can be seen, that district heating with steam, fed by small back pressure turbines is with respect to its demand of primary energy for heating supply not better than decentralized gas-boilers (or good fuel oil boilers), due to low electricity/heat-ratio and high energy losses of the steam pipes. This allows, however, for the use of primary energy sources, such as coal, wood, lignite, peat or solid refuse, which can only be used in central plants. On the other hand, with thermodynamically optimal designed cogeneration plants and district heating systems, cogeneration can allow for significant energy savings which explains the high interest for district heating with cogeneration in almost every LEP-project.

In addition, one can calculate also the dependancy of $\beta_{cog}{}^{DH}$ from the performance of the power plant which is substituted by the cogeneration plant, using the same formula. Fig. 3-7.4 shows the result. It can be seen, that only in the case of a very well designed cogeneration system with an electricity/heat-ratio s > 0.60 the cogeneration system will have significant advantages when compared with the latest technologies for separated generation of electricity (η_{el}-values of 0,45 to 0,51 represent the state-of-the-art for new large power plants) and heat (β_B = 1,10 for a modern condensating gas-boiler). Old cogeneration plants, as indicated in lines 1 and 2 from fig. 3-7.3, show on the other hand a primary energy performance which is appreciably worse than what can be achieved by the latest power plant and boiler technology.

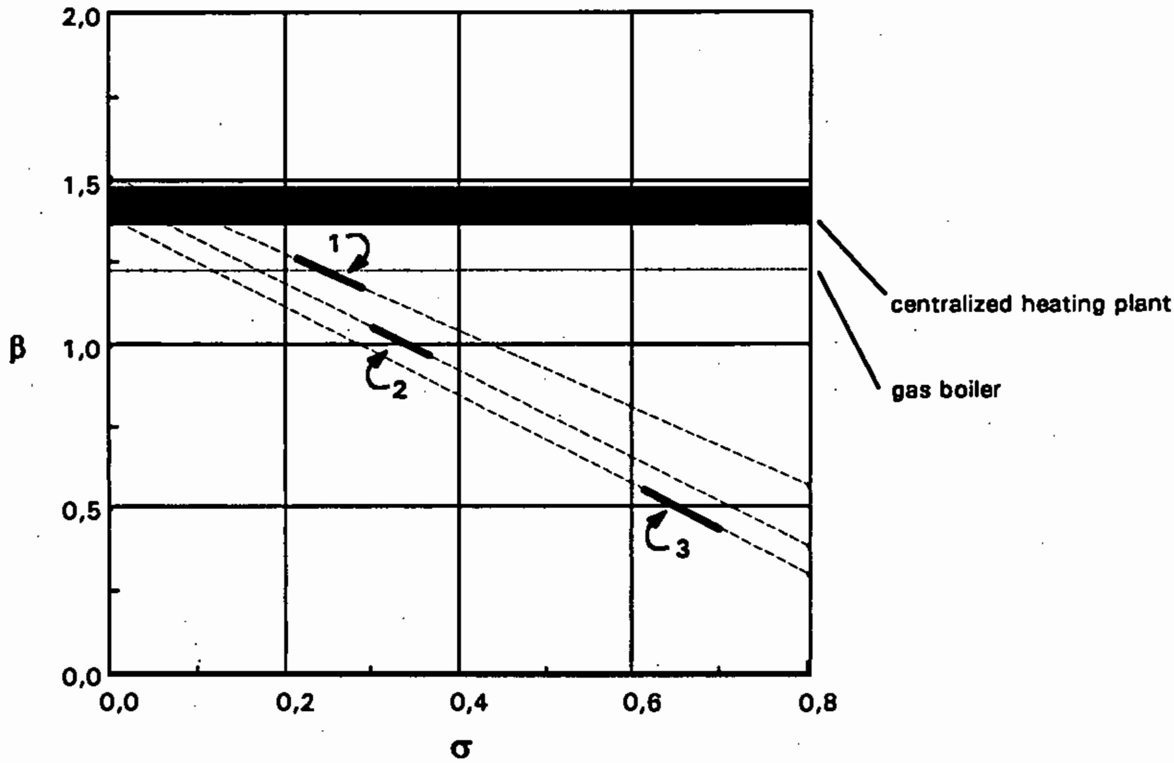

Fig. 3-7.3: Specific primary energy demand β_{cog}^{DH} [MWh_{PE}/MWh_{th}] for one unit of usable heat in district heating systems with 3 different cogeneration plants as base load systems as function of the electricity/heat-ratio σ [MWh_{el}/MWh_{th}], using the parameters given in the text. The shadowed horizontal range shows the specific primary energy demand of a central heating plant without cogeneration; the dotted horizontal line shows the specific primary energy demand of a conventional decentralized gas boiler.

1: Back-pressure cogeneration with 3 bar steam output;	σ = 0,25
2: Back-pressure cogeneration with hot water supply;	σ = 0,33
3: Gas turbine with reject-heat utilization (hot water supply);	σ = 0,63

3-7.2.2 CO_2-Reduction Potential of Cogeneration

The calculation of the reduction of CO_2-emissions which is enabled by cogeneration is principally similar to the calculation of primary energy savings. It must, however, be kept in mind that with different kinds of fuels used different CO_2-emission factors f_{CO2} [kg CO_2/MWh_{PE}] are involved.

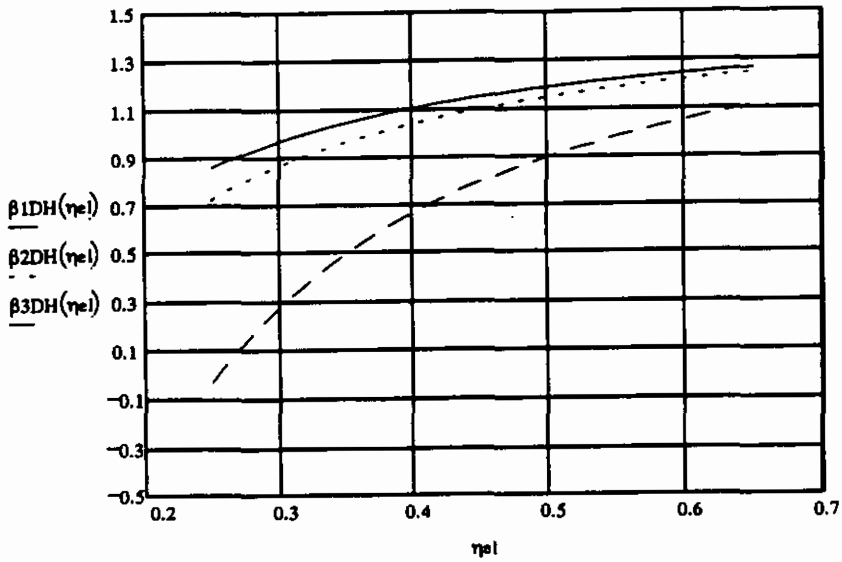

Fig. 3-7.4: Specific primary energy demand β_{cog}^{DH} according to the formula and parameters given in the text as a function of the performance η_{el} of the condensing power plant whose electric output is substituted by the cogeneration plant; three different values of s according to the cogeneration processes 1,2 and 3 of fig. 3-7.3 have been used.

If the comparison is related, as above, to the unit of useful heat supplied, in the case of a *fuel oil boiler* with a specific fuel consumption of β_B [MWh_{PE}/MWh_{th}] the CO_2-emission e_{CO2}^B, using the fuel oil CO_2-emission factor $f_{CO2}^{f.o.}$, is given by

$$e_{CO2}^B = f_{CO2}^{f.o.} \cdot \beta_B \text{ [kg } CO_2/MWh_{th}\text{]}.$$

Using the formula given above for the specific fuel consumption β_{cog} of *cogeneration plants*, it has to be considered in the second term of that formula that the CO_2-emission factor of the fuel used by the "comparison process" will in general be different from the cogeneration fuel. For example, if natural gas (f_{CO2}^{gas}) is used for cogeneration and hard coal

($f_{CO2}^{h.c.}$) for the (substituted) electricity production, the specific CO_2-emission of the cogeneration process is calculated from

$$e_{CO_2}^{cog} = f_{CO_2}^{Gas} \cdot \left((1+s)/\eta_{u} - \frac{s}{\eta_{el}} \cdot \frac{f_{CO_2}^{h.c.}}{f_{CO_2}^{Gas}} \right)$$

(using the same symbols as indicated above). Table 3-7.4 shows CO_2-emission factors for some fuels (without corresponding "fuel cycle" emissions).

Table 3-7.4: CO_2-emission factors for usual fuels. CO_2-emissions along the fuel chain according to table 3-7.2 have to be added to these values.

Primary energy source		**CO_2-emission factor** [kg CO_2/MWh_{PE}]
natural gas	f_{CO2}^{gas}	205
fuel oil	$f_{CO2}^{f.o.}$	266
hard coal	$f_{CO2}^{h.c.}$	308
nuclear energy	$f_{CO2}^{n.e.}$	0

Using the formulae given above, it can be shown that cogeneration, *if realized with an optimal design*, can have appreciable advantages due to its potential of energy saving and of reducing CO_2-output compared to separated supply of heat and electricity. This is, however, only true if cogeneration substitutes *fossil fired* power plants. Depending from the supply structure of electricity within a country, cogeneration technologies can be judged quite differently in different countries. Cogeneration cannot be considered as a general multi-purpose instrument, but must be valued within the context of the local and national supply structure into which it is embedded. This can lead to different results depending from the considered country, as tables 3-7.5 and 3-7.6 indicate.

Table 3-7.5: Supply structure of electricity within the participating countries (1989)

participating country	demand 1989 TWhel	specific electricity consumption MWh_{el}/Cap	nuclear energy %	hydro energy %	fossil %	cogeneration from fossil sources %	η_{net}*)	η_{distr}
Belgium	63,9	6,4	61	2	35	~ 0	?	?
France	387,3	6,7	75	13	12	?	?	0,92
Germany	411,5	6,6	34	5	60	14	0,329	0,949
Italy	199,7	3,5	0	19	79	?	?	?
Sweden	129,6	14,9	44	51	5	4	?	0,935
Turkey	76,0	2,1	0	42	58	~ 0	0,315	0,90

*) average end-efficiency including distribution losses, without hydroelectricity and cogeneration

Tab. 3-7.6: Electricity generation from fossil fuels (1989)

(including combined heat and power and cogeneration plants, excluding waste incineration plants)

participating country	electric energy from fossil sources (TWh_{el})	shares of coal (%)	 fuel oil (%)	 natural gas (%)	 peat (%)
Belgium	22,4	64	4	32	0
France	46,5	63	23	14	0
Germany	246,9	79	4	17	0
Italy	157,8	17	61	22	0
Sweden	5,6	38	9	42	11
Turkey	44,1	55	23	22	0

From the tables above it can be seen, that district heating with cogeneration and combined heat and power plants will in general be an interesting option for energy supply (if economically), but with very strongly varying potentials in the different participating countries, with Germany, Turkey, Italy and Belgium as countries with quite high cogeneration potentials and France and Sweden with rather restricted potentials, due to their high percentages of nuclear and hydro power. It was shown, moreover, that a strategy of separated electricity generation using latest available technology can in many cases be similar successful if the system is optimized as a whole.

The dominating medium load electric power plants are in general - with the exception of France and Sweden - medium and large hard coal or fuel oil power plants, whose electric output will generally be substituted by cogeneration plants. As long as cogeneration does not substitute a significant portion of the domestic electricity supply from non-fossil energy sources, its energy saving benefits can be assessed quite similarly among the participating countries, as described above.

3-7.3 External costs

As discussed above, some of the environmental impacts of energy supply can be "monetarized". By this, environmental costs can at least partially be internalized, though uncertain and object of many controversies. Despite the fact, that it will remain necessary to consider also qualitative aspects which cannot be monetarized, external costs can provide interesting informations in assessing different energy service options.

In contrast to direct damage costs, which are disputed very controversially, with the exception of the external costs of nuclear energy the costs of pollution abatement given in the literature are frequently in a quite comparable order of magnitude, as long as "reasonable" goals of abatement are considered. By "reasonable" in this context abatement measures according to present pollution control legislation are understood. The following tables give some informations on external costs according to present discussions in Germany, which should be considered as rough and approximative. Similar figures from other participating countries have not been available. Table 3-7.7 shows, instead, estimates which were recommended by the Massachusetts Department of Public Utilities (MDPU) to be considered in economic calculations. These figures were published in 1990 and are calculated into present values with an inflation rate of 4 % and a currency conversion factor of 1,70 DM/$.

External costs of CO_2 are very difficult to derive, since they are depending strongly from the method used for abatement (improved energy performance, for example, can result even in "negative abatement costs", if the improvement goal is moderate). All values of table 3-7.7 and 3-7.8 have to be treated very cautiously!

Table 3-7.7: External costs of atmospheric pollutants (plausible values from GEMIS 2.0, 1993, and Massachusetts Department of Public Utilities, 1990)

	DM/t (GEMIS 2.0)	DM/t (MDPU)
SO_2	5.000 - 8.000	3.000
PM	1.000	8.000
$NO_{x(2)}$	4.000 - 5.000	13.000
CO_2	10 - 100	40

Adding costs as mentioned above one receives the sum of external costs (or benefits, if alternative supply options are considered) of electricity production. As mentioned, the assessment of nuclear energy is at present - and presumably will stay - extremely difficult, due to the uncertainties with nuclear accidents and costs of the final treatment of nuclear waste. In the following table, ranges for external costs are indicated which reflect the present discussion on this issue [III-5].

Table 3-7.8: Range of external costs (Pf/kWh_{el}) of electricity production as discussed at present for German conditions, compared with internal costs (further details see Subtask B report)

Power plant type	internal costs	external costs	total costs
large hard coal power plant	12	3 - 13	15 - 25
large nuclear power plant	9	0,3 - 70	10 - 79
wind (medium size)	16 - 25	0,02 - 0,40	16 - 26
photvoltaic cells	100 -200	0,50 - 1,00	100 - 200
biomass	14 - 25	1 - 2	15 - 27

3-7.4 Assessment of heating energy demand

One of the most important and at the same time most difficult questions in LEP is the estimation of the heating energy demand of whole building or settlement areas (existing or new). There have been different approaches been developed and applied, dependent from the available data base.

(a) The indicator approach

Due to given experiences there exists some correlation between the age of buildings and its specific heating energy demand ($kWh_{th}/m^2 \cdot a$ or $kWh_{th}/m^3 \cdot a$), in addition dependent also from climatic zones of the country. Since in LEP-projects normally a large number of individual buildings have to be considered, this first "statistical" approximation allows often for quite reasonable results which can be used as outset for further considerations. This method is apparently applicable in all participating countries, since the age of buildings is a basic information one can gather from census data (frequently often in addition to data on the existing heating system), together with floor areas.

Table 3-7.9 shows an example of such data for the building stock of West-Germany (East-German data would be quite different).

Year of construction	average dwelling area [m^2]		specific heating demand [$kWh_{PE}/m^2 \cdot a$]			
	SFH	MFH	SFH		MFH	
			centr.	decentr.	centr.	decentr.
> 1948	92	67	201	126	166	99
1949-1968	102	61	182	114	175	105
1969-1978	119	73	145	88	119	73
1979-1983	120	68	120	73	115	69
>1984	118	66	115	70	83	46

Table 3-7.9: Characteristic primary energy demand data for existing dwellings in West-Germany

SFH ... single family houses
MFH ... multi family houses
centr. ... centralized building heating systems
decentr. ... single dwelling heating systems

(b) Method of "settlement typology"

This approach seems to be specifically developed only in Germany, where in 1981 - 83 a comprehensive investigation on characteristic data of typical settlement structures has been made. Here, for 14 different such settlement types data have been empirically determined, such as age, ground area, floor number, surface/volume-ratio, U-values and window area [III-6]. From these data, the statistical energy demand for individual buildings and whole settlement structures as well can be derived. This method can be used by the experienced planner to determine quickly and with comparable little effort the heating energy demand of urban settlement structures, if he is able to divide the investigated area into typical settlement zones. It is in quite frequent use in Germany.

(c) Individual calculation of heating demand

In LEP-projects usually such individual calculations cannot be afforded due to the large number of buildings. Often calculations for typical buildings are made and extrapolated to others using indicators such as the floor area, thus also a kind of building typology is applied in practice. In such cases, the degree day method, supported by some empirical values for determination of external passive and internal loads, is in widespread use within the participating countries. This method is used also in building codes and standards and therefore, though not very precise, is widely accepted.

In recent years, this method is increasingly substituted by computer assisted simulation calculations as described in further detail in Subtask A. The globally at present most frequently used building simulation software is TRNSYS. Comprehensive work on that field has been done by the IEA-Implementing Agreement on Solar Heating and Cooling within the following tasks to which the interested reader is referred:

- *Tasks 8&11:* Passive Solar Buildings: Design and analysis Tools
- *Task 9:* Test Reference Years
- *Task 12:* Building Energy Analysis

In combination with a data base which contends census data, it is possible to determine the energy demand of a specific investigation area as the sum of the individual buildings with comparably little effort and sufficient precision. At present, among the participating countries this is only possible in Sweden, where the necessary data and computer models (such as HOVA) are available and the existing laws on data handling allow for the use of individual data.

(d) Geographical information systems (GIS)

An increasing number of cities are applying GIS-systems for land surveying and administration of building and estate catasters. Such systems can be extremely useful in determining the heating demand of whole settlements, if they can be combined with databases from census or utility customers by suited interfaces. Such a development is still at the beginning in some of the participating countries, with the exception of Sweden, where the use of general census data by GIS-systems is effectively supported already today, using the database MASTERFILE. This approach will definitely be of high importance for the future development of LEP.

Annex 22 - Energy Efficient Communities

PART IV

RESULTS ON SUBTASK C: MEANS TO REPRESENT, DEMONSTRATE AND ADVERTISE PLANNING SOLUTIONS

4-1 Introduction

One important problem of the implementation of LEP-results is the lack of information of the various actors being involved in the realisation process as a follow-up to an LEP-project. The different decision makers in administration, utilities and other involved institutions have to be convinced of the usefulness of the LEP proposals by persuasive energy plans. Above all executing parties such as architects, engineers or craftsmen must be informed and qualified to be able to cooperate within the LEP-implementation. Dissemination of information is the connecting link between planning, decision making process and implementation of energy projects and the crucial point for an effective and successful realization of LEP-measures.

For a successful dissemination of information there are on the one hand information media necessary which are specifically taylored to the target groups and on the other hand institutions to transfer the various kinds of information to the actors in different positions and on various levels. Subtask C focuses on the different possibilities to represent, demonstrate and advertise planning solutions by examples from Sweden, Belgium, France and Germany.

4-2 Information Media

In the participating countries information media are used in different ways and at different levels of intensity. Two different types of information media are generally used to support LEP implementation in its various phases:

- printed media and
- information networks

4-2.1 Printed Media

Printed media are the most popular and simple way to spread information and therefore this traditional form of information dissemination is still the dominating means of communication. For a survey one can divide the large number of documentations in three categories:

- documentation on new energy technologies,
- documentation on examples for LEP and
- documentation of municipal energy plans.

4-2.1.1 Information on New Energy Technologies

Swedish experiences:

The SEU (Swedish Energy Development), an institute founded and co-financed by the Swedish electricity producers, reports continuously about projects concerning efficient use of energy and new energy technologies through widely disseminated brochures. Information about development and demonstration projects, (e.g. local energy projects, wind energy, conservation systems, cogeneration plants, district heating etc.), where NUTEK (the Swedish National Board for Industrial and Technical Development) has participated, is regularly distributed to interested parties.

Belgian experiences:

In Belgium until recently dissemination of information about efficient energy use and new energy technologies by brochures for all citizens is not very common. Following to the Belgian state reform in 1988, the "National Service for Energy Conservation" has reassigned a lot of its tasks to the regional government level. In 1990 the Flemish Bureau for Natural Resources and Energy and the Institut Walloon were established. One of the main tasks of these service organisations is the dissemination of information on and promotion of energy research.

French experiences:

In France the range of documents concerning new energy technologies is very wide. Different kinds of documents, targeted at designers and decision makers, in municipalities or other professional organisations, are published by ADEME (Agency for Environment and Energy management) and by its regional energy offices and are so available to a wide body of potential users.

German experiences:

In Germany an interesting example exists for systematically processed and widely disseminated information related to efficient energy use and new energy technologies called BINE (Bürger Informationen Neue Energietechniken), sponsored by the Federal Ministry for Research and Technology . Target groups are not only interested citizens but also experts and decision makers in communities and in the industry-sector. The range of topics includes most energy issues in the fields of housing construction, agriculture, industry and commercial sectors and, increasingly, also environmental items.

The documentation on these subjects is presented on a four - paged leaflet, of which approximately 25 are edited per year. The number of printed copies is between 80 and 120 thousand. Since each document is read by an average of 5 persons (50 % of whom are professionals, 50 % private persons) information on innovative projects is brought to some 500 000 persons per year with each leaflet.

4-2.1.2 Documentation of Local Energy Planning (LEP)

Swedish experiences:

Aiming at both the concerned organisations and the citizens within a municipality the results of local energy planning are widespread presented within the adressed communities only by means of brochures and reports. From a few LEP-projects information has been spread also nationwide by newsletters or brochures, when external organisations have sponsored the LEP-projects.

Other examples of general infomation and guidelines on LEP in Sweden at the national level are the publications of

- NUTEK (1988): "Perspective on municipal energy planning"
- "Energy and Environment", published by the Swedish Association of Municipal Authorities in 1991
- NUTEK (1991): "Environmentally adapted local energy planning" which presents a method for combined environmental and energy planning.

Belgian experiences:

In five cities of the Flemish region energy offices started activities. Since 1987 Brugge, Gent, Antwerpen, Leuven and Hasselt try to inform their citizens about rational energy use in their homes. Another initiative in the Flemish region was started with a programme on applications of new technology for energy savings in municipal buildings by VITO (Institute for Research on Technology). In the Walloon region 14 energy offices are working. They provide free information for all inhabitants and organize training courses for special energy coordinators in public buildings.

French experiences:

Whereas rarely a document deals exclusively with LEP projects there, single aspects of LEP, aiming at municipal energy management and energy auditing of buildings, are included in the already mentioned documents of ADEME.

German experiences:

A considerable number of LEP-projects had started in the 80's by a nation-wide demonstration programme and accordingly the number of studies and basic documentation of LEP-projects and of methodological questions is large. One can divide these documentations into categories as follows:

- documentation at field studies from the Federal Working Programme "Local and Regional Energy Supply Planning"
- documentation of applied methods for LEP studies
- evaluation of the Working Programme.

During the 80's about 300 LEP-projects have been made in Germany. Many of them may be good examples for other communities, but most of them are available only in a very limited number of copies.

4-2.2 Information Networks

Information networks are computer-assisted services for the central storage, processing and exchange of data. They can play an essential role in the process of developing energy plans for communities, if used. Consequently it is interesting to shed some light on the data aquisition methods and the type and content of information stored in existing information networks.

Swedish experiences:

With the exception of KADETT (a database carrying informations about new energy technologies aimed at the energy production sector and at the energy end use sector, organized by some IEA countries under the lead of The Netherlands and Sweden), an exchange of information concerning energy planning is not really systematically organised there. Nevertheless, information concerning energy planning and new energy technologies are collected and exchanged by national and regional organisations for different issues and professionals. One interesting example is the data base MASTERFILE (see Subtask A) which provides actual informations concerning almost every building in Sweden, which is a very useful tool for LEP.

Belgian experiences:

In Belgium information networks like computer-assisted services for collecting, processing and exchange of information do not exist. In 1992 an energy accounting system based on a software tool called COMEBAT was installed in 19 Walloon municipalities. This initiative is the result of the previous investigations of energy management in public buildings started in 1989 by the Organisation of Belgian Municipalities.

French experiences:

In France many computer-assisted information networks dealing with concrete data and information referring to LEP and design of energy systems inclusively renewable energies exist. ADEME supported computer based information networks accessible through the widely spread "Minitel" service. More than six million users have access to "Minitel" information about

- energy conservation and new energy techniques
- technical or weather data regarding design of energy systems
- detailed specifications of solar heating systems.

Further information networks can be used in context with LEP by professional organisations:

- Ingenieurs des Villes de France
- Association des Techniciens en economie d'Energie
- AMORCE (organisation of municipalities dealing with district heating).

German experiences:

In Germany a special computer - assisted information system for communal energy issues has been developed. This information system called KEV (Informationssystem Kommunale Energieversorgung) consists of an information transfer facility and a special database. Target groups of KEV which includes bibliographic information, data and facts, free texts and also diagrams are urban administrations, utilities, suppliers, associations, architects, consultants and manufactures. Main goal of KEV is to collect already existing data and to process it in one unified system. At present this comprehensive information system is being tested by a couple of representative users.

Other less advanced information systems on new energy technologies are already in use. Examples are the central data base of solar energy installations and solar energy products in Germany operated by the Institute for Solar Energy Supply Systems (ISET Institut für Solare Energieversorgungstechnik, Kassel) or a similar database for the field of wind energy, operated by Deutsches Windenergie-Institut, Wilhelmshaven.

4-3 Institutional Arrangements

4-3.1 Local Level

Swedish experiences:

In Swedish communities municipal energy planning is generally made by different parts of the administrations. A good example is the "Gothenburg energy plan", which was organized by a committee called "the energy group". This group consists of representatives from different municipal administrations which are responsible for energy related issues. The municipality owned utility Göteborg Energi AB and the real estate board have been responsible for major parts of the analysis and considerations which are the basis for the energy plan. Today it has become quite common in Sweden for utilities and district heating energy suppliers to offer services in the field of efficient use of energy by information campaigns etc. They thus play a role as commercial disseminators of relevant informations on energy issues which seems to work well in a "consensual society" as that of Sweden.

Belgian experiences:

In Belgium five cities (Brugge, Gent, Antwerpen, Leuven and Hasselt) founded municipal energy offices in the late eighties with different experiences. In 1981 an "energy cell" was installed in the Gent city administration. The task of this group is to monitor the energy consumption of city buildings and to advise in renovation of inefficient heating installations.

French experiences:

As a consequence of the highly centralized energy supply and distribution system in context to the legal framework in France, again only ADEME and its regional offices are engaged in LEP at the local level.

German experiences:

Due to long experiences with LEP several examples for institutionalized transfer of information at the local level are available. Energy officers are frequently established either as a central staff position or as member of special working-groups in the particular departments, e. g. department for construction.

The scope of activities of these institutions include in particular

- supervision of the development of communal energy plans,
- implementation and control of energy plans,
- energy management (e. g. control of consumption, financial management) of public buildings,
- energy optimization of new communal construction projects (development, planning and heating system technology),
- training of the relevant service personnel,
- optimization of energy supply contracts,
- elaboration of (annual) energy status reports.

Regular energy coordination conferences are of central significance for the transfer of information within the communal administration, due to the existence of a large number of actors and the need to reconcile their many different interests in order to find consensual solutions.

4-3.2 Regional and National Level

Swedish experiences:

Today a number of examples of organized regional cooperations on energy planning between municipal electrical utilities exist. These activities of the utilities are getting more and more common in Sweden as the market situation is changing from monopoly-like structures towards deregulation. A good example of a regional cooperation is the Energy Group of Skaraborg county, which tries to coordinate energy planning, initiate projects and facilitate information exchange at a regional level.

On national level several institutions and organisations are active in the field of local energy planning and new energy technologies. Examples are:

- NUTEK, National Board for Industrial and Technical Development
- BFR, National Board for Building Research
- SEU, Swedish Energy Development
- The Swedish Association of Municipal Authorities
- different universities and trade associations.

Belgian experiences:

In Belgium the regional administrative services are active in the field of rational energy use and new energy technologies since they got most of the tasks emerging from the national service on energy conservation in 1990. Concerning rational energy use these services have functions mainly in three areas:

- financial support, subsidies, fiscal discounts
- information dissemination
- promotion of results of energy research.

On national level 'het Nationaal Centrum voor Wetenschappelijke en Technische Documentatie' among other activities also provides the data base "Scientific Technical Information Network" (STN). Within the national energy administration in Belgium a "concentration cell" between national and regional administrations concerning rational energy use (ENOVER) was founded after the state reform in 1988. ENOVER among other activities is promoting Belgian participation in international initiatives in the field of energy.

French experiences:

Two kinds of organisations acting at the regional level exist:

- the national organisation ADEME has created regional offices in every French administrative "region". These regional offices called "Delegation Regionale" have the task to conduct the nationally defined ADEME policies in cooperation with the municipal authorities,

- in four French regions (Nord Pas de Calais, Rhône Alpes, Provence côte d'azur, Aquitaine) the elected regional councils have created specific funds and regionally responsible *energy agencies*. The activities of these regional energy agencies have been focused on information dissemination and on consulting the communes to optimize communal energy supply and to upgrade district heating.

German experiences:

The activities on the regional level in Germany can be assigned to

- utility associations
- energy agencies

- municipal partnerships and
- other organisations.

By the end of 1992 some 130 communal suppliers had joined the Association of Communal Utilities for the Promotion of Rational, Efficient and Environmentally Compatible Energy Use and Rational Water Use (ASEW). The association is open for all communal utilities and its main goals are information and experience exchange among all members and support of new technical and organisational solutions by the following means:

- development and testing of software for energy management,
- training and higher qualification of energy managers,
- implementation of energy management centers,
- development of financing models for energy conservation investments and energy services including public support schemes and grants,
- proposition of referees and development of presentation material,
- development of integrated plans for energy conservation,
- planning of public relations and information campaigns for customers,
- proposals for energy conservation in the building area, in the communal area and in the residential heating/hot water supply area,
- proposals for use of renewables,
- proposals for rational and efficient water use.

In addition there are numerous other activities of various organisations and associations engaged in the information transfer or the training/qualification sectors. The Center for Energy, Water and Environment Technique of the Chamber of Tradesmen (Handwerkskammer) of the city of Hamburg is but one example which stands for many other similar activities. This organization is adressing its services to its members. They can be grouped into three main areas:

Qualification:	training courses, workshops, seminars and lectures for professional qualification
Consulting:	consulting in technical issues and economics, technology transfer, innovators contact unit, group and policy advice, studies, and investigations
Development:	technical research and development work, testing, examinations and measurements, transfer into projects .

The costs are covered by the Chamber of Tradesmen. Because of the co-operation with the Technical University Hamburg it is possible to make use of the latest measurement and laboratory possibilities in the energy and environmental sectors.

4-3.3 International Co-operation

The Directorate-General for Energy of the *European Commission* has defined a programme aimed at the support of energy programmes in cities. This is the so-called "CITIES project", where CITIES stands for Community Integrated Task for the Improvement of Energy & Environmental Systems in Cities.

Participating cities are Amsterdam, Besançon, Braganca, Cadiz, Dublin, Esch/Alzette, GentMannheim, Newcastle, Odense, Thessaloniki and Torino. Each of these cities has produced a report focusing on successful examples of urban energy policy. A summary of these reports is contained in a document which highlights important topics that emerge from this study of the European Community.
The *OECD* has a new project with the goal to promote sustainable energy supply structures in cities as part of a process of urban environmental improvement. The project goals are:

1. Evaluating innovative urban practices and instruments.
2. Improving the concept of measuring energy efficiency.
3. Providing linkages for improved information exchange.

The main methods of work are draft reports for the OECD guide and a series of workshops. A time frame of three years is planned for developing this "Guide to Good Practice in Urban Energy Management".

A further additional example of multilateral cooperation in the field of local energy planning is a continuously organized seminar by the *Nordic Institute for Studies in Urban and Regional Planning*, "Energy - Environment - Methods in local energy planning". At this seminar representatives from the Nordic Countries discuss problems and solutions concerning LEP and exchange experiences in this field.

4-4 Qualification by Seminars and Workshops

Swedish experiences:

Higher education in the field of local energy planning is supplied by some Universities of Technology. There are however no specific "LEP Qualification Programmes" available. At

Chalmers Universitiy of Technology a post-graduate study programme on "Energy Systems and Use of Energy" is preared. As a consequence of their increased interest in the field of efficient energy use and renewable energy technologies Swedish utilities are also striving for qualification and training of their own personnel to enable it for new commercial tasks in the market of energy services.

Belgian experiences:

In Belgium in the last few years similar qualification and training offers as in Sweden were developed in the field of efficient use of energy both in Flanders and in the Walloon region by the institutions mentioned alrady above.

French experiences:

Again ADAME has the responsibility for offering specific training material and aids in the field of common energy planning, most of them being focused to professionals dealing with various kinds of energy techniques, but also training courses are offered to municipal officers and municipal engineers. Main topics of these special training courses are environmental aspects of municipal management and re-negotiation of concession contracts between the national supplier EDF and French municipalities.

German experiences:

In 1987/88 the special field of Urban Development within the Department of Architectural Design at the TU Darmstadt arranged a seminar on energy in community and building planning. The seminar aimed at making the multiple interdependencies clear, that exist between architecture, city development, and communal administrations on the one hand and the areas of energy supply, rational energy use and energy conservation on the other hand. A further significant offer is the Post-Graduate Study "Energy Consultant/Energy Manager" at the Technical University Berlin. This qualification programme was first implemented in 1983 and has successfully been continued since then. It is offered to university graduates and qualified professionals.

4-5 Summary Assessment

A comprehensive evaluation of the various means to disseminate informations on LEP to achieve a widespread application of this planning instrument does not exist in either of the participating countries. For an assessment of the value and effectiveness of the enumerated examples of information media and means the following main criteria are used:

- expected impacts on energy conservation
- volume of the target group addressed with the aspect of information dissemination
- anticipated multiplier effect
- relevant costs required for the realization of the measures.

The assessment is summarized in table 4-1.

While discussing all those different efforts with respect to the results achieved, it has turned out so far that an evaluation of support and dissemination programs for energy conservation and their respective cost/benefit - yields has rarely ever been made. First conclusions from German experiences indicate, that a *combination of measures*, tailored to specific target groups, can be generally expected to be most effective.

A broad information campaign alone, for example, will have little effect. It should be accompanied by specific "on-the-spot" consulting, combined with financial programmes for measures which have proven to be economic, for instance, in order to surmount the implementation barrier of energy saving measures which generally have to compete with other possibilities of investment. The advisory process should preferably be organized by a public institution or an association. By this, in general, optimal public relation channels are accessible as well as support in organisation and management problems. Qualified and free-of-interest service which is normally best accepted by the target group is provided by this approach.

Measures/Institutions	Adressed Target Group	Multiplier Effect	Cost	Effects on Energy Conservation	Extent of Application in Participating country	
Information and Advisory Campaigns	high	high	small	small	Sweden Belgium France Germany	medium small medium high
Specific Consulting and Qualification Measures						
Energy Conservation Programmes	small	small	medium	high	Sweden Belgium France Germany	medium small medium high
Demonstration Projects	high	medium	high	small	Sweden Belgium France Germany	medium small small medium
information Systems	high	high	high	high	Sweden Belgium France Germany	medium small high high
Energy Agencies	small	medium	small	medium	Sweden Belgium France Germany	medium medium small high
Experience Exchange	small	medium	small	small	Sweden Belgium France Germany	medium small medium medium
Specific Institutions at the local level						
Energy Officer, Energy Coordination Conference	small	small	small	high	Sweden Belgium France Germany	medium medium medium high
Energy Councils	small	high	small	small	Sweden Belgium France Germany	medium small medium high

Table 4-1: Assessment of the efficiency of dissemination activities and the extent of their application within the participating countries

A very good example for such an integrated approach is given by the Swiss "Impulse program", by which outstanding and very useful teaching material for energy conservation in the building sector has been prepared in co-operation between universities, industries, consultants and the Swiss association of craftsmen. This program was not subject of our investigation, but it has turned out that within the Annex 22 participating countries no efforts of comparable quality have been carried out. It is this integrated approach of combined and specifically tailored measures, which can be expected to be adapted most efficiently by the target groups, while at the same time the percentage of free-riders is kept low. In contrary, isolated measures, such as some single, mono-oriented energy conservation programmes, may turn out to be of quite doubtful success in terms of their cost/benefit ratio. In order to arrive efficiently at the desired energy savings and environmental improvements and to support the implementation of the LEP-plan as the essential aim of LEP, a bundle of measures is necessary. These measures have to be elaborated and implemented on different levels (national, regional and local) and by different actors (administrations, communities and utilities).

Annex 22 - Energy Efficient Communities

PART V

RESULTS ON SUBTASK D: IMPLEMENTATION OF INTEGRATED PLANNING PROCEDURES

5.1 Structural differences in energy supply systems

Experiences of participating countries with the implementation of LEP-plans within their communities have shown, that there exist large differences according to quality and scope of LEP and according to the extent and success to which such plans are there realized. The question arises what the reason for these differences could be and which lessons one could learn from those countries which are more successful in that field.

Some of the differences can be explained by different natural boundary conditions such as the availability of hydropower or solar energy, but since also countries with rather similar such boundary conditions - as for example Sweden and France - show remarkable differences with respect to extent and success of LEP-applications and since the availability of technical resources is quite comparable in all of those countries, *structural and/or social barriers* have to be considered as dominating reason for such differences within the participating countries.

Table 5-1 shows characteristic informations demonstrating some principal agreements or differences between the participating countries with respect to their responsibility and organization of energy supply.

The scope of and the responsibility for LEP is in these countries strongly dependent from the role municipalities play in the supply of (electric and natural gas) energy. This is shown by the examples of Sweden and Germany: despite principal differences in the availability and philosophy of the national electricity supply sources - due to major differences in natural boundary conditions and different political attitudes towards nuclear energy within those two countries - the concept of local energy planning is both in Sweden and Germany very far developed. This results from the fact, that in both countries the cities have the principal responsibility for the supply with wire or pipe bounded energies rather than a regional or national energy supply company. The municipalities can deliver the task of supplying their territories with energy to either an own company or to a third party company for a limited time. By negotiating concession contracts the municipalities are able to take strong influence on the kind of energy supply and the general behaviour of the supply company. This ensures in many cases, that the local boundary conditions and potentials are being used in the best possible way.

From table 5-1 it can also be seen, that a strong monopoly of the national electricity supply does not principally prevent the application of LEP. However, it can cause a delay of a comprehensive introduction of LEP and will have influence on the scope and quality of LEP as well.

Whereas only in Sweden the establishment of municipal energy conceptions is required by law and therefore consequently a broad experience with that instrument was achieved there within quite a short period of time, in Germany the usefulness of LEP was recognized by the utilities only with significant delay despite the decentralized organisation of utilities there. A principal change in the attitude of utilities came only with the decision of the German federal anti-trust commission of 1985 concerning the regular expiration of concession contracts and the necessity for the utilities to periodically negotiate new contracts under quasi-market conditions with "their" municipalities. Because of this new situation the German regional utilities very often offered comprehensive cooperation contracts with communities wherein the assistance of the municipalities by the utilities in completing an LEP-conception and its implementation was agreed upon.

One effect of this new attitude is the proclaimed change of many German utilities to companies which offer energy services rather than the traditional supply of energy. Despite it is a long way from the propagation of a new strategy to its realization by the enterprise - particularly in such a conservative field as energy supply - by the twofold push of the threat of new regulation laws for the energy market (either at national level or at the level of the European Union) and the economic chances which are seen by the utilities in extending their business to really integrated energy services it can be expected that a rather efficient transformation of that branche will happen towards fully competitive business organizations in the market of energy services.

Table 5-1: Some characteristic data on energy industry structure and LEP-involvement within the participating countries (+ ... "yes"; - ... "no"; ? ... information not provided by participant)

	Belgiu m	France	German y	Italy	Swede n	Turke y
supply monopoly (at least > 90 % of the consumption) for a national electricity supply company	+	+	-	+	-	+
concession contracts	< 30 a	?	< 20 a	?	< 15 a	-
municipal concession charge for electricity supply to be paid by supply company to municipalities	+	?	+	?	+	-
use of fossil fuels for electricity production > 50 % of electric primary energy demand	-	-	+	+	-	+
obligation to take over surplus electricity from cogeneration into the public grid with fair prices	-	+ **)	+	+	+	-
legal requirement to take over electricity from regenerative energy sources into public grid with fair prices	-	?	+	+	+	-
LCP-programs by utilities	-	-	+	-	+	-
legal responsibility of communities for local gas/electricity supply	-	-	+	-	+	-
widespread experiences with LEP	(+)*)	(+)*)	+	-	+	-
joint LEP`s with utilities	-	-	+	-	+	-
quantified national energy plan in force	-	+	-	+	+	?

*) special institutions within those countries only

**) $< 100\ kW_{el}$

5.2 Essential preconditions for an increased role of LEP

Comparing the developments in Sweden and Germany with Belgium and France, in the latter it can be seen that the role of the utilities as a source of expertise and as a financial resource, which they have now in Sweden and Germany, is taken by state or regional organisations (e.g. Insitut Walloon in Belgium and ADEME in France). In both countries, despite remarkable single successes (for example a comprehensive building audit programme in France), it can be said that the original idea of LEP, namely making use of all possible potentials to improve the economic and ecologic quality of energy services at the local/municipal level with the aim to achieve a sustainable local energy supply system, seems to be realized less effectively by such central solutions. Their assistance is directed primarily towards municipal administrations to optimize the energy management of the communal buildings and to the building owners/companies to offer their advices on energy savings and the use of regenerative energies. But LEP has a much broader approach, adressing single buildings/users as well as whole settlements and searching for integrated solutions where all aspects of energy saving and energy conservation are considered simultaneously with optimized supply options, such as cogeneration or heat pumps and the possible use of local potentials of regenerative energies like biomass, sewage gas, solar energy or waste heat and waste incineration: LEP is the instrument to quantify the targets of national energy policy in the concrete local context. Such a broad approach must necessarily result into an equally broad spectrum of measures, covering a long period of time and numerous groups of decision makers being involved in the process of LEP-development and its implementation.

Superficially observed, the legal responsibility of a municipality to arrange the local energy supply is the necessary condition to achieve a sustainable energy supply structure by implementation of an LEP-plan. The experiences in Sweden and Germany show, however, that the most important condition is a close cooperation between the municipal administration and the utility which guarantees a consensual strategy for a local optimization by LEP, because the technical and organisational know how and the financial resources of the utility are generally indispensable as an essential input to the LEP-effort. This condition can be achieved also in countries with a rather centralized energy supply structure such as Turkey, Belgium, Italy and France, if it is possible to synchronize the interests of the utility and of the municipality, for example by long-term cooperation contracts which allow for mutual advantages of both the municipality and the utility.

In agreement with the present discussion of least-cost-planning ("LCP"-) programs of electric utilities in a number of European countries also models have been proposed by which the saving of electric energy rather than the selling of it is of economic interest for the utility. This is going into the same direction as described above: the utilities shall develop themselves from mere supplying kWh's to the offer of full energy services, including energy conservation or energy saving measures, which in an LCP-process are considered under the same conditions than and as real alternatives to supply-oriented investments. This will make the business more complicated, in particular with new types of contracts which will have to be developed and with the accompanying extension of the boundaries of the technical energy system which has to be optimized, but it will give the utility more market chances and in the same time more possibilities to behave in an ecologically sustainable manner.

There is no reason to assume that this solution is only possible within an energy supply structure which is already decentralized. Also large national supply companies should be able to follow this strategy, although perhaps with major changes of their corporate strategy. Even in the case of France this must not necessarily be in contradiction with the prevailing strategy of large nuclear power plants, since there still is, on the one hand, even in France a major potential of cogeneration niches - cogeneration is very often considered as the pivot of LEP-projects - and on the other hand, it is frequently possible to achieve many of the advantages of cogeneration with respect to energy saving alternatively also with a combination of other energy conservation measures which - dependent from the boundary conditions in specific cases - even could be more economic.

5.3 Cogeneration and the System of National Electricity Supply

The issue of combined heat and power (CHP) supply deserves a special discussion since its development (or the absence of it) is frequently the kick-off to initiatives to start local energy planning projects. CHP is, for example, an important technology to supply low temperature heating energy in Germany, because of its manifold advantages such as energy saving (compared to separated generation of electricity and heat), use of difficult energy carriers (coal, waste heat, refuse), reduction of pollutant immissions in the cities and, last not least, comfort. In a very profound German investigation [5-1] it was estimated that the economic supply potential of district heating based on CHP/cogeneration in (West-) Germany could be increased to 28 % of the demand for low temperature heat. At present, only 9 % of this demand are covered by district heating from CHP, with very low increase rates. This low figure is due to the fact that, despite its advantages, district heating is in many cases only able to compete with alternatives under specifically favourable conditions or when it is directly supported by energy policy, setting special frame conditions such as enforced connection to district heat, special energy taxes, advantageous take-over regulations for electricity, financial starting aids etc. Denmark is an example for such a (successful) policy, which however, is only reasonable as long as electricity from cogeneration does not replace other ecologically desirable sources such as hydro-electricity (or, eventually, also nuclear energy).

Therefore, the reasonable potential for CHP/cogeneration will be strongly dependent from the general energy supply boundary conditions of a country as a whole. It is this question where there is a direct interaction between LEP and national energy policy. But despite the fact that in France more than 85 % of the electricity is generated by nuclear or hydro power plants, also in this country district heating supplies today 6,5 % of the low temperature demand, even though the heat supply here is rather based on waste heat, biomass and refuse incineration than on cogeneration. It can be assumed that there still is a major potential of district heating in both countries, either using direct CHP (as in Germany) or, for example, large electric heat pumps, which can be considered as "indirect CHP", as in France. In both cases, however, the goal must be to use all available sources of primary energy and to make the maximal possible use of the end energy input, in other words to optimize the energy system as a whole.

Since at present 10 % of low-temperature heating demand are covered in Germany by (direct heating) electricity, generated in roughly equal amounts by nuclear and lignite, and 36 % in France (by nuclear and hydro energy), the question still remains open which one of these two supply systems is to be considered "better" under ecologic criteria. The answer will depend also from the individual assessment of nuclear energy. However, apart from concerns with respect to the risks of nuclear energy, it must not be forgotten that renunciation of nuclear energy will be equivalent of wasting a huge energy potential which then has to be covered by alternate sources. Under global ecologic aspects and in the long term, however, it is unimportant if some countries abandone nuclear energy if others will make use of it (and in the same time making use of the economic advantages of this energy carrier).

5.4 Conclusions

It was generally agreed by the Annex 22 experts that there are indeed energy saving potentials in the local energy supply in all participating countries which could be exploited more effectively if there was an integrated LEP-conception and concerted efforts at the local level to implement it. It was also agreed that the management of the municipalities should in general be the main actor in developing LEP, but, independent from the legal structure of the national (electric) energy supply, that it was important to involve the utility being responsible for the local supply into that process of finding an optimized use of energy. The municipality shall play an active role in

- inclusion of all relevant groups
- formulating a steady urban energy policy which is oriented to the long-term objectives of national energy policy and with clear priorities and quantified goals at the local level
- exerting influence, if possible, to the actual boundary conditions to support those goals, such as adaptation to general urban planning and declaration of district heating priority areas
- formulating an autonomous program of projects and other measures to minimize the energy consumption of municipal buildings and establishing a continous energy management for them
- establishing a long-term municipal energy plan in cooperation with the existing utility as a basis of an integrated energy policy which is oriented to economic and ecologic goals as well
- creating a position or institution which is responsible for the control of the implementation of this conception.

The inclusion of the local (or regional) energy suppliers was considered to be crucial for such a program, since only then sufficient technical, financial and data resources for such a program would be available. To avoid possible goal conflicts, incentives should be negotiated with the utility such as long-term contracts and extension of its energy services, accompanied by defined obligations of the utility to support the development and implementation of the energy conception. With such a strategy, which however presupposes the principal willingness of the utility to develop itself towards an energy service company rather than a traditional supplier of kilowatthours, legal and structural differences of the national energy structure of the participating countries could be balanced out at the level of municipal energy demand and supply optimization with the result that LEP could be considered as an equally successful instrument towards a sustainable energy supply policy regardless to the national structure of energy legislation.

Finally, the example of the city of Mannheim should be mentioned, where a municipal energy policy was already introduced as early as in the late fifties, when the erection of a large hard coal CHP-plant was planned at the premises of the city and it was decided to construct a large district heating network to make maximal use of the cogeneration potential. This decision was due to economic and ecologic reasons as well, since by cheap low temperature heat from cogeneration plants, compared to the quite high levels of electricity and fuel oil prices at that time, the substitution of individual coal ovens could be expected by that plan. Such ovens then still had a major share of the heating supply and were responsible for much of the atmospheric pollution in Mannheim in that time.

Whereas the local utility had the sole responsibility for that project until the seventies, it was than decided to support the utility by a municipal energy policy which had clear goals and priorities to establish an integrated plan where the former support of district heating was substituted by a well balanced strategy of gas and district heating extension and support of demand side energy saving measures, accompanied by a regular inclusion of the investment programs for gas and district heating into every actualization of city planning.

The result of this long-term policy can be seen in fig. 5-1. Of particular interest is there the considerable time which is needed to see measurable changes of the situation and the fact, that only after starting a really integrated energy policy including efforts to save energy a real "phase change" in energy consumption patterns could be achieved.

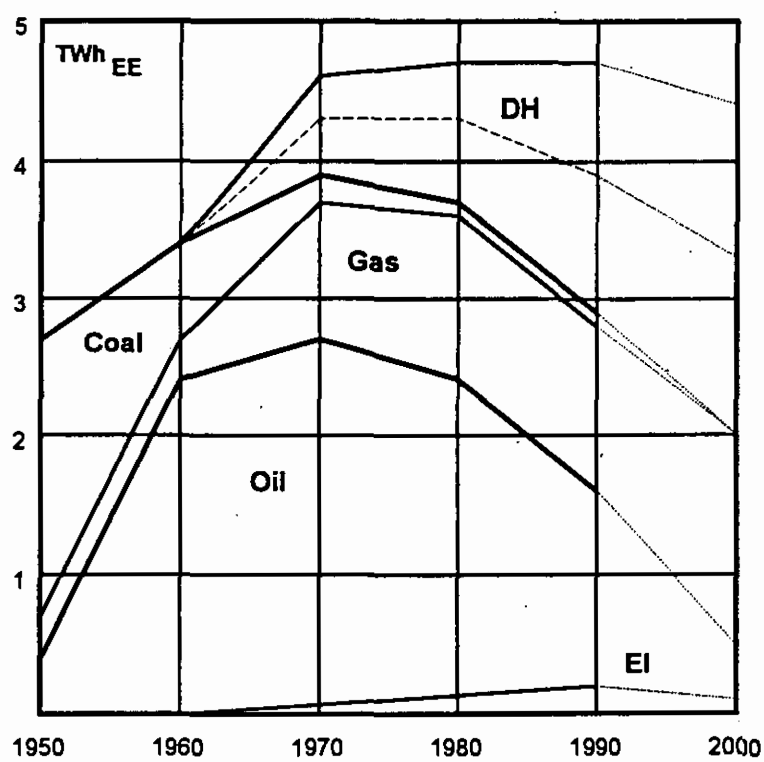

Fig 5-1: End-energy demand for space heating and hot-water supply 1950 - 2000 in Mannheim (dotted line in district heating (DH-) sector corresponds to an average of β_{DH} = 0,65 MWh_{PE}/MWh_{th} for the supply of CHP-heat). El ... electric direct heating (night storage).

Bibliography

The following references represent a subset of important bibliographic sources which have been used by the authors of the Annex 22 reports and which have been considered to be of particular relevance. This is, of course, only due to their private opinions.

Part I:

[I-1] Johnsson, J.; O. Björkquist, C.-O. Wene: Integrated Energy Emissions Control Planning in the Community of Uppsala. Int. J. of Energy Research **16** (1992) 173-188

Part II:

[II-0] Fishbone, L. G.; G. Giesen, G.A. Goldstein, H.A. Hymen: User's Guide for MARKAL (BNL/KFA Version 2.0), BNL 51701, Brookhaven National Laboratory, Upton, New York (1983)

[II-1] Wene, C.-O.; B. Rydèn: A Comprehensive Energy Model in the Municipal Energy Planning Process. Eur. J. of Operational Research **33** (1988) 212-222

[II-2] Henning, D.; M. Söderström and B. G.Karlsson: Supply and Demand Side Management in Municipal Energy Systems Optimisation. Proceedings of the 1992 European Simulation Multi-conference, York, UK (1992) 631, SCS ISBN 1-5655-013-7

[II-3] Wene, C.-O.: Using a Comprehensive Model for Community Energy Planning, in Lundqvist, Mattsson and Mattson, eds; Spatial Energy Analysis, Gower, Aldershot (1989) 271

[II-4] Walbeck, M.; H.-J. Wagner and D. Martinsen:Energie und Umwelt als Optimierungsaufgabe - das MARNES-Modell. Springer Verlag Berlin-Heidelberg-New York-London-Paris-Tokio (1988)

[II-5] Pillmann, W. und A. Jaeschke (eds.): Informatik im Umweltschutz. Proceedings of the 5th Symposion on "Informatik im Umweltschutz", Vienna, September 1990. In Informatik-Fachberichte **256** (1990), Springer Verlag Berlin-Heidelberg-New York-London-Paris-Tokio.

[II-6] Messner, S. and Strubegger M.; The Energy Model MESSAGE III/1.0, TEMAPLAN-Group, Vienna (1991)

[II-7] Goldstein, G. A. and L.D. Hamilton; PC-MARKAL and the MARKAL User Support System (MUSS), User's Guide, BNL 46319, Brookhaven National Laboratory, Upton, New York (1983)

[II-8] Schlenzig, C.; P. Schaumann and G. Schmid: A Standardized Relational Data-base for Process Engineering Oriented Network Systems Analysis Models, Institut für Energiewirtschaft und rationelle Energieanwendung (IER), University of Stuttgart (1994)

Part III:

[III-1] Garriba, S.F. and B. L. Long (eds.): Life-Cycle Analysis of Energy Systems. Proceedings of an experts workshop held 21st - 22nd May, 1992 in Paris. OECD Publications Service, Paris (1992).

[III-2] Sassone, P. G. and W. A. Schaffer: Cost-Benefit Analysis. A Handbook. Elsevier, New York-San Francisco-London (1978)

[III-3] Fenhann, J.; H. Larsen et al. (eds): Environmental Models: Emissions and Consequences. Proceedings of an International Conference at Risoe (DK), 22nd - 25th May, 1989. Elsevier, Amsterdam (1990)

[III-4] Fritsche, U.; L. Rausch and K.-H. Simon: Umweltwirkungsanalyse von Energiesystemen: Gesamt-Emissionsmodell Integrierter Systeme (GEMIS). (Analysis of Ecological Effects of Energy Systems). A study carried out under commission of Hessisches Ministerium für Wirtschaft und Technik, Wiesbaden (1990).

[III-5] Hohmayer, O.: Soziale Kosten des Energieverbrauchs (Societal Costs of Energy Consumption). Proceedings of the Conference "Soziale Kosten der Energienutzung", VDI, Düsseldorf (1991)

[III-6] Roth, U; H.-P. Winkens et al.:Wechselwirkungen zwischen der Siedlungsstruktur und Wärmeversorgungssystemen (Interactions between Settlement Structures and Heat-supply Systems). A study carried out under commission of Bundesministerium für Raumordnung, Bauwesen und Städtebau, Bonn (1980)

[III-7] Bechmann, A.: Die Nutzwertanalyse. In Storm, P. C. und Th. Bunge: Handbuch der Umweltverträglichkeitsprüfung. Springer Verlag Berlin-Heidelberg-New York-London-Paris-Tokio (1988)

[III-8] Deutscher Bundestag, Ref. Öffentlichkeitsarbeit (ed.): Schutz der Erde. Endbericht der Enquete-Kommission des 11. deutschen Bundestages "Vorsorge zum Schutz der Atmosphäre" (12 Volumes). Bonn (1993)

[III-9] Bossel, H.: Umweltwissen: Daten, Fakten, Zusammenhänge. Springer Verlag Berlin-Heidelberg-New York-London-Paris-Tokio (1990)

[III-10] Baumbach, G.: Luftreinhaltung: Entstehung, Ausbreitung und Wirkung von Luftverunreinigungen. Springer Verlag Berlin - Heidelberg - New York - London - Paris - Tokio (1990)

[III-11] Dobbins, R. A.: Atmospheric Motion and Air Pollution. John Wiley & Sons, Inc., (1979)

[III-12] Pasquill, F. and F. B. Smith: Atmospheric Diffusion. 3rd edition by Ellis Horwood Ltd., (1983).

[III-13] Witte, H.: Die Integration monetärer und nicht monetärer Bewertungen. Volkswirtschaftliche Schriften, Heft 388 (1989); Duncker & Humblot Verlag, Berlin

[III-14] Leonhardt, W.; A. Klopffleisch and G. Jochum (eds.): Kommunales Energie-Handbuch. Verlag C. F. Müller GmbH, Karlsruhe (1989)

[III-15] Jank, R. and G. Korb: Nutzungsmöglichkeiten von Blockheizkraftwerken - ein komplexes Problem. Energie-Spektrum 9 (1993) 57

[III-16] NUTEK/Naturvardsverket: Miljöanpassad lokal energiplanering; ISBN 91-38-12669-9, Stockholm (1992)

Part IV:

[IV-1] Bundesforschungsanstalt für Landeskunde und Raumordnung (BfLR), ed.: 10 Years of Local Energy Planning. Series of Publications on "Informations to Regional Development", Vol. 6-7, Bonn (1990)

[IV-2] Hanitsch, R. and D. Winje: Development of an Education Programme for Energy Advisors. Internal report of the Technical University of Berlin (1984)

[IV-3) Technical University of Darmstadt (ed.): Development of a Lecture for Architects on "Energy in Buildings and Communities". Series on Studies of the Department "Communities", Vol. 33, Darmstadt (1988).

Part V:

[V-1] Matthöfer, H. (ed.): Gesamtstudie über die Möglichkeiten der Fernwärmeversorgung aus Heizkraftwerken in der Bundesrepublik Deutschland (Supply-potential of District Heating by Combined Heat and Power Plants in the Federal Republic of Germany). A study carried out under commission of Bundesministerium für Forschung und Technologie, Bonn (1977)