

**INTERNATIONAL ENERGY AGENCY**  
**ENERGY CONSERVATION IN BUILDINGS AND COMMUNITY**  
**SYSTEMS**  
**PROGRAMME**

**ANNEX 33**

**Advanced Local Energy Planning**  
**(ALEP)**

**A Guidebook**

**Participating Countries:**

**Germany**  
**Italy**  
**Sweden**  
**The Netherlands**

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## 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 information exchange towards achieving the objective of a sustainable energy supply system. This IEA-work is realized by undertaking a series of "Annexes", which are established to coalesce the knowledge gained through research and development performed by participating countries on a particular topic.

Since 1977, more than 40 Annexes have been started by all, or a subset of the 18 countries which have undersigned that Implementing Agreement. Almost all of these Annexes are devoted to the first part of the agreement's title, Energy Conservation in Buildings. Much progress there has been made in this field since 1977, which is also documented in many of the final reports of these Annexes. In contrast to this „microscopic“ view of the municipality, the municipal energy supply and demand system as a whole was hardly ever the subject of R&D – with some exceptions. Whereas the analysis of the energy demand of buildings requires research in buildings physics, as well as methodological research, such as the development of dynamic simulation models or data bases for life-cycle analyses, „community systems“ analysis requires the consideration of the „macroscopic“ aspects of a municipality, including the municipal energy supply infrastructure, along with waste incineration. Thus, the „systems“ aspect is much more important in this case.

Energy supply of communities and the potential to improve energy efficiencies to tap into new energy resources and to reduce energy demands has gained increasing interest from municipal administrations in recent years. Environmental issues shifted more into the center of interest during the eighties, and this was later enforced by increased concern about the effects of green house gases on the atmosphere. Due to these developments, major efforts have been undertaken in some countries to develop and apply the instrument of *Local Energy Planning* (LEP) as a tool to make integrated planning of entire community systems possible. In fact, LEP was in recent years increasingly considered as a kind of "meta-planning" instrument, which integrates the knowledge and experiences of various planning disciplines to enable the urban administration to simultaneously optimize the entire municipal organisation under a variety of given goals.

The potential of LEP to improve the urban environmental situation is by far not exhausted. The reduction potentials of municipal energy consumption and the actual reductions attained still diverge widely (in most cases). Often this is caused by insufficient application of LEP or the absence of LEP at all, such as when the responsibility for energy conservation is left to the owners of individual buildings and the local utility. Moreover, due to quite different legal requirements/regulations, major differences in the development and application of LEP in different IEA-countries have been observed, as reported in Annex 22, *Energy Efficient Communities*, which was carried out between 1991 and 1993 in six IEA countries (Belgium, France, Germany, Italy, Sweden, Turkey).

One result of this Annex 22 was that continuous application of LEP in countries like Sweden or Germany gave planners in municipal administrations, utilities and private consultants an overall familiarity with the means and tools of LEP. With increasing use of personal computers, planners began to use a growing number of special tools for economic or environmental calculations, geographical or customer information systems and data bases. Many of these were described in Annex 22. However, one important conclusion of Annex 22 was that almost no use of *systems optimization models*, developed and available in the field of systems analysis, were found in the application of LEP, with the exception of applications at Chalmers University of Göteborg and in Denmark. The reason for this was the absence of any information on the existence of such models amongst planners. In the final report of Annex 22 it was stated that „whereas partial solutions and tools have been developed and documented quite broadly 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.“

Recognizing this gap between the availability of scientific solutions and their use in practice, four countries decided to carry out practical applications of the Linear Programming Optimization Model *MARKAL* with concrete case studies, to exchange experiences on the use of the model and its outcome, and to provide a „Guidebook on Advanced Local Energy Planning“ (ALEP). The four countries (Germany, Italy, Sweden and The Netherlands) then began Annex 33 „*Advanced Local Energy Planning*“, focusing both on the application of *MARKAL* in LEP case studies, as well as on the evaluation of modern methods of „process management“ in LEP projects, which are usually used in complex decision-making processes. One product of this Annex is the „Guidebook on Advanced Local Energy Planning“, which is presented here.

Many colleagues have contributed to this work, which is the product of a continuous co-operation throughout the course of Annex 33. The four participating countries established a guidebook working group to discuss all material. The main authors of the specific chapters are:

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I gratefully acknowledge the cooperation of these individuals. In addition, I want to emphasize the helpful cooperation of all participating countries, represented by Prof. Vincenzo Cuomo, Prof. Maria Macchiato, Monica Salvia, Lucia Mangiamele and Carmelina Cosmi, from INFN – National Institute for Physics of Matter; IMAAA-CNR – Institute of Advanced Methodologies for Environmental Analysis – National Research Council of Italy; DIFA – Department of Environmental Engineering and Physics, University of Basilicata; Prof. Evasio Lavagno, Chiara Cordegone, D. Scaramuccia, Angelo Venezia and Giuliano Zoppo, from LAME – Energy Department, Politecnico di Torino; Bo Rydén and Håkan Sköldb-berg from Profu AB, Mölndal; Daniel Stridsman and David Weiner from Chalmers University, Dept. for Energy Systems Technology, Göteborg; Robert van Driel, Sander Willemsen, Frank Spruit and Wilbert Grevers, G3 Advies BV, Beusichem, The Netherlands; Thomas Kilhau, Mannheimer Energie AG; Wolfgang Krüger, Thomas Wilde and Stephan Rath-Nagel, IC Consult, Aachen; and Thomas Steidle and Christoph Schlenzig, University of Stuttgart, Institute for Energy Economics and Rational Utilization of Energy, who have carried out the different tasks of Annex 33 and contributed to the edition of this guidebook. I also appreciate our discussions with the ETSAP group, in particular with Tom Kram from ECN Policy Studies Group in Petten, The Netherlands and Gary Goldstein (ERG, Washington). Our text was revised by Karl Stellrecht, Saratoga, California, who polished our English and managed to provide a „readable“ publication.

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 are to be achieved in an efficient way.

Karlsruhe, June 2000

Reinhard Jank

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## **INTERNATIONAL ENERGY AGENCY**

In order to strengthen cooperation in the vital area of energy policy, an Agreement on an International Energy Programme was formulated among a number of industrialised countries in November 1974. The International Energy Agency (IEA) was established as an autonomous body within the Organisation for Economic Cooperation and Development (OECD) to administer that agreement. Twenty-two countries are currently members of the IEA, with the Commission of the European Communities participating under a special arrangement.

As one element of the International Energy Programme, the Participants undertake cooperative activities in energy research, development and demonstration. A number of new and improved energy technologies which have the potential of making significant contributions to our energy needs were identified for collaborative efforts. The IEA Committee on Energy Research and Development (CRO), assisted by a small Secretariat staff, coordinates the energy research, development and demonstration programme.

### **Energy Conservation in Buildings and Community Systems**

As one element of the Energy Programme, the IEA encourages research and development in a number of areas related to energy. In one of these areas, energy conservation in buildings, the IEA is encouraging various exercises to predict more accurately the energy use of buildings, including comparison of existing computer programmes, building monitoring, comparison of calculation methods, as well as air quality and inhabitant behaviour studies.

### **The Executive Committee**

Overall control of the R&D programme "Energy Conservation in Buildings and Community Systems" is maintained by an Executive Committee, which not only monitors existing projects but identifies new areas where collaborative effort may be beneficial. The Executive Committee ensures all projects fit into a predetermined strategy without unnecessary overlap or duplication but with effective liaison and communication.

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# ALEP - Advanced Local Energy Planning - a Guidebook -

## Chapter 1 Introduction

### 1.1 Sustainable Development

During the last decade of this century, industrialized countries have increasingly recognized that their societies must develop a „*culture of sustainability*“; if they do not want to irresponsibly and irreversibly damage the ability of future generations to satisfy their own needs. This issue was the subject of a number of recent UN conferences, culminating in the signing of „Agenda 21“ during the UN Conference on Environment and Development (Rio de Janeiro, 1992).

This agreement is the most concrete international declaration so far on the necessity of change towards a sustainable development. According to chapter 28 of Agenda 21, „communities within the signing countries shall develop a guideline for a sustainable development within their area of competence accompanied by a consultation process with their citizens“ („**Local Agenda 21**“). Since the quantity and patterns of energy consumption are one of the most important reasons for a „lack of sustainability“, and since a large portion of overall energy consumption takes place within the local community, the responsibility to develop local energy systems that are increasingly „sustainable“ rests to a large extent with local decision makers – amongst them, primarily, the local administration.

### 1.2 Local Energy Planning (LEP)

„Sustainability“ has many different facets, such as ecologic and economic development, reduction of greenhouse gases, responsible use of natural resources, social equity or the so called „north-south-compensation“. At the *urban level*, however, the consumption of energy is, along with traffic and land use, the most important issue in this context. The decisive instrument for urban energy policy is „*Local Energy Planning*“ (LEP), an approach to support the development of a local energy strategy by means of rational planning and management principles.

LEP is based on methods and experiences developed after the first energy crisis in 1973, with the purpose of influencing the local energy system according to the specific goals of (local) energy policy. The prevailing objectives were then focused on the reduction of oil consumption, improved energy efficiency by the use of, for example, cogeneration technologies, and, during the eighties, reduction of pollutant emissions. Today we are observing a shift to local sustainability and a strategic optimization of the energy system under deregulated market conditions. Thus, LEP is for many reasons an important task for both the municipal administration and the local utilities.

In the process of carrying out LEP projects in some countries like Sweden or Germany during the last two decades, it was recognized that partial solutions for individual projects and a long-term strategy for the whole municipality have to be optimized *simultaneously*, and that a variety of different decision-makers and interest groups have to be involved in the decision making and implementation process. Therefore, LEP is a long-term iterative process, rather than a short-term planning task. However, only in recent years have features of a „consistent methodology“ emerged in response to the requirements of such an „integrated“ or „holistic“ approach. Consistent system optimization is a prerequisite for achieving the goal of sustainability at the urban level, since it allows for adequate consideration of the many interactions between the different components of the local energy system.

As a consequence, LEP is quite different from the traditional engineering approach. Although it makes use of methods and tools of traditional technical planning (from an engineers viewpoint), it also has to deal with a more „societal“ approach by including aspects of motivation and communication, group dynamics, conflict resolution and project management. In addition, the aspect of „institutional learning“

as a means of developing consensual solutions is of special importance for the successful implementation of the LEP results.

The term „*integrated solutions*“ means that a combination of different measures shall be developed to realize a strategy that will achieve the given goals in the best possible way. Besides the traditional planning of individual measures, it is necessary to consider the municipal energy system as a whole, including possible interactions and interdependencies of its components: a comprehensive view of the overall „complex“ system and its long-term behavior under different assumptions and influences.

With this requirement we enter the field of systems analysis, which so far has not generally been applied in the context of LEP, despite its already long scientific tradition in other disciplines. In the final report of IEA-Annex 22, „Energy Efficient Communities“ (FZ Jülich, 1992), it was stated that this was a major weakness of LEP, since the potential of systems analysis and operations research could provide a significant advance in the design process of complex technical systems. Today, there are a number of „Energy System Models“ available which have been developed for the planning of large energy systems on national or regional levels. In Sweden and a few other countries there have been initial attempts to apply such models within LEP-projects at the municipal level. These experiences have proven the potential benefits, but also the necessity of further development and propagation of the existing knowledge of the systems analysis approach among traditional planners.

In addition, technological data bases, such as the German IKARUS data base, have been recently developed. Such data bases would realize their full benefit in combination with suitable computer models. Moreover, computer based marketing and infrastructure planning, using for example utility customer support systems or geographical information systems (GIS), is today as normal to the planner as the presentation of results by appropriate presentation tools. Therefore, the time has now come to make proper use of all these tools to improve and accelerate the planning process, and create a sound basis for LEP by using the comprehensive and detailed energy models which are provided today by modern systems analysis.

### **1.3 Advanced Local Energy Planning (ALEP)**

The application of methods and models of systems analysis enables the planner to simulate and optimize the behaviour of systems as a whole, rather than only optimizing its individual components. As a much better understanding of the results of specific planning decisions is attained, this facilitates the involvement of affected local decision makers. At the same time this is a prerequisite for successful implementation of the planning results.

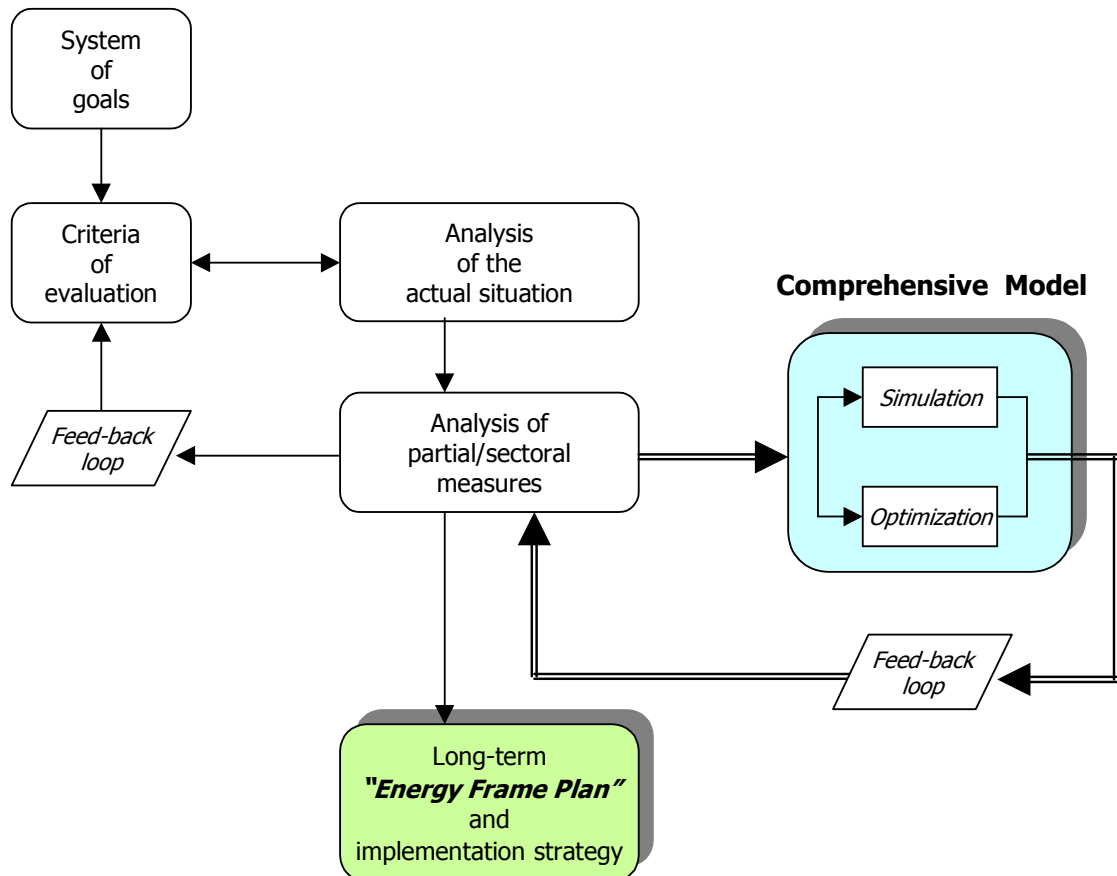
It is this combination of the use of energy models for comprehensive and detailed energy planning, participative involvement of affected groups and modern methods of project management, which we understand as „**Advanced Local Energy Planning**“ („**ALEP**“). Such an ambitious approach will generally be necessary to carry out complex projects in a complex environment, and to find consensual solutions which have a realistic chance of implementation.

ALEP is applicable to a municipality of medium or large size with a complex energy supply system (such as a combination of centralized and decentralized components, a variety of different energy carriers, cogeneration potentials at different scales, waste incineration, potential for renewable energies, and major retrofit potentials in the existing buildings stock). For such a complex system, a long term strategy for the energy supply should be developed by either the municipal administration or the local/regional utility (or both), which is even more important under deregulated market conditions. The strategy is optimised to a system of different goals that are generally a subset of the overall goal of sustainability.

ALEP, therefore, is an extension of the traditional LEP approach, as shown in fig. 1-1. It is based on tools and methods of systems analysis for the technical planning process of the (complex) local energy system to develop a consistent „comprehensive energy plan“. The results serve as the basis for a group-dynamic approach to achieve consensual solutions among the different actors who are involved in the implementation of the comprehensive strategic energy plan.

To summarize, ALEP is more than the traditional LEP because it

- makes use of comprehensive models of systems analysis which are capable of simulating (and optimizing) the whole system, rather than only considering its components
- provides a long-term strategic energy plan which satisfies different sustainability goals
- involves all affected groups and decision makers to maximize the chance of realization
- employs principles of modern project management and group dynamics
- is a continuous process rather than a project with a defined end.



**Fig. 1-1:** Traditional LEP and ALEP approach (double line) using support of existing software tools and a „comprehensive model“ (of the entire local energy system)

In fig. 1-1, the traditional LEP approach, as shown by the left part of the graph, is supplemented by the use of a comprehensive energy systems model capable of simulating and optimizing the entire local energy system (right part of the graph, double line). Partial or sectoral measures are still made with traditional tools, using input data from the comprehensive model in an iterative process. Once the comprehensive model for the local energy system is established, consistent model runs with different scenarios can be carried out very easily.

#### **1.4 The ALEP-Guidebook**

This guidebook is the result of the experiences compiled from the case studies of IEA Annex 33: Advanced Local Energy Planning. It is intended as a guidebook on advanced energy planning, as defined above, and is designed for readers with a background in traditional energy planning, such as the optimal economic design of a cogeneration plant or the calculation of the heating demand of a building. The guidebook focuses on those aspects of LEP, which have been characterized here with the attribute „advanced“. After reading this guidebook, the reader should be able to understand the potential benefits of comprehensive systems analysis tools for strategic planning. In addition, the reader will receive an overview of the principles of „interaction management“ for complex projects, in order to achieve maximum consensus among the affected groups and decision makers, which is the primary requirement for the implementation of the planning results.

The following two chapters in the guidebook describe the principles and logical sequence of individual steps in an ALEP project. In the fourth chapter, the use of „models“, comprehensive and detailed, is discussed and concrete examples of their application are provided. In Chapter 5, the case studies which have been carried out within the participating countries in the course of this IEA Annex 33 project are presented in a condensed form. In particular the „advanced“ aspects of ALEP within these case studies are stressed. Finally, a short description of the models and computer tools that have been used in the case studies is provided in the Appendix to present to the reader some examples of existing tools and their practical use.

## Chapter 2 Basic Principles of Advanced Local Energy Planning

### 2.1 Introduction

The purpose of ALEP is to find a path towards an economic and ecological sustainable local energy system while also taking into account limited financial and human resources as well as incomplete insight into the future development of economic, technical and social conditions. This task falls under the responsibility of either the local/regional administration or the local utility.

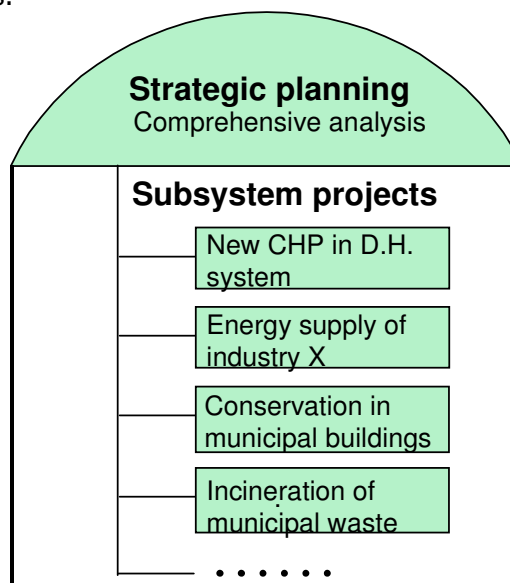
The planning approach outlined in this guidebook to achieve these goals follows four basic principles:

- (1) Combine integrated long term strategic planning of the whole energy system (= comprehensive analysis) with detailed planning of concrete subsystem projects
- (2) Utilize system analysis methods and computerized energy system models
- (3) Involve all relevant interest groups in the planning process
- (4) Set-up a plan for continuous improvement and monitoring.

### 2.2 Combining integrated long term strategic planning with detailed planning of concrete sub-system projects

Energy systems in agglomerated urban regions consist of highly interconnected subsystems. Planning of this energy system comprises two levels:

- (1) Comprehensive analysis of the overall local or regional energy system for long term strategic planning.
- (2) Analysis and optimization of subsystems like the heating system of individual buildings, insular district heating systems or the energy supply of production plants.



The traditional approach is to study and plan each subsystem of an energy system individually (and combine them, eventually, into an overall energy plan). In general, this will lead to a sub-optimal system, because it neglects numerous interdependencies which may exist between the system components. To understand the advantage of a systems approach and the need for long term strategic planning, it is important to recall some facts about energy systems:

- Planning and operation of the energy system is generally carried out by different actors with sometimes conflicting goals. Local interest groups may have different opinions concerning the "optimal" energy supply system.
- A local energy system consists of long-lived infrastructures (planning horizon of 10 to 30, and eventually up to 50 years), which does not lend itself to quick modification or response. Changes of the energy system generally establish long lasting facts. Thus long term developments of frame work conditions (energy prices, economic growth, socio-economic changes etc.) must be adequately considered in the planning process.
- There are many different options for technologies and energy carriers available to supply the energy demands and services.



- The energy system contains many interdependent subsystems (changes to one subsystem may have effects on other subsystems).
- Measures on the supply-side compete with conservation measures on the demand side. Capital and human resources are scarce and must be directed towards the most effective measures.
- The economic success of investments must be evaluated in the context of uncertain socio-economic factors, like general economic development, energy prices, taxes and legislation.
- Energy system planning interacts with strategic planning in other fields. Planning tasks like environmental planning, urban planning or transportation system planning may affect the energy system.
- Changes in the energy system affect residents, local industries and the environment, and thus have a large impact on the urban environment.
- The exploitation of local renewable resources (biomass, wind, solar energy, hydro energy, waste heat etc.) is often expensive and needs stable, long term demand and commitment to justify the investment.

The ALEP approach comprehensively analyses the whole energy system of a region (e. g. municipality) and then explores and analyses different possible strategies. However, ALEP should not be a theoretical study, but should be oriented towards the development of specific energy projects within the community. Detailed subsystem analysis on the other hand only deals with the problems on a small scale. Here, there is a risk of losing understanding of the overall picture. Therefore, existing local energy projects like boiler retrofits, installation of co-generation plants, local district heating projects, energy conservation measures for individual buildings, planning of incineration plants, demonstration projects for renewables, etc. should be considered from a more comprehensive point of view. Ongoing activities like energy management of municipal buildings, urban planning or waste management, should also be integrated. All these individual activities should be considered simultaneously to provide a comprehensive and consistent long-term energy plan that analyses the behavior of the entire energy system.

The goal of the comprehensive analysis is to reveal the strengths and weaknesses of the present energy system and to identify needs, threats and opportunities for the future. ALEP should help to determine the most effective measures to achieve a given set of goals, while also taking long term projections of technical and socio-economic (frame conditions) into account. Individual subsystems are then planned or selected for further analysis depending on their priority and improvement potential in regard to the long term strategy.

Comprehensive and detailed subsystem analysis complement each other. As guiding principles for balancing comprehensive vs. subsystem analysis the following rules of thumb should be applied:

- Do not let the comprehensive analysis alone determine the choice of detailed projects for investigation, but also take the existing situation in the area into account.
- Prioritize among existing activities. Do not be too ambitious by creating too many new projects.
- Co-operate with those who are already engaged in specific projects. Integrate existing projects with the same planning „philosophy„. "Proper coordination is economical and efficient".

The following example shows the interaction between comprehensive and detailed studies.

### ***The balance between energy supply and energy conservation***

*The balance between heating energy supply and energy conservation can be studied both in subsystem analysis for „typical„ buildings, and as one issue in the comprehensive analysis. It is valuable to exchange information between these studies. Typical information which could flow from the comprehensive to the detailed study is the future mix of energy supply alternatives for specific user sectors (single family houses, multi-family houses etc.), future energy prices (gas price, district heating price etc.), optimal energy conservation levels as a function of heating system and building type, etc.*

*Information could also flow in the other direction, from the detailed to the comprehensive analysis. If the detailed study of „typical„ buildings indicates that the optimal energy conservation levels are robust with respect to certain assumptions regarding important parameters, such as energy prices, it may be favorable to simply use the calculated energy conservation levels from the detailed, study and reduce the net energy demands in the comprehensive analysis accordingly. The analysis of optimized conservation levels could thereby be left out of the comprehensive analysis. This simplifies the comprehensive analysis considerably and could facilitate more detailed investigation of other aspects of the total system.*

*Source: Local Energy Planning in Goteborg, Sweden*

### **2.3 Utilisation of systems analysis methods and computerized energy system models**

It is quite difficult to consider all possibilities and facts and develop a long term strategy for a complex energy system. Experiences with traditional LEP have shown that a systems analysis approach to the planning process, supported by computerized energy system models, is necessary in order to describe the entire energy system adequately and find the best strategy.

An energy system model is a simplified mathematical representation of the energy flows and costs of an actual (technical) energy system. Such energy system models were first developed some 20 years ago to describe national energy systems. Today some of these models may be run on personal computers and can be applied to local or regional energy systems (refer to chapter 4.7 for an explanation of models).

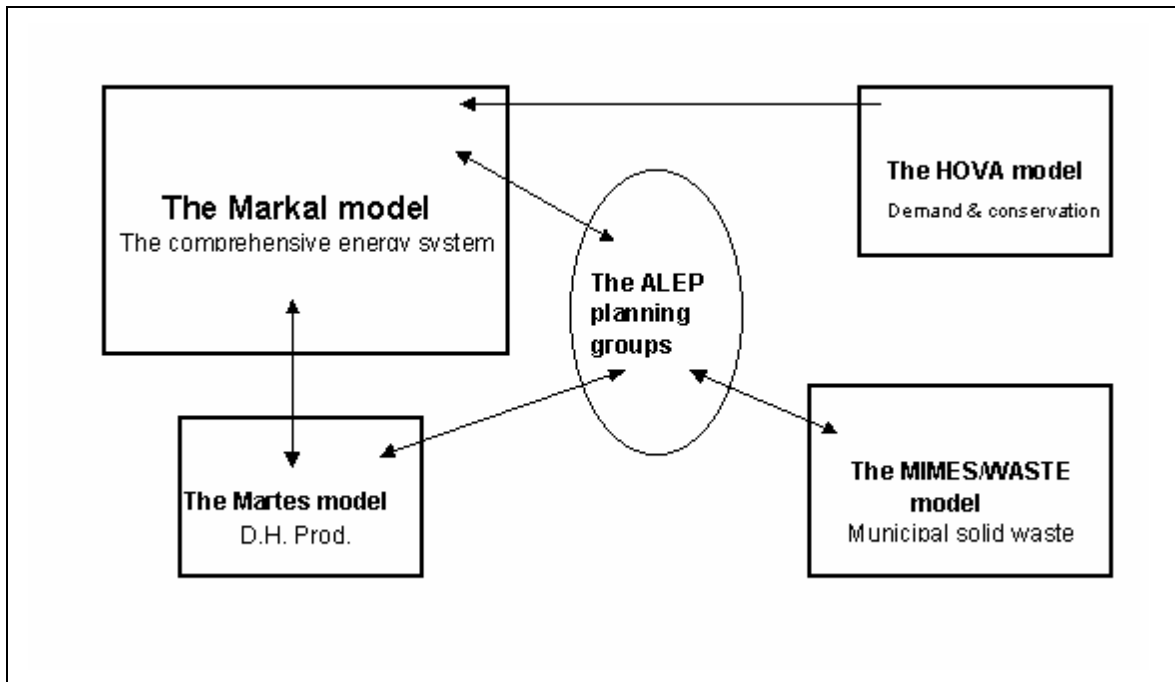
The energy system model serves several different purposes in the ALEP process:

- it provides a common structure and "language" for the discussions
- it is neutral in the sense that the methods of calculation and the input data and assumptions are transparent and accessible to all parties involved
- it is interactive and supports communication since new ideas and questions can be evaluated very quickly once the model is established
- it can manage the large amounts of data necessary for a regionally dis-aggregated and complex analysis.

The interaction between comprehensive studies and subsystem analyses must also be accompanied by the use of models (see Figure 1.2). In the ALEP case studies presented in this Guidebook (chapter 5) the energy system model MARKAL was used for the comprehensive analysis. Some of the subsystem studies, coupled with the comprehensive analysis in the case studies, also included models for the analysis of specific problems in the subsystems. Models for subsystems are familiar to planners, and are therefore well accepted by the individual actors involved in the energy system. The following example gives an overview of the models used in the Göteborg study.

#### **Models used in the Göteborg energy planning project**

- *The MARKAL model was used for the comprehensive study.*
- *MARTES is a user friendly simulation model for detailed analysis of district heating production, including total cost, marginal cost, production strategies, emissions, etc.*
- *HOVA is an Excel-based model for analysis of energy conservation potential. Based on data for individual measures and the structure (age and numbers) of buildings it is possible to calculate conservation costs and potential. Measures can also be aggregated into „packages„ to facilitate use in the following models, e.g. MARKAL.*
- *MIMES/WASTE is an optimization model for strategic analysis of waste management systems. It is designed to facilitate new solutions for future waste management systems that are both cost-effective and environmentally sound. The model includes a detailed breakdown of the waste, which makes it possible to analyze e.g. the cost of separation and energy recovery.*



#### 2.4 Involving local interest groups in the planning process

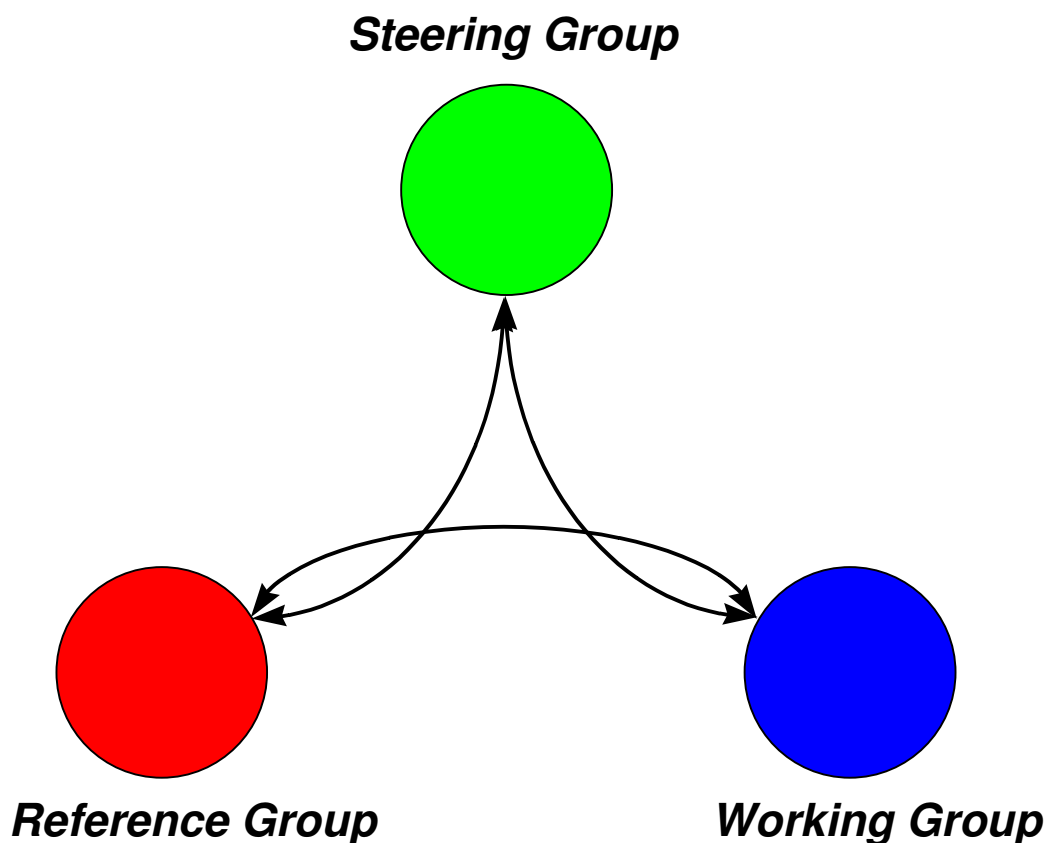
A planning approach that considers only technical aspects and neglects social and political factors of the region is not adequate and often fails because it lacks consensus. The planning process must be embedded in an organizational scheme which includes all local interest groups. Only early involvement and motivation of these groups will ensure achievement of ambitious objectives. The institutional organization defines the roles of the actors directly or indirectly involved in the planning process. Examples of such actors include:

- political decision-makers at the local level,
- representatives from utilities,
- representatives from the municipal or regional administration,
- industrial energy consumers, chambers of commerce,
- environmental groups.

The institutional organization should be tailored to the existing decision mechanisms within the local area. These mechanisms are quite different in European countries; therefore no general recommendation for the institutional framework can be offered.

Figure 2-1 shows an example of an organizational set-up (Refer to chapter 4.3 for an explanation of the different functions of these groups):

- Steering Group: Decision-makers, stake holders of the project and key persons from different interest groups, responsible for the general goals of the ALEP project,
- Reference Group: Experts from local organizations and interest groups. The reference group may include temporary experts for specific questions.
- Working Group (Study Team): Local and external experts carrying out the study.



**Figure 2-1: Example of an organizational set-up for an ALEP project**

*In the Swedish city of Göteborg the organisational set-up was as follows:*

*The initiative to the new Energy Plan 2000 came from the Environment Policy Steering Group, a group of key politicians with special interest in environmental issues. They gave the task to the Göteborg Planning Commission (Steering Group), who thereby became responsible for the preparation of the energy plan.*

*This plan was then developed by the "Energy Group" (Working Group), which was chaired by a city staff person, and consisted of personnel from Göteborg Energi AB (the utility), the Planning Commission, the Agency for Environmental Protection, the Agency for Traffic, and the Agency for Real Estate.*

*The Energy Group established a Reference Panel (Reference Group) with experts in different fields. The reference group included members from the following institutions: Göteborg Energi AB (the utility), large industries, the county administration, the municipal building authority, the agency for real estate, the agency for Environmental Protection, Chalmers University of Technology, and occasional appearances by selected experts. Experts from this panel were invited to hearings when certain issues were discussed. This was felt to be a very effective way of getting the opinions of experts outside the Energy Group into the planning process.*

The purpose of using a comprehensive energy system model within the organizational set-up is to provide an approved method to calculate the effects and costs of policy strategies proposed by different interest groups. The impartial and reliable results from the model help to determine the different positions and find a settlement to conflicting interests.

It is important to understand that local energy planning is not a one time event, but rather an iterative process. The refinement and improvement of strategies is accomplished through continuous communication and discussion of partial results and new ideas between the groups.

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ALEP fosters understanding of problems and possible conflicting goals associated with the local energy system. Thus ALEP will include a learning process concerning the various social and technical aspects of energy systems. This will improve the ability of the parties involved to take an active role in the planning process (see chapter 4.3 for more information on the learning process).

## **2.5 Continuous improvement and monitoring**

The main result of ALEP is a *local/regional energy plan*. The implementation steps of this energy plan must be checked and improved, when frame work conditions change or new experiences are gained during implementation. The actual development should be compared continuously with the planned development using suitable indicators. Through this continuous improvement process it is possible to identify areas where the actual development differs from that specified in the action plan.

After implementation of the energy plan, the ALEP planning process shifts to a monitoring phase. Monitoring and evaluation is necessary, for example, to detect changes in basic assumptions used for the energy plan or to detect problems caused by the energy system. Such findings may make it necessary to adjust some of the goals and parts of the action plan which might have been based on other assumptions. One monitoring activity could be an annual report to the decision makers.

The different steps and phases of the planning process for the ALEP project mentioned throughout chapter 2 are explained in more detail in chapter 3.

## Chapter 3 The Phases of the Planning Process

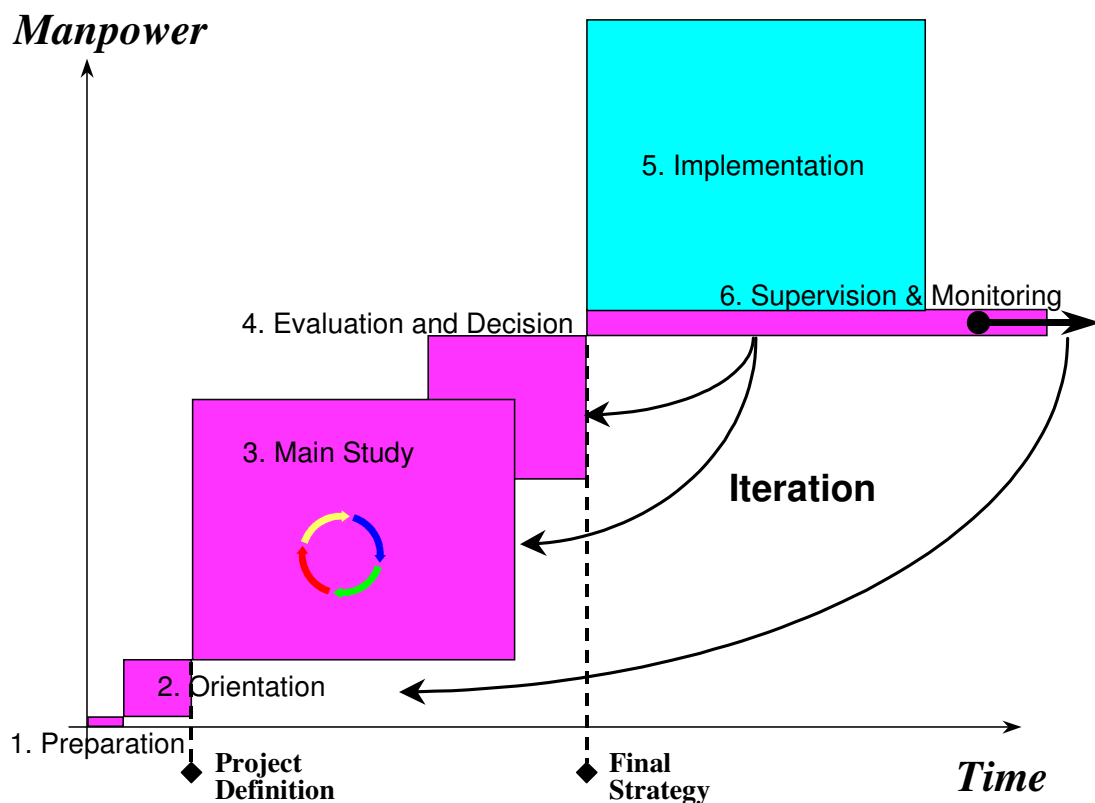
### 3.1 General overview of the planning process

An ALEP project will in general involve many people with different backgrounds and sometimes competing agendas. It is a large-scale project packed with complex technical details. Most importantly, the objectives are not well defined at the beginning of the ALEP project but are rather themselves part of the analysis. Therefore ALEP must be supported by a well structured planning approach. In addition to using computer based models from systems analysis, as mentioned above, the „structured planning process“ as described in this chapter is a decisive characteristic of an ALEP project.

The planning process can be divided into six phases:

1. Preparation phase to begin the ALEP process.
2. Orientation phase to formulate goals and set up the ALEP project.
3. Main study phase with comprehensive strategic analyses and subsystem analyses to examine different strategies.
4. Evaluation and decision phase to define a final energy plan and climate protection strategy.
5. Implementation phase to implement the energy plan in individual projects.
6. Supervision & monitoring phase to detect erroneous projects and deviations from the energy plan.

Each successive phase goes into more detail and improves the understanding of the energy system. Iteration loops are necessary to include important new findings. Figure 3-1 shows the phases of the planning process.



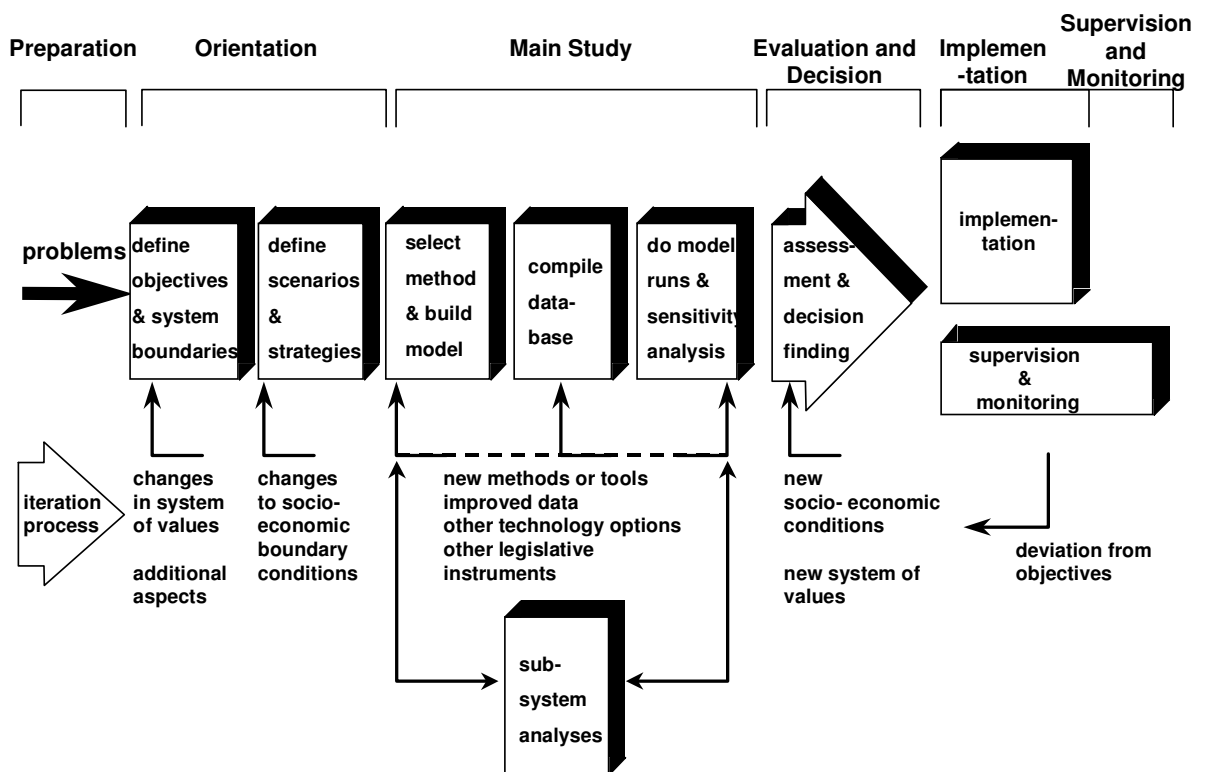
**Figure 3-1:** Phases of the planning process

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The x-axis is the time frame for the project. The y-axis stands for the manpower needed for the different phases. Both axis have a purely qualitative scale, indicating also that the different phases build upon each other, while main study phase and evaluation and decision phase need a certain overlap. Thus the area of a phase indicates the human resources allocated to it in a qualitative manner. The sizes of the areas shown in Figure 3-1 should be seen as a rule of thumb. The implementation phase in particular may need considerable more time and resources than the main study. The monitoring phase on the other hand could be a very small annual effort.

The preparation phase serves to start the ALEP process by collecting basic information on local problems connected to the existing energy system, and by identifying and inviting local interest groups who may participate in the project. The orientation phase is decisive for the project. Here the objectives and scope of the study are defined based on a first assessment of the present situation of the energy system. After completion of this phase the tasks and scope of the project should be well defined. In the main study phase, the objectives serve as guiding principles for the development of the energy system model and the necessary data acquisition (see chapter 4.2 for a definition of the term model). With the help of the model, different options for competing measures and strategies will be analyzed. The results of the main study are discussed during the evaluation and decision phase. Normally, some iteration loops within the main study phase and during the evaluation phase are necessary to find an optimal solution, e. g. a solution that best meets the different goals of all interest groups. This iteration procedure is made much easier by the use of a model. With the finalized strategy described in the final report, ALEP has reached its most important milestone, the Local Energy Plan. The ALEP process continues with two additional tasks, however: the implementation phase and the supervision and monitoring phase. Implementation means realization of the energy plan through individual projects. A supervision phase should then be used to check the success of the implemented projects. Unfavorable developments detected during the supervision phase may lead to new iterations in the planning process and even a re-evaluation of the energy plan.

After implementation, the performance of the system should be monitored regularly over several years. This helps to detect situations where a re-orientation or a completely new ALEP process should be started. During the supervision and monitoring phase the energy system model is very helpful. The report formats developed during the ALEP project can be used to analyze and document the performance of the system using actual measured data. When a new ALEP planning cycle starts, the database will be up to date, and only minor changes to the model and minimal data acquisition will be necessary to update the model. This reduces the cost and time for the revision of the ALEP project enormously.



**Figure 3-2:** Phases and Tasks of the ALEP process

Figure 3-2 shows the phases and tasks of the ALEP planning approach. The tasks are linked together by an iterative process. Reasons for iterations are indicated. Findings and results in later phases may lead to new considerations which must be fed back into the process, leading to a refinement of the model and the associated energy plan. Some findings may be more fundamental to the plan, such as a shift in the system of values. They may require changes of the objectives, or a new decision phase. Detailed information for each phase is described in chapters 3.2 to 3.7.

An equally important part of the project, besides the technical analysis, is the involvement of interest groups in communication and decision making (refer to chapter 4.3 for more information on project organization and "institutional learning process").

The project structure and working plan of an ALEP project should be based on the ideal approach described above. To which extent the different phases and steps are actually executed and how much time is devoted to them depends on how the concrete planning tasks are defined, and on the priorities of the planning team. Therefore no general rules for the budgets of the different phases can be given.

Since it is not possible to calculate the budget for the main study before the scope of the work has been defined, it would be advisable to split the ALEP project into two consecutive parts. The first part should cover the orientation phase, including assessment of the present situation and definition of the objectives. The scope, content and budget of the second part (main study and evaluation and decision phase) are defined according to the results of the orientation phase. If the organization responsible for local energy planning does not have sufficient human resources, then it may also be necessary to include the initial preparation phase into the first part.



## 3.2 Detailed description of the planning steps

### 3.2.1 The preparation phase

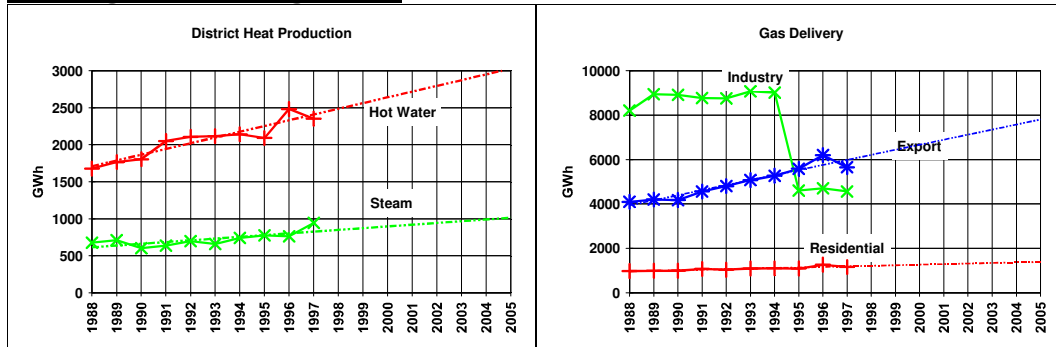
When the need for local energy planning emerges in a region, the responsible organization or actor assigns a specific person, organization or an especially selected team to launch the planning process (the initial group most likely consists of representatives from the city and/or utility and perhaps external experts). In general a meeting or workshop is organized to initiate the planning process. A workshop is best suited for this purpose because it enables active participation, rather than passive receiving of information. The main objective of the workshop is to define the general tasks, the organizational set-up and the financial framework. The workshop should be attended by all local actors that will be affected by the ALEP project.

During the preparation of this workshop the initial working group collects basic information and a „rich picture,, of the present situation. Prior to the workshop, the driving actor in this phase of the project provides this background material to the other actors and interested groups. This information material may also include suggestions about project organization, choice of methods, budget, time frame etc.. However, at this point of the project, most of the information is not very detailed or of preliminary character. The following check list can help to characterize the present local situation (see also chapter 4.1 for examples of background information):

- What are the most urgent energy problems in the community?
- Which long-term objectives for energy supply may be suggested?
- Is there an actual demand for concrete decisions which may affect the energy system?
- Who are the important actors and decision makers. What are their responsibilities and relationships?
- What are reasonable system boundaries for analyzing the local energy system?
- Which areas can be influenced and which technical solutions could be considered?
- Are there already pertinent ongoing activities and information materials, or results from existing studies?
- What was the "historic" development of local energy planning in the community?
- What are the potential benefits of a long-term energy plan?
- What possibilities exist to finance the work necessary to develop the energy plan?

If all these questions can be answered, the „rich picture“ mentioned above will be apparent to the working group.

The following figures show a very simple example of background information for the case study Mannheim:

***Learning from existing trends***

*District heat production and gas delivery from recent years show a constant increase indicated by linear extrapolation. Almost 81% of the customers in the heat market are connected to gas (33%), district heat (44%) and electricity (4%) with a massive substitution of oil since 10 years from 37% to 19% currently. This development was the result of the old energy plan from 1984. A key aim of the Mannheim study was to verify this old energy plan and to determine the optimal balance between district heat and gas expansion in different areas. The gas delivery to industry is characterized by a sharp decline due to one major customer who changed suppliers and a substantial increase in exports to a neighboring city. An important question for the future liberalized energy market is the consequences of such losses in production cost of gas and especially district heating.*

An agenda for the work-shop where these questions should be addressed could be:

- description of the present situation,
- identification of existing and expected problems,
- possible objectives for developing the local energy system,
- presentation of possible system (boundaries), scenarios, strategies,
- outline of planning approach and choice of methods,
- position statements and objectives of the different participating organizations.

The following results should be achieved during the workshop (examples in chapter 4.1):

- list of problems and questions that need more detailed analyses,
- outline of problem identification and agreement on main objectives,
- approximate definition of system boundaries and scope of planning approach,
- overall budget limits and time frame,
- definition of preliminary organizational set-up and general framework,
- choice of general planning approach and methods,
- preparation of ALEP action plan, time schedule and assignment of subsequent tasks.

The preparation phase will clarify the main problems and objectives. For the next step, a work plan for the project must be prepared. If external consultants assist in the planning process, this work plan should be used to prepare the material for a bid proposal for the ALEP project.

### **3.2.2 The orientation phase**

The orientation phase is devoted to the detailed description of

- (1) problems
- (2) objectives
- (3) system boundaries
- (4) scenarios and measures.

The identification of problems and the definition of scenarios and measures requires more detailed information about the energy system than is normally available after the initiating phase. Thus the orientation phase begins with an assessment of the local energy system, including input from all actors to attain a more detailed picture of the present situation and actual problems. Examples for this data collection and analysis are given in chapter 4.1.

The most important activity in the orientation phase is the clear formulation of the problems and a detailed definition of the planning objectives:

- Objectives are needed as guiding principles for all other phases of the study. They affect the selection of system boundaries, the definition of scenarios and strategies, and the development of the energy system model. This does not imply that objectives can not be changed during the planning process, but rather that changes must be discussed and documented in the steering and reference group.
- A major task during the subsequent main study phase is the preparation of a database. Thus, the orientation phase helps to direct and limit data collection to specific topics to avoid unnecessary work.
- Lack of transparency or unresolved issues in this phase can later threaten the implementation of the energy plan, since an interest group may not accept the results of the study and may prevent or delay the implementation process.

The objectives should be accepted by all groups, and a formal agreement should be reached. Sufficient amount of time should be allocated to achieve this.

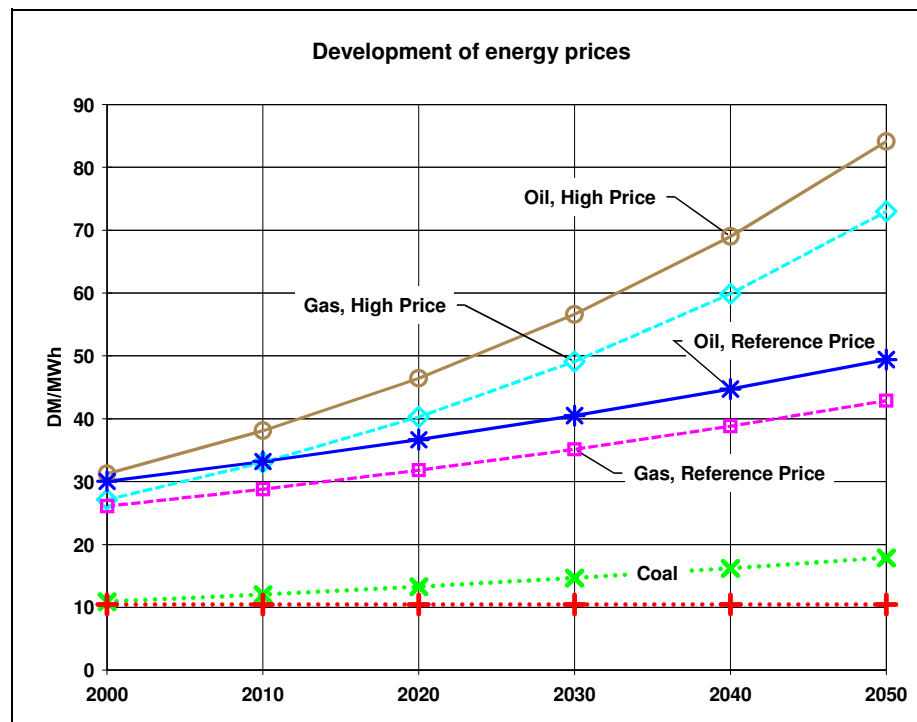
The next step, which is strongly influenced by the established objectives, is the definition of the system boundaries and the socio-economic framework of the study. When defining the scope of the study, the goal is to focus the work on the most important issues and to exclude those parts and questions of minor interest. In this way the geographical boundaries are drawn and the complexity of the actual technical energy system is reduced to a structure which is the object of further analysis. A very appropriate method, which should be used for the description of the structure of the energy system, is the "**Reference Energy System**" (RES) method (see chapter 4.2 for an explanation and examples of the RES).

Within the system boundaries we describe the socio-economic framework. One should make clear which developments of the energy system are assumed to be exogeneous (e.g. can not be influenced by the local planners), and which parts of the energy system can and should be influenced by the planners:

- Developments of population, energy prices, discount rate and technologies or decisions of national politics can not be influenced by the planner or decision makers at the local or municipal level. Specific assumptions for the development of these parameters are called scenarios. Scenarios set the socio-economic stage for the development of the energy system.
- Three principal types of actions to be taken by the decision makers can be distinguished:
  - (1) control system parameters such as (local) taxes restrictions or subsidies,
  - (2) behave as an actor on a market, and
  - (3) communication.

*Example: introduction of new technologies or fuels, demand-side management programs, information campaigns, emission restrictions, subsidy programs, or the construction of new power plants. (Combinations of measures are called strategies. In this sense we use the term strategies already at this stage of the planning process. During the main study, different strategies are evaluated to identify a dynamic strategy or energy plan (see chapter 4.6 for examples of scenarios and strategies)).*

The following graph shows the development of energy prices as an example for a typical exogeneous parameter:

**Definition of energy prices as a scenario parameter**

*The development of prices shown is a synthesis of different and in some cases more detailed projections by different authors. Resources of coal are abundant and the price should stay low. An increase of 1% per annum is assumed in the high price scenario. The demand for gas in Europe is expected to grow considerably which will put some stress on the available transport capacities and resources. World market prices for oil are expected to increase mainly due to growing demand and price control by OPEC. Therefore a 1% per annum increase is assumed for the reference scenario, and a 2% per annum increase for the high price scenario. The oil and gas prices shown in the graph are wholesale prices. Since the development of these assumptions, crude oil prices on the world market have increased much faster due to OPEC agreements. The wholesale gas prices in Germany, however, dropped considerably due to regulatory interventions of the government. A projection cannot include these effects, especially if the forecast period is very long.*

At this point the planners have to make some important decisions. The planning approach, the energy system models and the computer software for the comprehensive study must be selected now, before data collection and model building is started (refer to chapter 4.3 and 4.4 for a discussion on how to make such a choice).

- The first question concerns the role of the comprehensive study. The planners can place the main emphasis and effort on the comprehensive study and the development of an optimized overall strategy ("comprehensive approach"). In contrast, the planners can instead base the work on ongoing projects and studies, and try to co-ordinate them with a comprehensive study ("project oriented approach"). In the latter case, the comprehensive study is rather small, and less extensive. This approach might be adequate for smaller communities (30.000 to 50.000 inhabitants) or a project with a limited scope.
- Other choices concern whether or not to use software tools for the comprehensive study and the subsystem or component analysis. These software tools employ different methods, such as simulation or optimization, and the planner has to select an appropriate tool for his purpose (see chapter 4.4 for more information on energy system models and the role of simulation and optimization).

The final organizational set-up adopted according to the questions and problems of the project must be established during the orientation phase. This will define the role and responsibilities of

each participant as well the communication patterns. The organizational set-up, as described in chapters 2 and 4.3, serves to integrate public opinion and different interest groups into the process. It helps to find consensual solutions and to prepare the basis for decisions. In the orientation phase the reference group has a very active part. Members of the reference group must bring in the specific requirements of the different interest groups and build a common system of goals and a vision for the future. The task of the steering group is to negotiate compromises between the parties at the political level.

The orientation phase ends with a report which includes:

- a description of the present situation of the energy system,
- the planning task in detail (e.g. problems, objectives, system boundaries),
- scenarios and strategies which should be investigated,
- a draft version of the structure of the energy system model (for example as RES representation of the technical energy system),
- the institutional set-up and its responsibilities,
- existing or ongoing studies and projects related to local energy planning,
- the work plan with a time schedule and budget for the subsequent phases,
- additional information about the general framework,
- planning approach, modeling method and energy system models to be used.

The items of this report are subject to continual improvements during the project. The document defines the core of the project and should be accessible to all participants.

### 3.2.3 The main study phase

The main study integrates a comprehensive analysis for long term strategic planning with several detailed analyses of important subsystems or questions of specific interest. The information exchange between these two planning levels produces the necessary amount of detail that is required for the decision making process.

During the orientation phase it will already be decided whether the „comprehensive,, or the „project oriented,, approach will be used. This guidebook will concentrate on the comprehensive study. Therefore, in the following sections, we will describe the steps required to develop a detailed energy system model, which is the main task of the comprehensive study. The combination of the comprehensive model and detailed subsystem analyses will also be discussed, but we will not go into detail about modeling subsystems and using special purpose tools.

We strongly recommend to begin with a small (pilot) model containing only the most important components at the outset in order to obtain initial results, and then to refine this model during the course of the work. The simple preliminary model points to the strengths and weaknesses of the existing system, and to the dangers and opportunities of future developments. During the discussion of the preliminary results, questions about the accuracy will arise which will help the planners to gain new insight and to improve the model in these specific areas. This iterative ALEP planning process supports the successive refinement of the energy system model. The integration of all stake holders including those parties questioning this approach, will help to improve the acceptance of the model as a tool for ALEP.

Studies of subsystems which run in parallel to the comprehensive study, should use the same basic data in addition to their individual more specific data. Results from these analyses will contribute additional detailed information to the comprehensive study.

Since it takes a substantial amount of time to get optimization models running, a simulation approach could help in the beginning to become familiar with the modeling technique and to produce initial results. Simulations use an explorative approach for modeling. As opposed to optimization models, which calculate the optimal mix of technologies and energy carriers for a given cost structure and a given set of constraints, simulation models calculate the impacts of a clearly defined strategy path, i. e. a given technology and fuel mix.

The description of the different steps of the main study phase below distinguishes between building the structure of the model (e. g. the RES) and entering data. However, these two steps are often not clearly separated in the user-interface of the models.

### Step 1: Define the structure of the comprehensive model using the RES

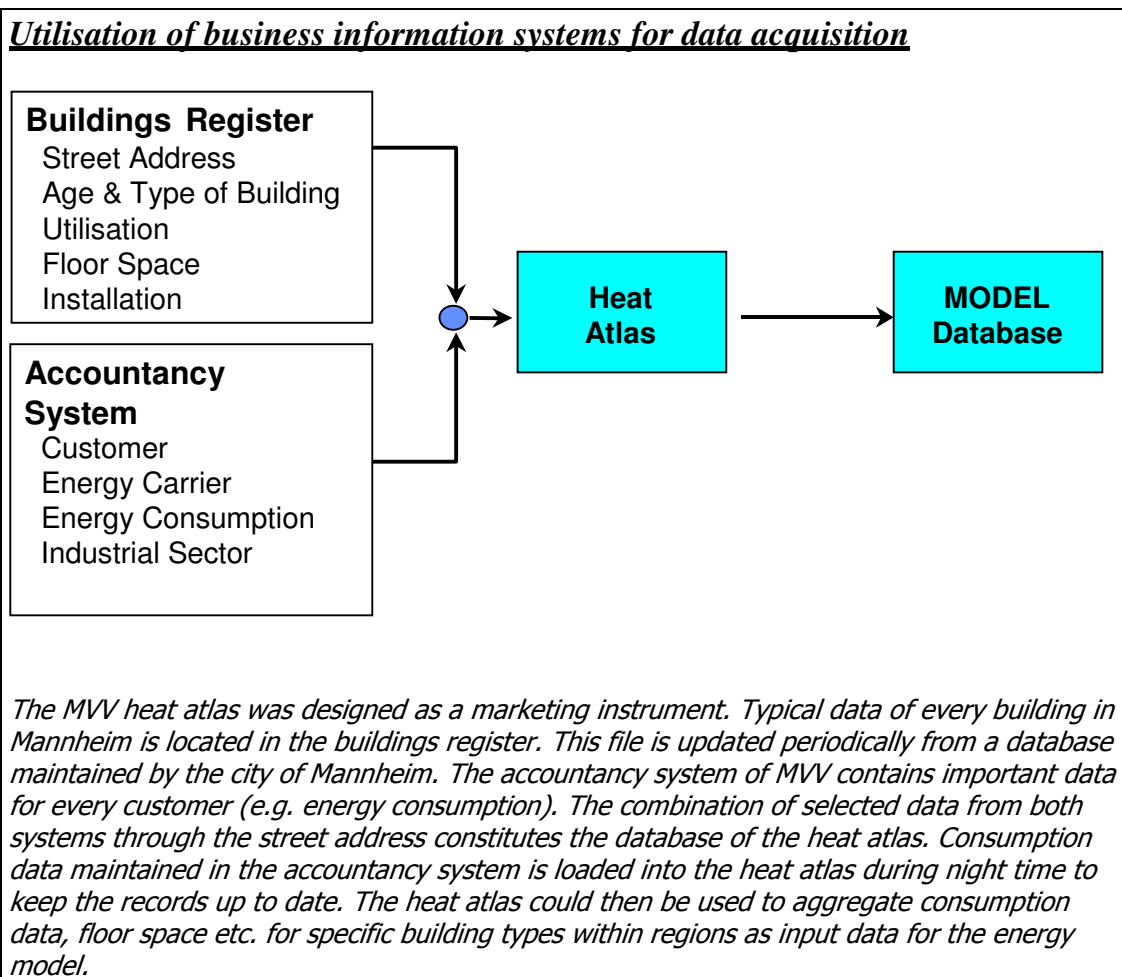
The first step of the main study phase is to use the available information from the preceding phases to develop the RES, a simplified representation of the structure of the energy system. Since the RES is very illustrative and helps to communicate planning issues, developments of the RES could already be started in the orientation phase. The information contained in the RES is then transferred to the energy system model. Different software tools use individual specific methods and user interfaces to support this step. Refer to chapter 4.2 and the case studies in chapter 5 for RES examples.

### Step 2: Compilation of a model database

A major task of the main study is to establish a reliable database with validated data (for example, energy demand, characteristics of supply systems, etc.). Data mining in databases of utilities, municipalities, statistical offices or other sources can be very helpful. Refer to chapter 4.5 for more information on data acquisition and databases. Some examples of data sources are:

- Business and customer information systems of utilities
- Statistical data from administrations or business organizations
- Geographical information systems (GIS)
- other similar modeling case studies

The following example shows the utilization of business databases as sources for the energy model in Mannheim.



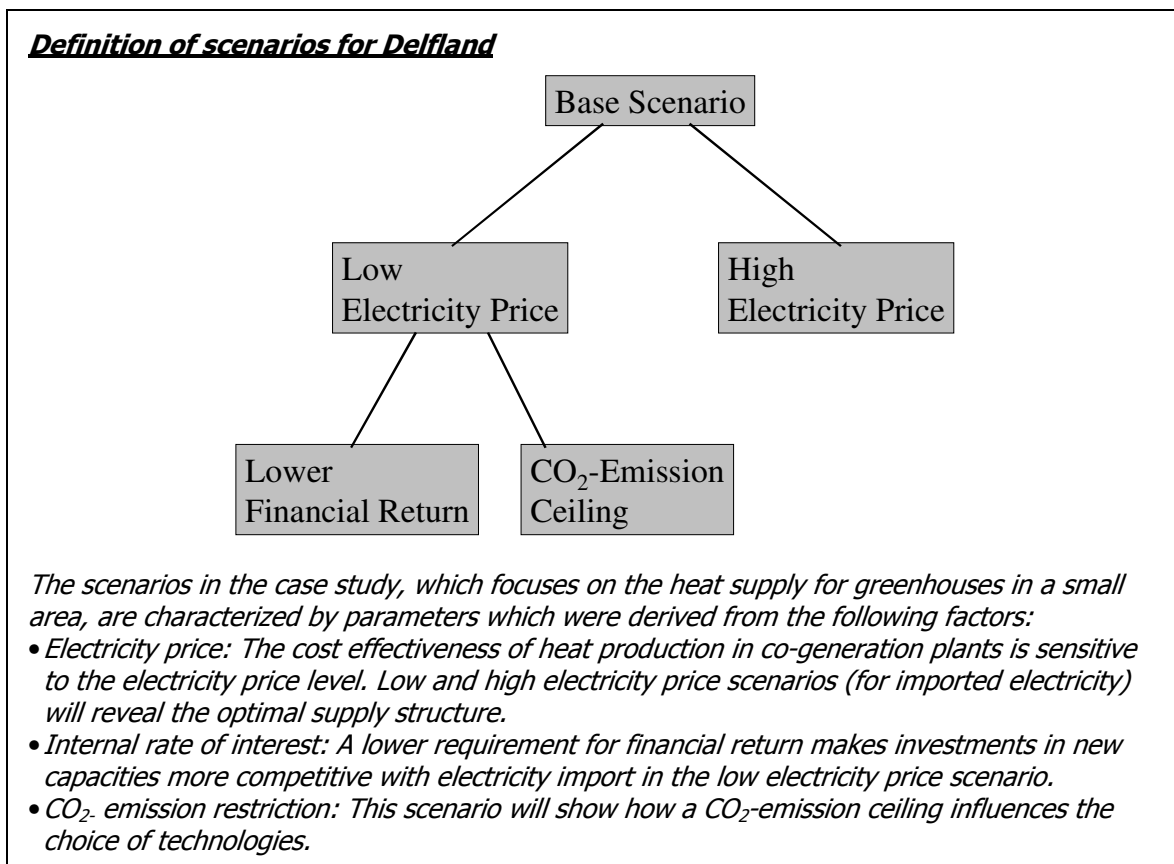
Building a valid database is not only important for computer based models, but also has value for the conventional planning approach and the communication between the planners and the interest groups, since everybody has access to the numbers and the assumptions used for the calculations. The database management system should have a good user-interface, so that the data can be easily stored and retrieved in a multi-user environment, and the validated database can be used as a common source for inputs to all models and calculations. One common database is advantageous. However, if data must be stored in different models, it is important to be very cautious with the update of the data in order to avoid inconsistencies between the models.

The RES representation and technical input data need not be generated from scratch. Results of existing studies from other cities or specially prepared example databases can be used as starting points. They provide sources for technological and economic data for the adequate representation of specific features of the energy system. These examples should then be adapted to the local situation.

### Step 3: Calculation of scenarios and strategies

When the model database contains all the necessary structural, technical, economic and other data (such as discount rate and modeling period), the first model runs can be performed. First, the model is calibrated to the base year with historic data. Further model runs are devoted to investigating the development of the unaltered system. These runs are made for the base scenario, which is in general the most likely representation of the existing system along with the expectations of its future development. Finally, the behavior of the system is examined when new technologies or other measures according to the proposed strategies are introduced.

The following figure shows the scenarios for the Delfland case study (see chapter 5.6):



The results of these model runs are analyzed very thoroughly, in order to fully understand them and to judge if they are realistic for the actual energy system. In reality, changes to the structure of the energy system occur over long time periods. Results of model runs suggesting unsteady or discontinuous behavior of energy carrier utilization, phasing out of technologies, build up of capacities for new technologies, etc. may therefore be unrealistic. Results which are not

plausible in the model, indicate errors or inaccurate representations of reality. The improvement process continues until all results are well understood and validated.

One should always bear in mind that the results are only as good and accurate as the input data. The results from optimization model runs define the optimal strategies to achieve certain goals (e. g. minimal cost) under the restrictions defined in the scenarios. Therefore, the „optimal,, solution is an outcome of the assumptions and boundary conditions used in the set-up of the model. However they do consider all interdependencies of subsystems and future developments (dynamic models). Consequently models allow for much improved insight into the behavior of the system and its responsiveness to changes.

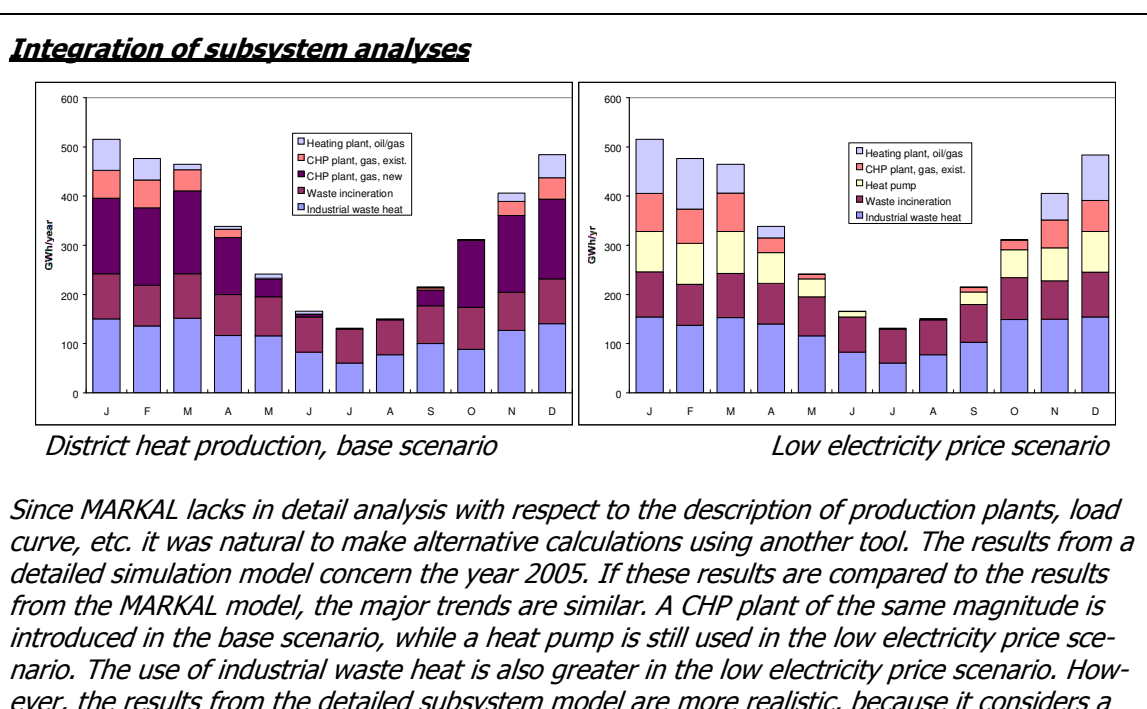
Working out measures and scenarios, and finding the necessary data is an iterative process. When the main study is finished and some results have been worked out, the robustness of these results will be checked under different scenarios with sensitivity analysis (see step 5).

#### Step 4: Integrating subsystem analyses

Due to some necessary simplifications, a comprehensive model is often not adequately detailed to allow for a single clear decision between two competing technologies or solutions for subsystems. Simplifications may concern the structural representation of the technical system, time resolution of energy demand or modeling of grid connected energy carriers. Problems also arise from uncertainties in data derived and adopted from statistical material, rather than from specific surveys of the subsystem.

At certain points of the planning process, it will therefore be necessary to carry out a detailed subsystem optimization or feasibility study of a subsystem to find a detailed optimized solution for a specific part of the energy system. On the other hand, results from detailed studies should be fed back into the analysis to improve the comprehensive study. Combining comprehensive models for overall optimization and subsystem models for detailed studies in iterative steps is generally advisable (see Fig. 1-1). For the linkage of comprehensive energy system models and subsystem models it would be useful to set up the models in such a way that data can be exchanged and interpreted without difficulty (e.g. using same units, parameters, aggregation levels, etc.).

The following example from a subsystem analysis with a detailed simulation model for district heating systems is derived from the Göteborg case study (see chapter 5.4 for more details):





*detailed load curve and production of the different plants month by month. After analysis of results from MARKAL and the detailed simulation model, it was possible to understand differences and make adjustments to both models.*

### **Step 5: Sensitivity analysis**

The objective of a sensitivity analysis is to validate the stability of the model results. Robust strategies have two characteristics:

- (1) Small changes in scenario conditions do not result in big changes to the effectiveness of the strategy,
- (2) A strategy will prove to be optimal or satisfactory under different scenarios.

An example of a robust strategy would be energy conservation in buildings, which is economical under a wide range of price scenarios in any case. Such robust measures can be included in the energy plan.

Results from the sensitivity analysis must also be discussed thoroughly. One should try to understand the changes in the solution due to variations in the input data. Un-plausible results indicate remaining problems with the model formulation. The model must be improved until the results are well understood and stable.

During the main study phase the working group does the hands-on work to construct the model, to input the necessary data, to complete the model runs and to prepare reports summarizing the results. Experts from the reference group assist the working group in developing solutions for specific problems and to provide necessary data and know-how. The working group and reference group discuss the model results and plan new developments (scenarios, strategies, technical options) for the model. The steering group must be informed when far reaching decisions for the development of the model are necessary which require political guidance. This may concern, for example, the definition of new scenarios, the analysis of additional technologies or the allocation of additional resources within the model development.

### **3.2.4 The evaluation and decision phase**

The purpose of this phase is to adopt a strategy for implementation. The different options elaborated during the main study will be assessed and prioritized by all groups involved in the project. The result of this phase is an agreement on the strategy, an action plan and a priority list for the implementation of measures thus providing the core of the local energy plan.

The results of the main study, for example the robust strategies, are presented to the steering group. Since the steering group may not have very deep understanding of the modeling technique, the working team has to prepare the results in easily understandable terms. The material (input data, results and derived indicators) is presented in the form of data sheets, graphs and a summary report. The inclusion of historic data in graphs is often very helpful, because one can judge how realistic the development of an indicator is. The following information should be prepared for the assessment and decision finding process:

- RES representation of the technical energy system,
- energy balance and emission balance,
- development and market shares of energy carriers,
- substitution of energy carriers,
- cost and effectiveness of proposed strategies,
- introduction and market penetration of new technologies,
- development of cost and emissions in different sectors,
- development of specific values and indicators (energy consumption per housing area, per capita consumption, consumption per household, energy use per GDP, specific energy consumption of industry, specific costs, etc.).

The documentation of the input data is of equal importance as the results. The following information could be included in the report (see also chapter 4.7):

- development of demand and development perspectives in different sectors.
- development of energy prices and taxes,
- development of population and housing markets,
- expected growth in commerce and industry,
- expected improvements of energy technologies.

The next task for the reference group and the steering group is to discuss the different options and proposed strategies, and to assess the advantages and disadvantages in relation to the goals specified at the beginning of the project. This can lead to a need for more information or the recalculation of scenarios and strategies to find more acceptable solutions, which triggers a new iterative loop in the main study. It is an important advantage of computer assisted models that this can be realized quite quickly and easily at this stage of the work. Finally, all groups should agree on a common strategy, an action plan and priority list for implementation. The final report is then presented to the decision makers, e. g. the City Council, the management of the utility and others, including the public.

At this point all „sins,, committed during the orientation phase in defining objectives and involving all relevant groups may result in strong objections against the project results. Clear communication of objectives and a consensual work program within the organizational set-up of the ALEP process will pay back at this point.

The end of this phase is the milestone for the ALEP project. The actual work on the project and the development of the energy plan ends here. However, it is very important to initiate a supervision and monitoring phase to accompany implementation, and to check the success of the implemented projects against the defined objectives.

### **3.2.5 The implementation phase**

The action plan and priority list completed during the assessment and decision phase, concerning the energy sector and the emissions reduction strategy, must now be transformed into reality. The different measures specified by the action plan must be planned in detail. These activities are subject to ordinary project planning and management practices, and will not be covered in this guidebook. It is not necessary to continue the original organizational ALEP set-up during this phase. We suggest assigning of supervision of implementation to a new group (e. g. part of the working group) to ensure that the measures are implemented in an effective manner.

### **3.2.6 The monitoring phase**

A good practice is to set up a continuous monitoring process over several years to compare the success of the action plan and implemented projects against the original objectives. Ineffective projects can be detected and reorganized. The monitoring phase does not only prove the success of the action plan, but also shows starting points for an iterative improvement of the energy system model, which may initiate a new ALEP process. The monitoring requires that a data collection and reporting process be organized. This can be achieved by an energy information system for the management of the data and the preparation of regular (e.g. annual) energy balances and reports. The content and format of the reports can be derived from the tables and graphs used in the evaluation phase. The monitoring process can be a part time activity for the organization responsible for energy planning, generally either the municipal administration or the local energy utility.

## **3.3 Interfaces with other planning activities**

Energy planning (or environmental planning related to the energy system; e.g. emissions) is not the only activity within a region. There are other activities which influence the energy system, and changes to the energy system also have an influence on other areas. An important aspect is that urban planning (planning of new dwelling areas or industrial zones, renewal of districts, retrofit of the building stock, infrastructure maintenance) can be combined with improvements in the energy system. For example, the cost for insulation of houses can be financed through the funding for a district renovation scheme, or the cost for installation of a district heating sys-

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tem can be lowered by integrating it with the development of a new dwelling area or industrial zone.

Although traffic accounts for a large (and increasing) share of energy consumption (approximately 35% in Germany), it is very difficult to influence this sector with local energy planning. Individual mobility is very much dependent on personal preferences and life style. Technical improvements occur outside the local reach. Changes of street layout, parking restrictions, fees etc. have little effect on mobility patterns. However, promoting public transportation has a direct effect on energy consumption. To attain a complete picture of energy consumption and emissions, it is useful to include a very simple description of the transportation sector in the model.

Another link exists with waste management. On the one hand power plants produce waste which must be disposed of, and on the other hand incineration plants make use of different kinds of waste (refer to the Basilicata study in chapter 5 for discussion of waste management). A similar connection exists with the use of bio-mass as fuel. Here, the relationship between production, consumption and price is important. If desired, the production and consumption of bio-mass could be included in a simplified way in the energy system model.

The consideration of energy issues in urban planning, environmental planning, waste management or traffic planning can contribute to decision-making in these areas. Information concerning energy balances and the operational energy cost of these projects can help to sort out unfavorable alternatives. The examples presented for urban planning suggest a very close relationship between these planning areas.

## Chapter 4 Steps and Tools in the Technical Analysis

In this chapter we will give a more detailed description of certain steps in the energy planning process, which was presented in chapter 3. We will also discuss a number of tools (computerised and other) which could be used in the different planning stages. Appendix A1 includes a presentation of different available computer models.

The text of this chapter is supported by examples, which to a large extent are based on the Göteborg case study (see chapter 5.4). A few simplifications and additions have been made to this case study in order to make the examples clearer and to facilitate the reader's understanding. (It is assumed that local energy planning is characterized by a continuous participation of different local groups and decision makers and by the common goal to find a consensual solution, as it is usually the case in Swedish LEP-projects)

Here follows a short introduction to the Göteborg case study:

*Göteborg's energy demand and supply have undergone dramatic changes over the last twenty years. The use of oil has been drastically reduced, replaced by a new natural gas system and an expanded district heating system. The district heating system makes use of industrial waste heat, heat generated from waste incineration, and a large electric heat pump plant that recovers the heat energy from the city's sewage treatment plant discharge.*

*This has resulted in a drastic reduction in air pollutants from stationary sources, and a more reliable energy delivery system. These changes were brought about as a result of a planning process implemented almost two decades ago. Between 1987 and 1995 several basic conditions changed, requiring a change in the "Energy Plan for Göteborg". Energy tax structures and levels were changed, charges for pollution emissions increased, and the relative price level between fuels and other energy sources changed. Furthermore, the impending deregulation of the electric energy market was expected to result in electricity prices driven by market forces different from the current regulatory framework. All these conditions made it necessary to update the "Energy Plan for Göteborg".*

*The objective of the "Energy Plan 2000" is to provide a long-term strategy for Göteborg's energy policy. The plan is used as an instrument to co-ordinate the community's joint efforts. Furthermore, it is used to develop a process that will lead to improved utilisation of resources and better prepare Göteborg for its energy future. Energy efficiency is promoted along with reliable and sufficient energy supplies. The purpose of the energy plan is to attain a sustainable development for the future.*

### 4.1 Description of the present situation

Every ALEP must contain a description of the present situation. This is the basis for the analysis of the development of the energy system. The description of the present situation is, for most planners, merely an overall picture of the base year for local energy planning. It consists of facts about energy production, energy use and emissions. A more advanced description of the present situation also includes an evaluation section. An experienced energy planner may draw certain conclusions based on the description of the present situation. Presented together with a simple analysis section, the description of the present situation thus constitutes an important first step in the comprehensive analysis within ALEP; both for the actors taking part in the planning process and later for the reader of the ALEP report. The evaluation section could also help the planner find issues that require more detailed studies.

#### Purposes of the description of the present situation:

- Derive starting points for the comprehensive analysis and for the subsystem studies.
- Make up the basis for the analysis of the future development. (Examples of questions to be answered are: What is the present trend of energy supply? What are the technical options to achieve the goals?)
- Evaluate the present supply and demand systems.
- Recommend possible strategies and measures.

- Help find important issues suitable for the detailed studies.
- Give background information for determining the focus of the ALEP study (e.g. concerning which emissions should be considered).

Activities included in the description of the present situation:

- Collecting and presenting data for the energy systems and emissions.
- Making a list of important questions.
- Making a list of subsystem studies.
- Compare with existing goals, e.g. "we are far away from the goal which we formulated and decided on 10 years ago, stating that 30 % of the energy supply to the community should be based on renewable energy". (The derivation of "new" objectives, i.e. the objectives of the advanced local energy plan which are to be worked out in this project, are discussed in chapter 4.3 below.)
- Making a description of actual development *trends* (e.g. "the district heating system has expanded by 10% per year for the last five years") and the status of *knowledge* (e.g. "we know that our district heating production system has a very small share of CHP production, compared to other systems in similar cities").
- Evaluation of strengths and weaknesses in the present energy system.

#### **4.1.1 The collection and presentation of data for the energy systems and the emissions**

The data collection and processing of statistics are a central activity within the description of the present situation, and are done in a traditional manner. In chapter 4.5 below, the data requirements and provision are described in more detail. However, it should already be stressed at this stage that :

1. you should not invest too much resources into these elements, and
2. you must allow for a certain amount of "approximation" in some of the data.

As long as you are aware of the approximations in certain data, throughout the analysis, and take note of them in the discussion of results, then the quality of the analysis should not be significantly affected. Example: If the emissions from the transportation sector are merely used as a level for comparison in the study, with which the emissions of the energy sector are compared, and no development plan for the transportation sector is to be developed by ALEP, then the emission data can be fairly approximate.

The *methods* for collecting data and processing statistics are well-known. A detailed presentation and discussion of methods is therefore unnecessary here. We restrict ourselves by focusing on a couple of items:

- A description of the present situation should be developed, both for the comprehensive analysis and for the detailed analysis (subsystem studies) which shall be considered by ALEP. The description of the present situation should have the same system boundaries and the same degree of detail as the ALEP analyses.
- However, the "official" description of the present situation in the final reports and in oral presentations will be more illustrative if it is given on a more aggregated level. Below, the total supply and demand of energy for the entire community of Göteborg, and the total emissions of sulphur, NOx and CO<sub>2</sub>, are given as an illustrative example of an "official" description of the present energy balance and emissions for a comprehensive study. (In the "official" final report for the Göteborg Energy Plan, this description is supplemented with a RES for the complete community energy balance, together with a description of the present situation for the detailed analyses, e.g. the district heating system.)
- The description of the present situation should also include the emissions caused by the energy system. If it is possible to show the emissions from other sectors within the system boundary at the same time, this will form a good foundation for comparisons. This is important for the analysis of results (see chapter 4.7 below).
- The description of the present situation, which forms the basis for the detailed subsystem studies, can be of a very different format and content. We therefore do not find it very

helpful, in a guidebook of this type, to present examples. Instead we refer to chapter 5: "Case studies". We would, however, like to offer two recommendations:

- The descriptions should show the *complete* picture within the specific system boundary.
- A GIS map can be very illustrative and helps to complete the description of the present situation (see examples in chapter 4.3 below)

What type of data is needed at this stage? The following is a list of data and presentations which are useful for this purpose:

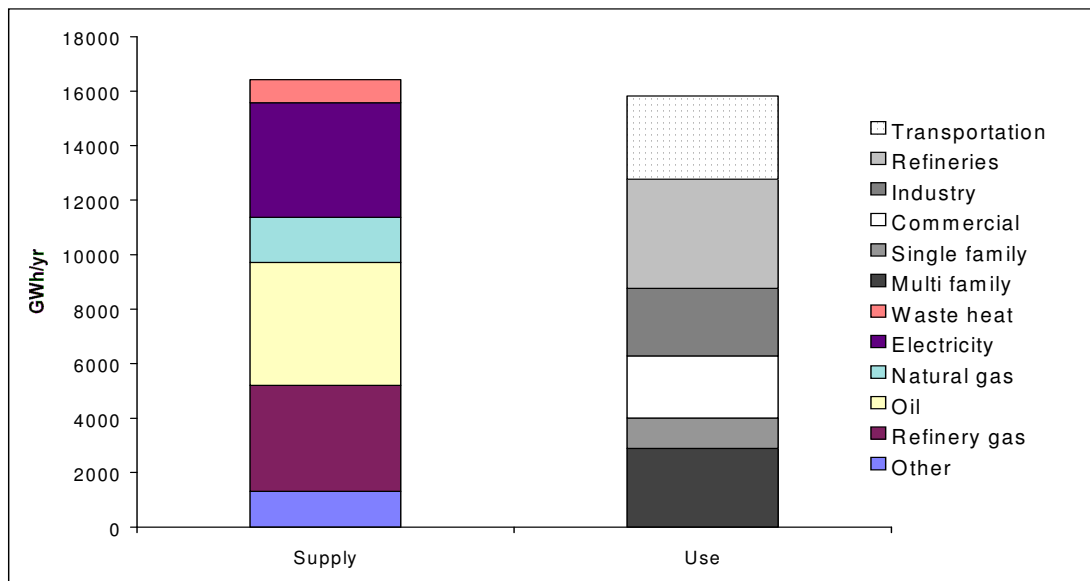
- Energy balances for the studied systems. (This can be given in the RES form, see chapter 4.2 below.)
- Emissions from the energy system, preferably in relation to emissions from other sectors within the system boundary.
- Useful energy demand: total, and divided by sector and/or demand group, for:
  - space heating, water heating and air-conditioning
  - lighting, ventilation, cooking, etc.
  - industrial processes, heating and cooling, etc.
- End use technologies used within sectors/groups:
  - e.g. different types of boilers for space heating
  - efficiencies
- Distribution systems:
  - total distributed energy
  - geographical distribution
- Technology for the production of district heat and electricity:
  - e.g. power plants, heating plants and co-generation plants
- Primary energy supply: total and individual energy carriers:
  - e.g. oil, natural gas, coal, biomass...

A more detailed description of the different aspects of the use of data and different forms of presentation can be found in other chapters in this guidebook. In chapter 4.5 a more complete list of data is presented, together with possible sources of data. chapter 4.2 contains descriptions of the Reference Energy System, the load curve and Geographical Information Systems.

Data is stored in databases and tables. In order to provide for a better understanding for those taking part in the planning process, the *data* should be presented in diagrams. The following examples show how the data could be presented:

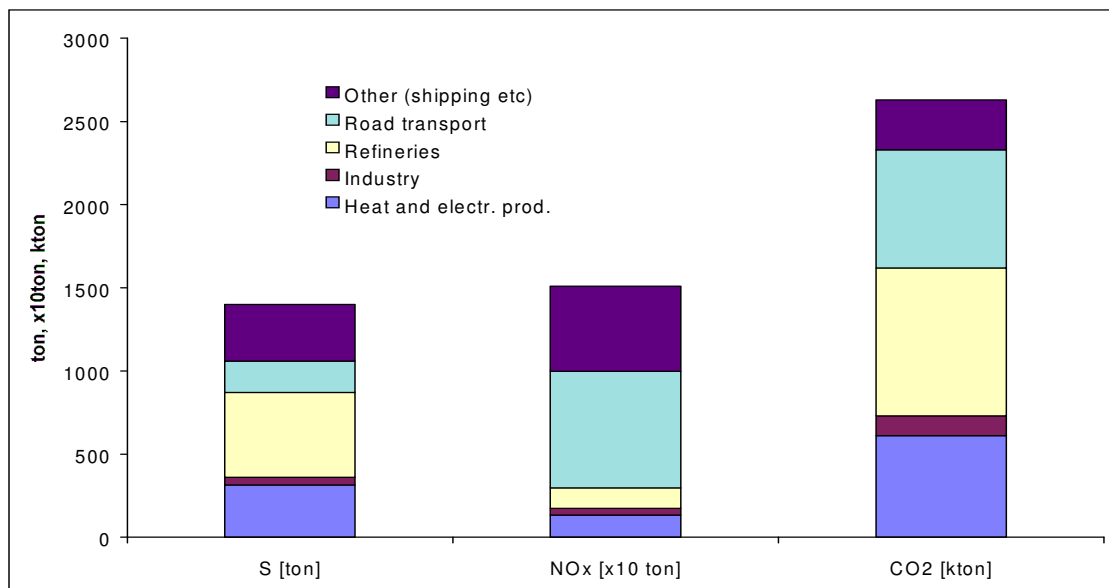
*Description of the present situation in Göteborg.*

*Electricity, oil and refinery gas are the three dominate types of energy supply, each with a share of 25%. The use of energy is divided into a number of sectors, with refineries making up the largest sector. (The refinery and transportation sectors are not included in the energy plan. They are, however, included in this energy balance to show their order of magnitude and for comparison with other sectors.)*



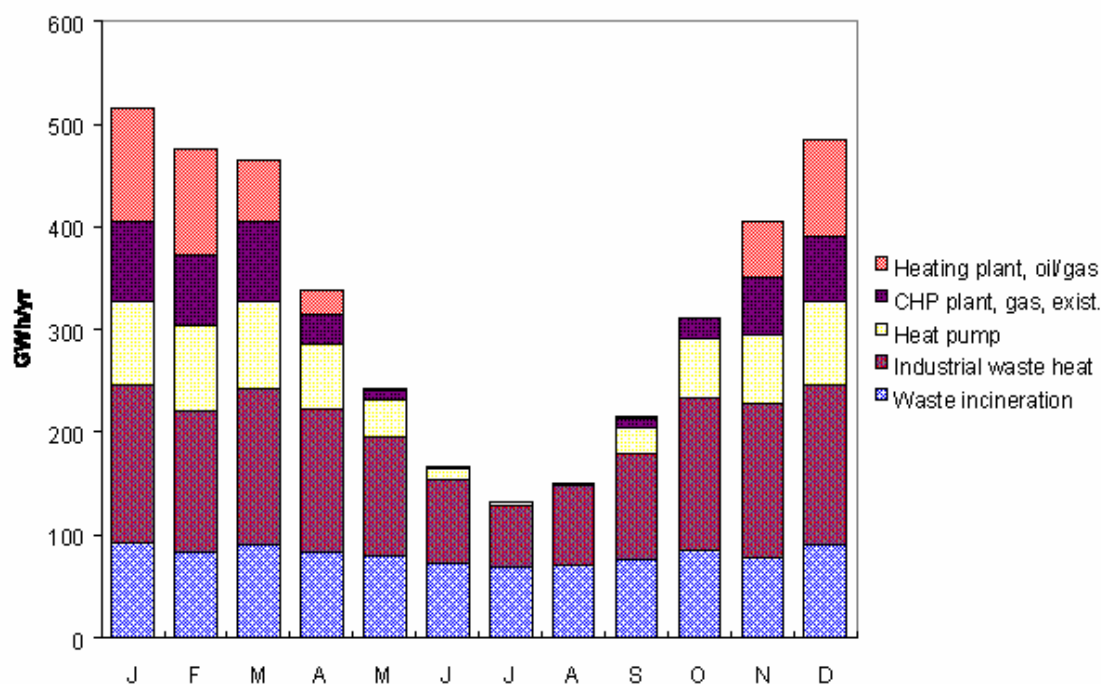
**Figure 4-1:** Primary energy supply and final energy demand in Göteborg 1993 [GWh].

*The emissions from energy conversion in Göteborg mainly originate from refineries and transportation. Energy used for space heating, industrial processes outside the refineries and use of electricity in appliances, etc (i.e. the part of the energy system which can be found within the system boundary of the energy plan) only account for about a quarter of the CO<sub>2</sub> emissions in Göteborg.*



**Figure 4-2:** Emissions of sulphur (1400 tons), nitrogen oxides (15000 tons) and carbon dioxide (2600 ktons).

*District heating is the main source of heating in Göteborg. The base load production comes from waste incineration and industrial waste heat (from the refineries). Heat pumps, natural gas fired CHP plants and oil- and gasfired heating plants make for the rest of the production. The share of heat from CHP plants is very small compared to most district heating systems of this size.*



**Figure 4-3:** District heating production [GWh/month]

Diagrams are easy to understand. Therefore we recommend the frequent use of diagrams in reports and oral presentations. However, they will never give the complete, detailed description of the present situation which is needed for the subsequent analysis, e.g. the model work. Tables and databases are needed to give the correct degree of precision for the calculations.

*Table 4.1: District heating production as presented in figure 4-3 [GWh/month]*

	<b>J</b>	<b>F</b>	<b>M</b>	<b>A</b>	<b>M</b>	<b>J</b>	<b>J</b>	<b>A</b>	<b>S</b>	<b>O</b>	<b>N</b>	<b>D</b>	<b>Year</b>
<i>Heating plant, oil/gas</i>	110	103	59	23	1	0	0	0	1	1	55	93	446
<i>CHP plant, gas, exist.</i>	77	70	78	30	9	1	0	1	9	19	57	63	413
<i>Heat pump</i>	82	83	85	62	37	11	2	1	25	57	67	83	595
<i>Ind. waste heat</i>	154	137	153	139	116	83	61	78	103	149	150	154	1475
<i>Waste incineration</i>	92	83	90	83	80	72	68	71	77	85	78	91	969
<b>Total (GWh)</b>	<b>515</b>	<b>476</b>	<b>464</b>	<b>339</b>	<b>242</b>	<b>166</b>	<b>131</b>	<b>150</b>	<b>215</b>	<b>312</b>	<b>406</b>	<b>484</b>	<b>3900</b>

#### 4.1.2 Objectives of the plan, important questions, subsystem analysis

At this stage of the planning process it may be too early to decide on the objectives of the plan. It is, however, advisable to check which goals exist among the stakeholders of the project and compare them to the present situation. This is a good basis for the development of "new" objectives for the local energy planning task. Objectives of advanced local energy planning are discussed in chapter 4.3.2.

Typical objectives in an ALEP could be:

- Reduction of emissions
- Increased use of renewable energy sources
- Increased energy savings.



It is also valuable to collect the actual strategic questions and other important questions discussed by the different actors within the local energy system. The list of important questions in Göteborg provides a good example.

*Here are some of the important questions which were identified at the beginning of the energy planning project in Göteborg:*

- *What role will natural gas play in the energy system? Is it wise to prepare for storage of gas? What is the environmental value of the gas?*
- *What fuels are possible to use in district heating production in the next 30 years? Will natural gas be a dominate fuel in the near future? Will the share of solid fuels change? Is biomass a realistic alternative for Göteborg?*
- *Should Göteborg commit resources to an expansion of electricity production from CHP plants, and if so, to what extent?*
- *Will there be a conversion away from electrical heating in single family houses, and if so how fast and what will be the alternative? Is it possible to influence this process, and if so how?*
- *How large is the potential of technical fixes in reducing of the use of electricity?*
- *Which influences and what effects can be expected from different advising strategies for energy conservation?*
- *How will the future use of electricity develop? Prognosis?*
- *How will restrictions on emissions of sulphur, nitrogen oxides and carbon dioxide influence the development of the energy sector? What will happen in other sectors? Should Göteborg formulate separate municipal goals?*

Although not all subsystem studies can be formulated (or be identified) already at this stage, the list which has been defined will become an important part of the "rich picture" that the description of the present situation gives. The list of detailed studies in Göteborg is as follows:

*At the very beginning of the planning process existing initiatives were identified in order to find relevant issues for subsystem analysis. Examples of such issues are:*

- *Large scale introduction of natural gas fired combined heat and power production, CHP, in the district heating system.*
- *Seasonal heat storage in existing rock stores, previously used for oil storage.*
- *Waste incineration; expansion and increased electricity production.*
- *The potential for energy conservation in residential and commercial buildings.*
- *The competition between district heating, natural gas and other alternatives for heating of single family houses.*
- *Alternative fuels for vehicles, e.g. electricity and natural gas*

### **4.1.3 System boundaries**

Local energy planning can be limited in practise by, for example, a city or community border line. Other systems boundaries can also be applied. In the case studies within Annex 33 we had the following boundaries:

- Mannheim: Municipal border, transport sector excluded.
- Delfland: Industrial zone.
- Basilicata: Province border, transport and waste management included.
- Göteborg: The community border has in principle been used as the system boundary, but the transport sector and the two refineries located within the community border have been excluded. The delivery of industrial waste heat from these refineries to the district heating system is, included within the systems boundary, free from emissions. Emissions from the production of electricity outside the system border were however included in the emission budget for Göteborg. A method for this "crediting of emissions" is given in the example of system boundary and the emissions of the imported electricity below.

*System boundary and emissions related to electricity import*

*A classic dilemma in local energy planning is how to treat electricity "import" from the international grid, from an emissions point of view. In the Göteborg energy planning project it was assumed that all electricity imported to the municipality was resulted in emissions typical of fossil fueled condensing plants. These emissions are relatively large. They can be reduced both through decreased electricity use in Göteborg and through increased CHP production of electricity, which is a much more efficient technology for electricity generation.*

*The fossil fueled condensing plants are assumed to cause emissions typical for an efficient oil fired plant. This is a reasonable assumption since the existing condensing plants in Sweden are oil fired. It is also reasonable since the emission data for oil fired condensing plants is calculated as an average of old coal fired plants and modern gas fired plants.*

*The following emission coefficients have been assigned to imported electricity:*

- Sulphur:	25 mg/MJ fuel	(90 mg/MWh)
- Nitrogen oxides:	100 mg/MJ fuel	(360 mg/MWh)
- Carbon dioxide:	78 g/MJ fuel	(280 g/MWh).

*An assumed plant efficiency of 45 % results in the following emissions per MWh electricity:*

- Sulphur:	$90 / 0,45 = 0,2$ kg/MWh
- Nitrogen oxides:	$360 / 0,45 = 0,8$ kg/MWh
- Carbon dioxide:	$280 / 0,45 = 620$ kg/MWh.

#### **4.1.4 Evaluation of the present situation**

There may be reasons to include an evaluation section in the description of the present situation. It can be useful for the description of the present situation, especially if the resources for the comprehensive analysis are limited. This evaluation is only of simple character, and can not replace the analysis in the main study.

One useful method is the "trend/knowledge-analysis", which is based on:

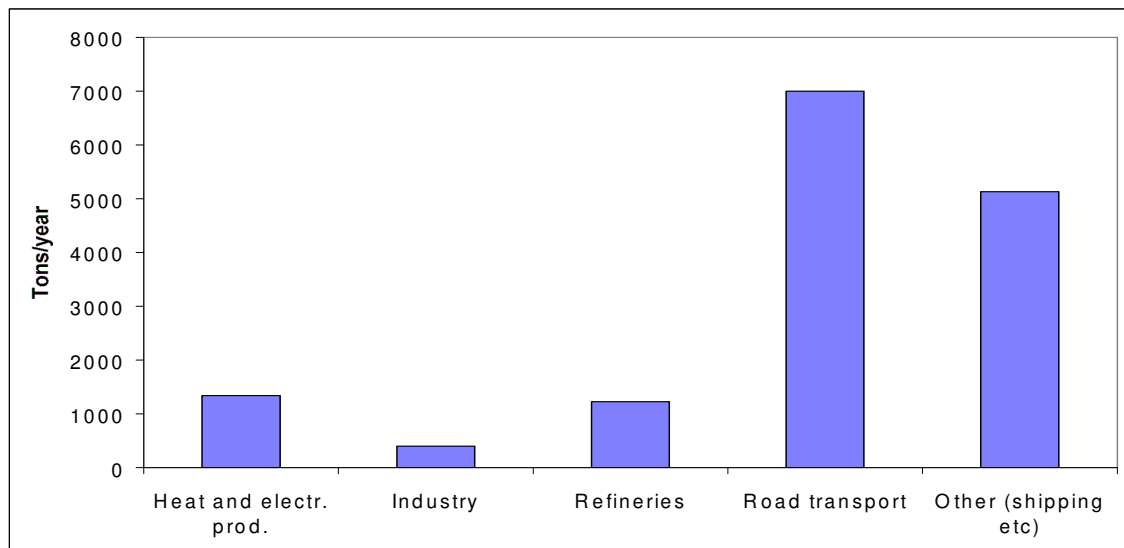
1. historical trends, e.g. the development of energy demand during the past decade
2. present knowledge, e.g. the market share of district heating in different sectors.

The results from the "trend/knowledge-analysis" could either be insights on the future development of parts of the energy system or more general insights about the characteristics of the energy system.

The two examples below illustrate how the "trend/knowledge-analysis" could be applied in ALEP. The first example offers general insights and the second offers insights into a part of the energy system.

*The presentation of NO<sub>x</sub> emission data (figure 4-2 is a part of that presentation) was supplemented in the description of the present situation by the following:*

*"Trend": NO<sub>x</sub> emissions from the energy sector (here=heat and electricity production + industry) had decreased by approximately 3% per year during the period 1990-1995. The energy sector's share of total NO<sub>x</sub> emissions had decreased from 20% to 10% during the same period, while the transportation sector had increased its share from 65% to 80%.*



**Figure 4-4:** The total CO<sub>2</sub> - emissions of different sectors in Göteborg. The transportation sectors are included for comparison

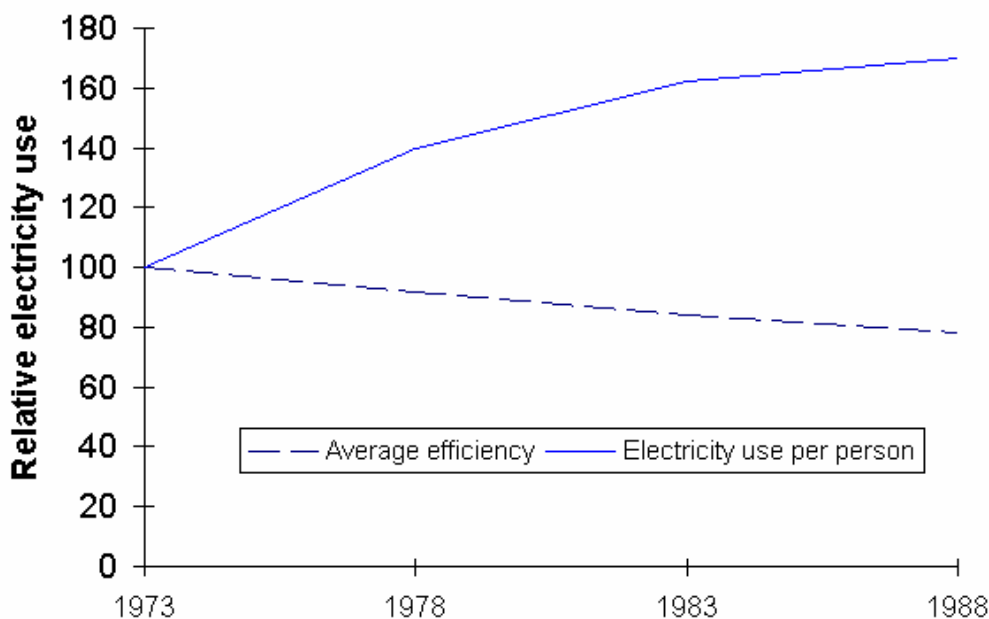
*"Knowledge": Most of the available cost effective measures for reduction of NO<sub>x</sub> emissions in the energy sector had already been implemented. The relative emission level from the energy sector was significantly lower than from the energy sectors of comparable communities. There are also cost effective measures available in the transportation sector.*

*Analysis and conclusion: A simple "trend/knowledge-analysis" of the emission pictures above led to a decision to refrain from including analysis of NO<sub>x</sub> emissions in the ALEP. This analysis was left to transportation planning, since the size of the emissions from transportation was many times larger than from the energy sector. There should be recognized that the most cost effective measures in the energy sector have already been implemented.*

The other example deals with the historical development of the efficiency of typical household appliances in comparison with the development of the total use of electricity for appliances in households. This comparison of efficiency and demand resulted in the conclusion that more efficient equipment does not necessarily lead to lower electricity consumption.

*There is a common view that more efficient appliances will automatically lead to reduced electricity use in this sector. An analysis of historical data, however, showed a different picture. The figure below contains two different types of information in the same table:*

- 1. The average energy consumption in typical household appliances (refrigerator, freezer, washing machine, dish washer, stove, and tumbler dryer) - lower curve.*
- 2. The total use of electricity for appliances per person - upper curve.*



**Figure 4-5:** Comparison of average efficiency of typical appliances and total use of electricity for appliances per person. Relative data. 1973=100

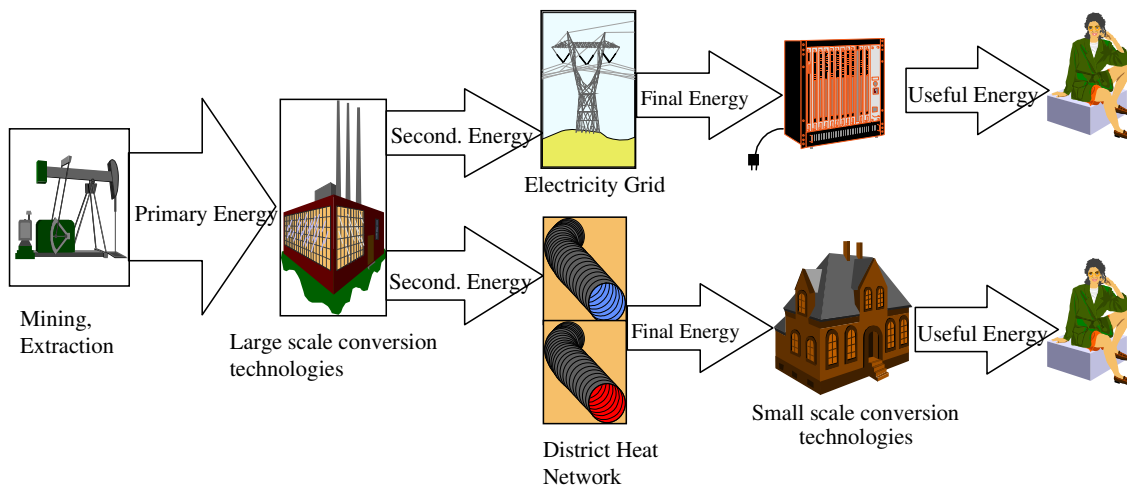
*Figure 4-5 shows that although appliances have become more efficient, the total use of electricity for appliances has increased. We can speculate on the reason for this: less people per household, more appliances per household, new types of appliances, etc. The important conclusion is that more efficient equipment does not necessarily lead to lower electricity consumption. This is important to be aware of when making prognoses for the future.*

## 4.2. Ways of representing the local energy system

In this guidebook we will focus on three useful tools of representing the local energy system: *the Reference Energy System (RES), the Load Curve and the Geographical Information System (GIS)*. These three representations are not alternatives, but rather complement each other. They are often required in order to analyse available information and produce the needed results for the different analysis' in ALEP.

### 4.2.1 The Reference Energy System (RES)

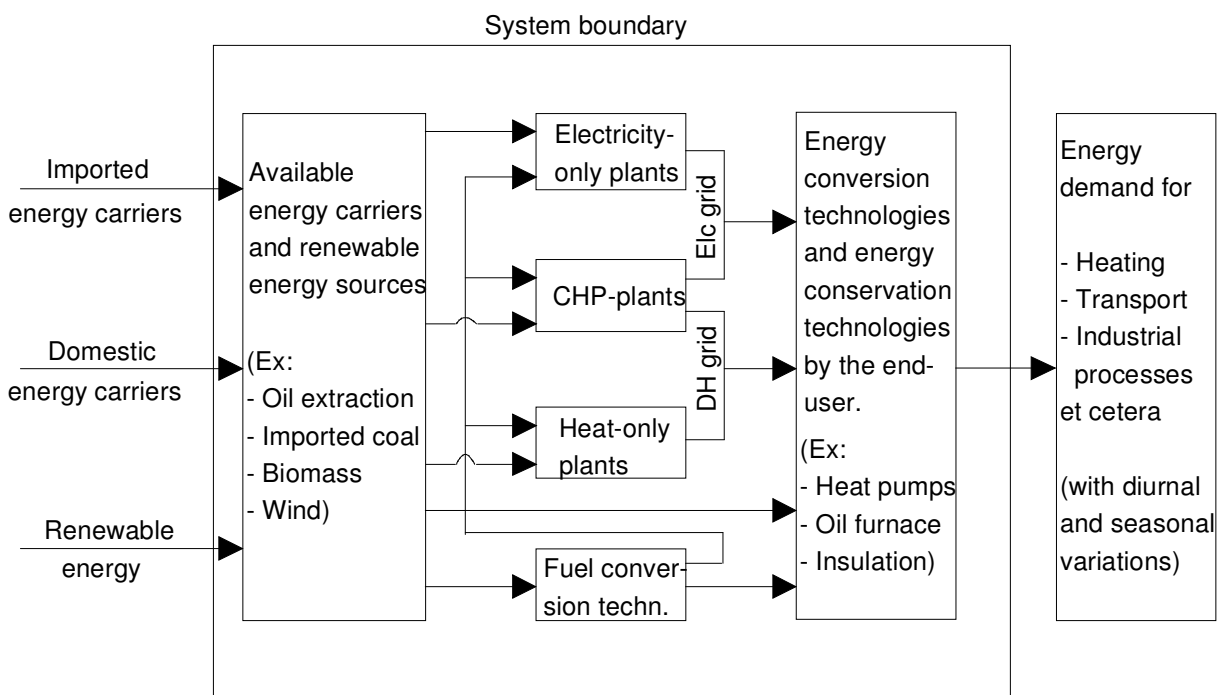
The Reference Energy System (RES) is a scheme which "models" the structure of a local energy system. The RES describes the flow of energy from the sources to the final use. It shows all flows of energy from the primary energy supply, large scale and small scale energy conversion, different distribution forms and the final use of energy in different sectors. Additionally the RES usually contains useful information on energy demand and even energy services (see figure 4-6). The RES, however, is *not* a geographical representation of the local energy system.



**Figure 4-6:** A “physical representation” of the Reference Energy System.

Using the Reference Energy System (RES) it is possible to see how energy flows and how energy conversion technologies influence the fuel-technology chains in an energy system. This means, that the benefit of coupled production can be estimated according to its contribution to both the district heating subsystem and the electrical subsystem. The roles of these subsystems can be evaluated from the perspective of the entire energy system and the requirements on this system. This overall perspective is particularly important when one evaluates demand side energy conservation technologies, i.e., the balance between supply and conservation measures, or the cost-efficiency of a proposed investment to control emissions.

A slightly more detailed RES than the one above illustrates the influence between energy flows and technologies.



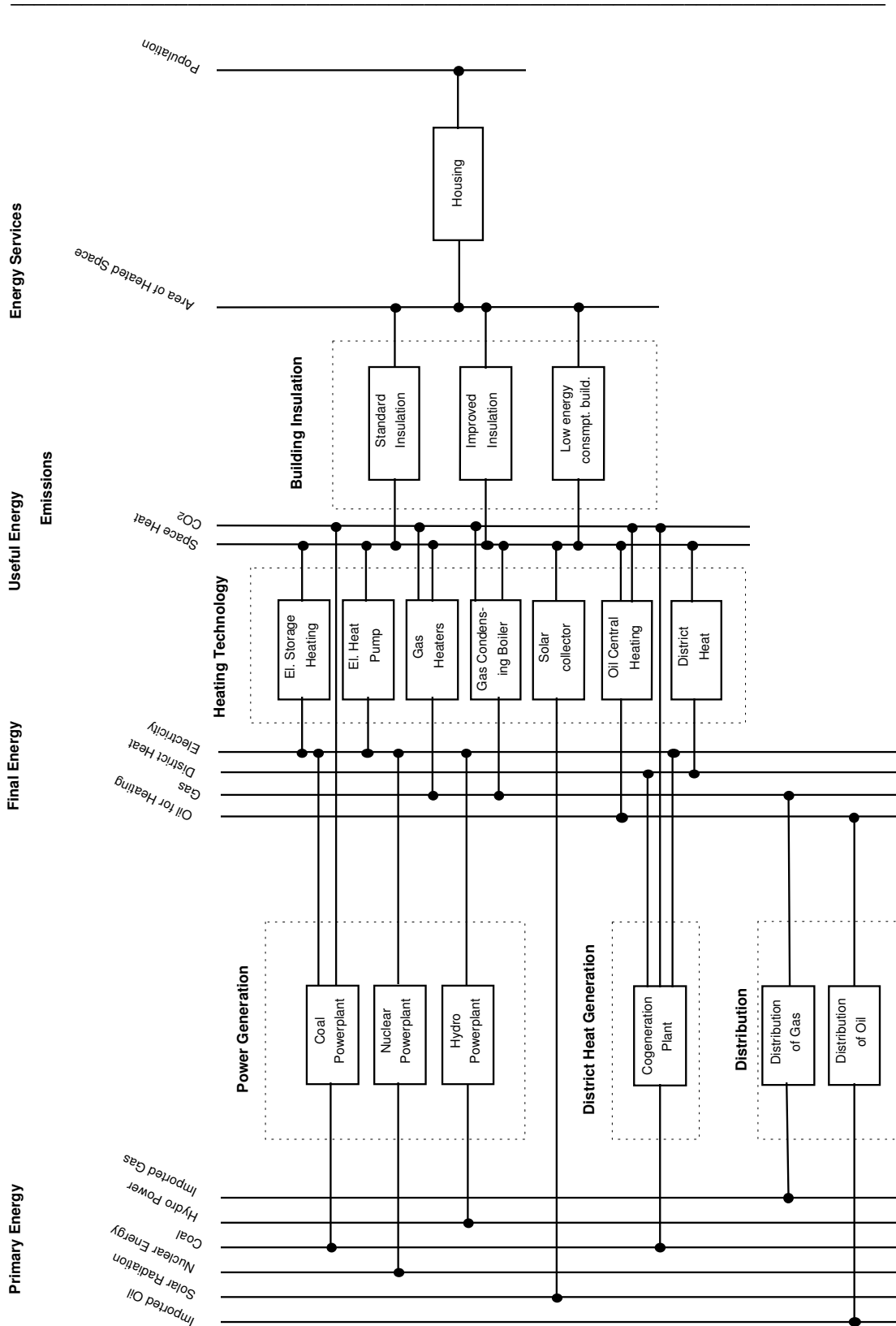
**Figure 4-7:** Principal representation of a Reference Energy System (RES) for an ALEP study at an aggregated level

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While the RES is a graph of all relevant energy flows within the energy system, an energy balance contains the values of all energy flows. Those can be included in the graph or be presented in separate tables. (The RES may contain more conversion levels like distribution, end use technologies and useful energy demands, which are normally not included in an energy balance.)

The RES is preferably built-up according to certain practical recommendations:

- Sources and primary energy supply: The RES begins at the far left of the diagram with the input flows of energy, e.g. oil, natural gas, coal, petrol and imported electricity.
- Processes: Next follows the processes which modify the fuels, e.g. oil refining and preparation of pellets from biomass. For ALEP it is in general not necessary to include all processes within the system boundary. In many cases it is more natural to describe e.g. refined oil or biomass pellets as the primary energy supply (or available energy carriers), since processing may have taken place outside of the studied community and had no noticeable influence on its energy system.
- Conversion technologies: Next the flow of energy enters the large energy conversion technologies, e.g. electricity production plants, district heating plants and combined heat and power plants (CHP).
- Distribution systems: Large scale conversion is followed by distribution systems for different energy forms, e.g. electricity, district heating and natural gas.
- End use technologies: The next step is the small scale energy conversion technologies, e.g. oil fired boilers for multi-family houses, solar heating systems for single family houses, electrical appliances, petrol fueled cars and small scale combined heat and power plants. All these technologies are supplied by "final energy" sources.
- Useful energy demand is the energy which is needed for different kinds of applications, e.g. space heating, lighting and cooking. Conservation measures reduce the need for certain energy services.



**Figure 4-8:** Example of part of the RES representation of a local energy system

In addition to the conventional energy balance and the RES, there is another representation tool which is used frequently: the Sankey diagram. In the Sankey diagram the flow of energy from input of energy to final use is illustrated by lines of different width, where the width is proportional to the size of the energy flow. This gives an immediate feeling of the relative importance

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of the energy flows. The energy system must often be more simplified than the RES, in order to fit all flows into one diagram.

From the Göteborg study we present the overall RES and a more detailed RES for the household sector in Göteborg. It is common to provide different levels of detail in RES. By working with different levels of detail, you avoid on RES that is too complex.

In ALEP studies, the RES representation will generally be the basis for all further analyses. For presentation purposes, it could very well be supplemented by energy balances or Sankey diagrams.

The Reference Energy System (RES) can be used to show different aspects of the energy system. It can cover the total energy system. In order to make it possible to include the total energy system, the RES must be somewhat simplified. Otherwise it will be too large and complicated for practical use. Below, an overall RES for Göteborg is shown.

Here we present the Göteborg RES as an example of how to use this principle for representing the local energy system. The specific Göteborg details are discussed in the Göteborg case study in chapter 5.

The complete picture can be presented if the RES is complemented by more detailed Reference Energy Systems for different parts of the system. In the figure below a detailed RES is presented for the household sector (upper right section of the overall RES). The total energy demand for the household sector was divided into four (more or less) homogenous groups of houses.



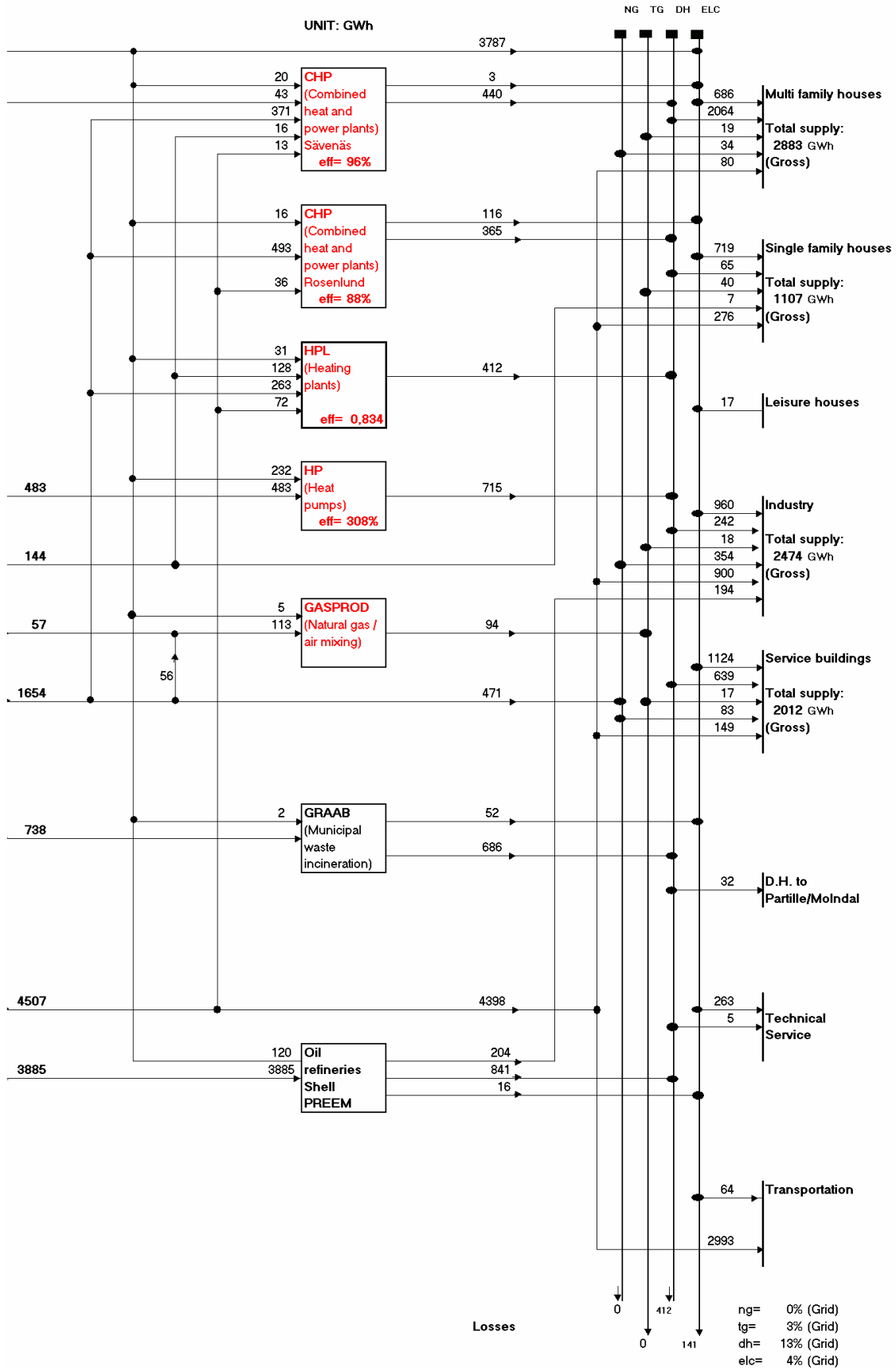
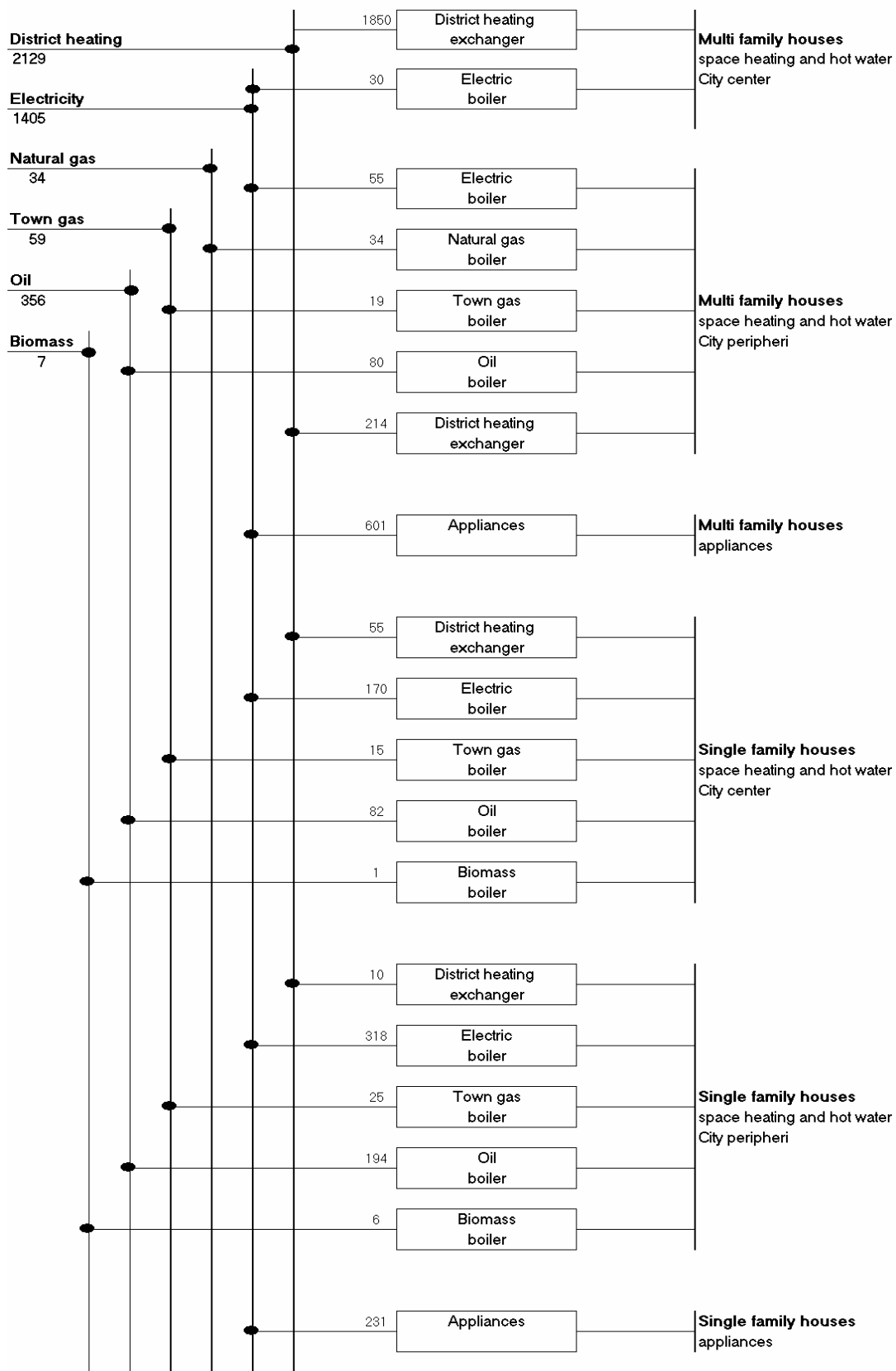


Figure 4-9: RES covering the total energy system of Göteborg, 1993, [GWh]



**Figure 4-10:** Reference Energy System for the household sector in the city of Göteborg, 1993 [GWh]

### 4.2.2 The Load Curve

The load curve is an illustration of how the demand for a certain energy form (electricity, heat or cooling) in a certain application varies over time.

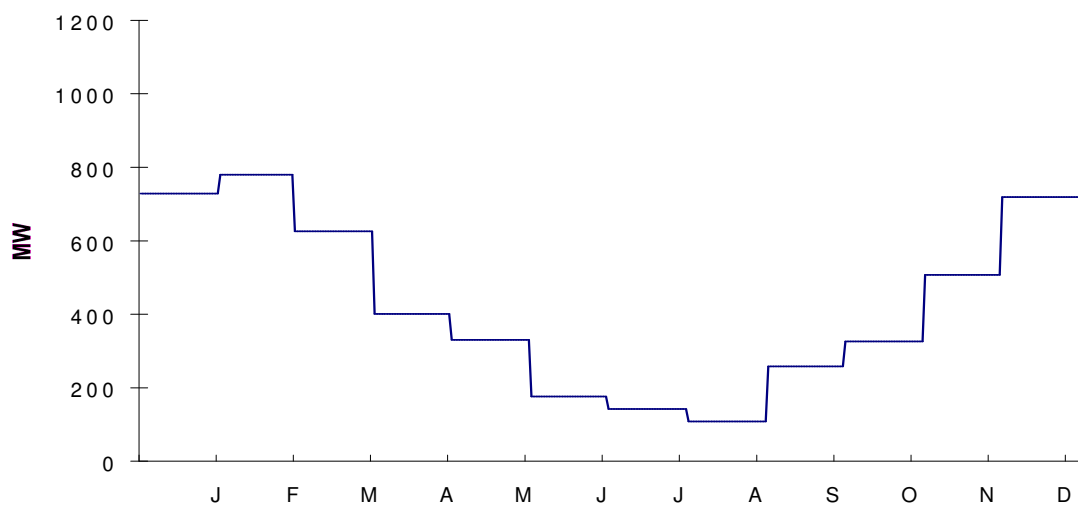
One example is the changing district heating production in Göteborg during a typical year, as shown in figure 4-11. The diagram starts on 1 January and ends on 31 December. This load curve is made up of daily averages. The diagram shows the typical pattern of high energy production during the winter and the small energy production during the summer. (During the summer there is no need for space heating, but the need for water heating remains.)



**Figure 4-11:** Detailed load curve for Göteborg district heating production

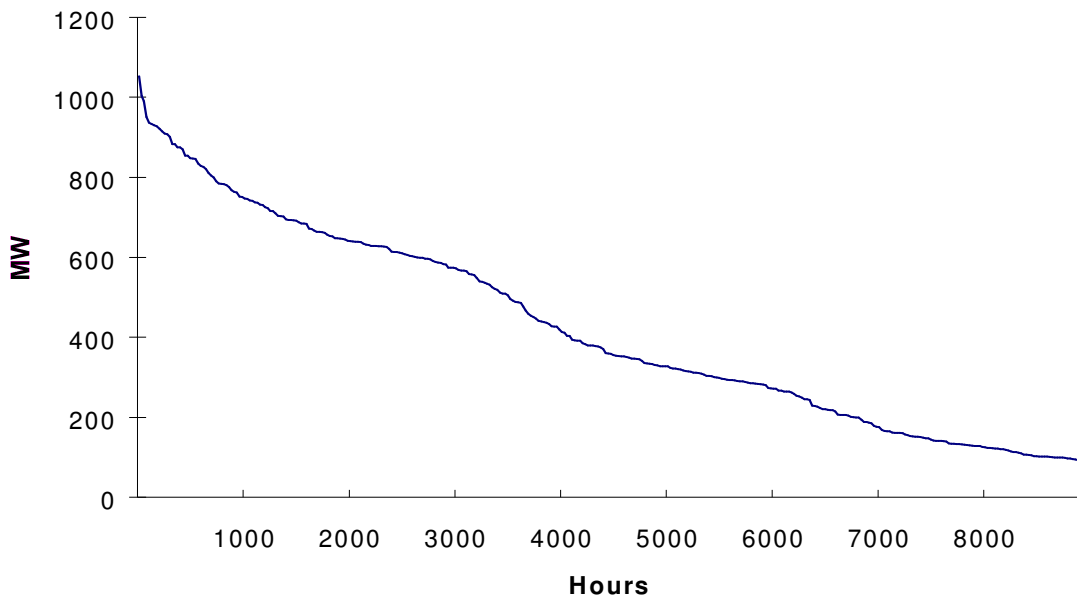
The energy demand variation is an indication of the heating power demand, i.e. the load curve contains information on both power and energy demand.

The load curve is often shown in a simplified form with load levels presented as monthly averages, figure 4-12. This makes the figure easier to read and it also makes calculations based on the load curve more practical to perform. However, a lot of information can be lost, e.g. about peak load.



**Figure 4-12:** Monthly average load curve for the Göteborg district heating production

Another way of representing the changing demand for energy is the duration curve. A duration curve for the production of district heating in Göteborg is shown in figure 4-13 below. This diagram is made up of the data from the detailed load curve above. The duration curve starts with the day having the highest energy production and ends with the day having the lowest energy production. In the duration curve it is possible to see how many days during the year the energy production was higher than 600 MW. The more detailed the data used for the development of the duration curve, the better and "smoother" the curve will be. It is therefore not a good idea to simplify the duration curve with monthly average load data, since this would result in a less useful duration curve.



**Figure 4-13:** Duration curve for district heating production in Göteborg

The load curve includes more information than the duration curve, since it contains the information regarding at what point during the year a specific load level occurs. This information is lost when the load curve is transformed into a duration curve. If, for example, both heating and cooling demands in an analysed energy system are known, and if they are in some way interconnected, then the load curve will show that the peak level of heating occurs in January, whereas the peak load of cooling occurs in July, i.e. never peaking during the same season. Such information is impossible to extract from a duration curve.

The *load curve* is typically used in order to calculate which production plants should be operating to cover the district heating load, day by day. The *duration curve* is suitable for more principle consideration of base load / peak load plants. The calculation of the total yearly energy production from each type of plant given their capacities. The duration curve is typically used in ordinary LEP, but is generally replaced in ALEP by calculation models which use the real load curve instead of the duration curve.

An analysis based on the load curve is only appropriate for a district heating system without coupled production, for a building where only the heat demand is considered. The investment decision should be quite well defined, e.g. finding a substitute for a retired heat plant. But if the value of the installation is influenced by choices outside the single-output or single-demand system, or if there is more than one output or more than one demand in the system, then the single load-curve representation may not be adequate for a meaningful analysis.

Computer models used in ALEP are generally RES-based, but also include load curves. They use seasonal and diurnal variations in demands (externally given as inputs), as well as load curves - internally constructed in the models - for the electric and district heating subsystems, and if

necessary also for the gas subsystem. The load curves will not be as detailed as the load curve models discussed above in order to reduce the size of the mathematical problem and the calculation time for the model.

### 4.2.3 Geographical Information System (GIS).

GIS stands for Geographical Information System which are computer programs for presentation and handling of information connected to geographical locations through maps. There are several Windows based PC programs which can produce maps with position based information (dots, lines, areas) through symbols, colours, diagrams, etc. To be able to present information through maps it is necessary to have geographically defined data available. Today, this is not always the case, but currently digitized maps with all the existing infrastructure are generally available.

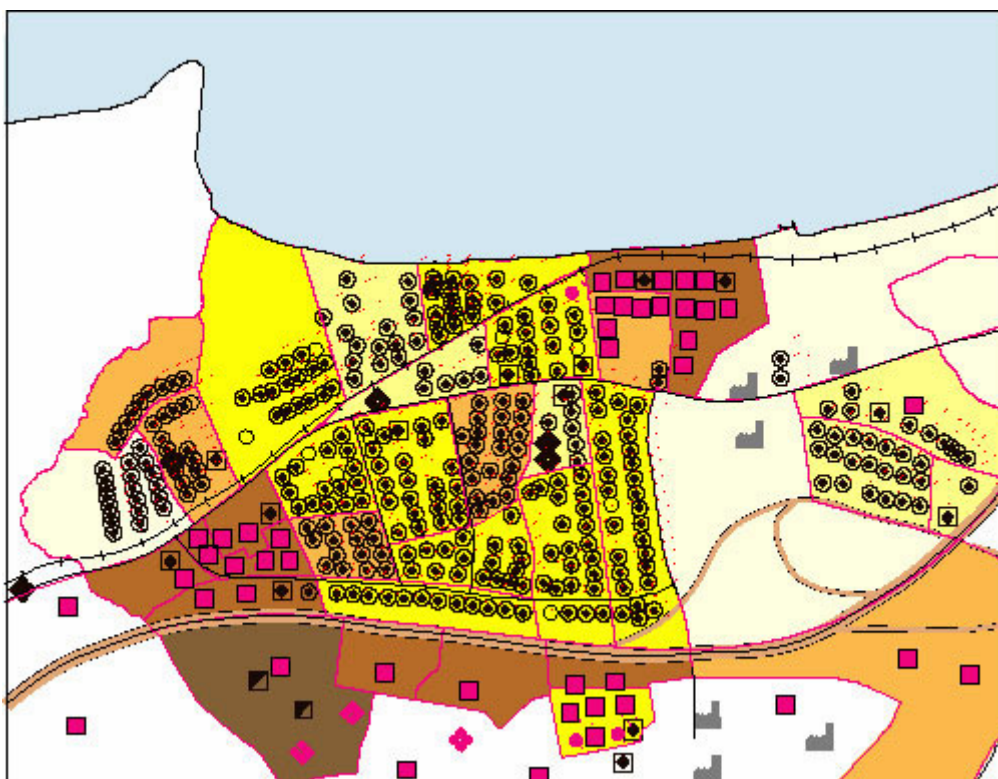
Different layers of information can be presented together or separately. There are a number of interesting GIS applications which are useful when working with energy planning. One example is the "heat map" presented below. It shows the location of heating plants in one layer, and heat density in another layer. A base map with roads and streets, lakes and rivers and the municipality border constitute the background.

"Heat map" - a GIS tool including several levels of information for ALEP

In a "heat map" you can combine information of different types on a GIS map:

- The existing demand devices per demand sector, and
- The heat density: The heat density is the total useful energy demand in a certain settlement zone, divided by the area of this zone. The unit could be GWh/km<sup>2</sup>, kWh/m<sup>2</sup> or MW/km<sup>2</sup>.

By combining these on the same map, you can e.g. get an idea of the possibilities to expand the district heating system.



**Figure 4-14:** A computer-based "heat map"

*Explanation of fig. 4-14:* The dark brown areas have the highest heat density and the light yellow the lowest. Demand devices in single family houses are given as circles; e.g. a single family house using an oil boiler is shown as a circle with a spot in the centre. Rectangles are used for multi family houses; e.g. a red

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*rectangle illustrates a multi-family house connected to the district heating grid. Commercial buildings are symbolized by rhomboids.*

### 4.3 The comprehensive analysis

The purpose of the comprehensive analysis is to give a foundation for the choice of development for the local energy system as a whole. It goes without saying that those who design a local energy plan cannot control the development, but their task is never the less to derive the development they consider best, based on available objectives and constraints, and then convince the relevant decision-makers to implement it. The comprehensive analysis serves as a basis for decisions on the future local energy strategy.

Such a strategy, however, cannot be based on a comprehensive analysis alone. Detailed analyses also have to be carried out. Depending on the chosen approach, strategic or project oriented, the comprehensive analysis will have different contents and importance for the ALEP project. This chapter describes how the comprehensive analysis can be realised, based on a number of good examples.

The comprehensive analysis is also important for the learning process. During the process of the comprehensive analysis all participating parties meet and deal with many of the central issues in the project. It is of particular importance that there is ongoing dialogue between the participating project groups and the working group responsible for the comprehensive analysis during the whole process, in order to establish continuous information exchange between them.

A full description of the different stages of the comprehensive analysis can be found in chapter 3. The different activities are briefly listed here. The planner, and the planning groups, will (as described at length in chapter 3):

- base the comprehensive analysis on the description of the present situation (see chapter 4.1 and chapter 3.2 and 3.3);
- find suitable ways of representing the local energy system (see chapter 4.2);
- decide upon the objectives for the study (see chapter 4.3.2)
- establish a RES (see chapter 4.2);
- select a computerised energy system model (see appendix A.1);
- develop a validated database (see chapter 4.5);
- construct one base scenario and several alternative scenarios from a reasonable set of assumptions about future development (see chapter 4.6), and run the model;
- analyse the model runs and present the results (see chapter 4.7)
- use an iterative process involving the comprehensive study and the subsystem and component studies within the ALEP project (see chapter 4.4).

#### 4.3.1 Description of the present situation

The basis for the comprehensive analysis is the description of the present situation, but it is recommended that the planner already begin the comprehensive analysis in the preparation phase. Then the description of the present situation can be designed to fit the demands of the comprehensive analysis. This "iterative process" in the beginning of the ALEP is the least time consuming, and is described in detail in chapter 3.2 and 3.3 above.

The comprehensive analysis is often closely connected to the use of a certain computer model. It is however, not wise to let the capabilities of a computer model shape the structure of the comprehensive study. It is better to develop the principal design of the comprehensive study first, then choose which model to use, and finally find the necessary balance between what you would like to do and what the model can actually achieve. (An overview over available computer models is provided in Appendix A.1.)

An evaluation of the description of the present situation should include a summary of the important questions to be treated by the ALEP -study, an overview of existing studies, a definition of the "local energy system" and its system boundaries etc. (see chapter 4.1).

### 4.3.2 Objectives

The process in which the objectives of the study will be decided should be started in the preparation phase as well. This process however, takes time, because it must be based on a broad discussion. The final determination of the objectives is not always made before the main study is started. It is instead most often one of the phases of the comprehensive analysis.

In an ALEP study, objectives of two principally different types are used:

- a) National restrictions, which can be treated as "fixed objectives" that the local government and decision-makers cannot influence.
- b) Objectives originating from local needs, which are formulated locally

Typical objectives, of both types, formulated by decision makers for local energy planning deal with:

- (1) Reduction of emissions
- (2) Increased use of renewable energy sources
- (3) Increased energy conservation

We suggest four criterias that objectives should fulfill in order to be useful for ALEP. The objectives should be:

- hierarchical,
- quantitative (magnitude and time),
- consistent and
- realistic.

These four criteria are useful to bear in mind when developing objectives for the energy plan.

During the analysis the objectives (e.g. objectives 1-3 above) must be operationalized. Only through this process can the objectives become useful for the comprehensive analysis. The following is illustrative, and shows one way of developing the three objectives listed above. Here the aspect *quantitative* has been defined much better, making it possible to measure whether or not the objectives have been reached.

- 1) *Emission targets for the energy sector in the municipality:*  
**Carbon dioxide** emissions from combustion of fossil fuels should be reduced by 8 % during the period 1990-2010, in accordance with the agreement signed by the European Union at the UN-conference in Kyoto, Japan, 1997.  
**Sulphur** emissions should decrease by 25 % by the year 2010, calculated from the 1995 level. Sulphur content in fuel oil must not exceed 0,1 %.  
**Nitrogen oxide** emissions should decrease.  
**Hydrocarbon** emissions should decrease through a high degree of substitution of old wood fired boilers by new boilers with accumulator.
- 2) *The use of **renewable energy** sources should increase. By the year 2000 renewable energy should make up for at least 50 % of the heat production which takes place in municipal energy production plants. This share should increase to 75 % by the year 2010.*
- 3) *Efforts for **increased energy efficiency and energy conservation** should be intensified. The objective is a 2% reduction of the useful energy demand for space heating per year, until 2010, and a 1% reduction of the demand for electricity for appliances in residential and commercial buildings per year during the same period.*

***The municipality should set a good example*** in its own administration and companies, as well as through the introduction of measures which contribute to the fulfillment of the above mentioned goals.

Another criterion for useful objectives is consistency:

- (1) internal consistency (between different local objectives), and
- (2) external consistency (between local and regional or national objectives)

The forms of consistency are exemplified below.

*The goals of the energy plan above are in accordance with the municipality's goals in the physical plan and in the Local Agenda 21 plan (first form of consistency). The goals should strive for consistency with the national and regional goals in the energy and environmental fields (second form of consistency). However, in three cases some important deviations from the regional goals were made:*

- I) *The regional goal to reduce the total use of energy was excluded, since it was in conflict with the municipal goal to encourage large industrial expansion. The specific energy use (energy use per useful unit) should, however, decrease through more efficient use of energy. This is an important goal (goal 3 above).*
- II) *The regional goal to reduce the total emissions of carbon dioxide from the energy and transportation sectors by 10 % between 1990 and 2000 was also not adopted. It was practically impossible to achieve this goal, both regionally and locally, since the 1997 level exceeds the 1990 level, and only a few years remain until 2000. The goal of the energy plan is instead formulated in accordance with the agreement for the European Union at the UN-conference in Kyoto, Japan, 1997, i.e. a reduction by 8 % from 1990 to 2010. The goal is also limited to the energy sector (including industry), since the municipality has few possibilities to influence the transportation sector.*
- III) *The reduction targets for nitrogen oxides and hydrocarbons have not been quantified. It was only specified that the emissions from the energy sector should decrease. The regional goals were a reduction of nitrogen oxides by 30 % and a reduction of hydrocarbons by 50 % by the year 2000. None of these goals will be achieved in the region. Emissions of both substances originate to a large extent from the transportation sector and can therefore be only affected marginally by local measures.*

For those who formulate and decide on local objectives it is important to be aware of the limitations to influence the development. It is not advisable to have goals which are unrealistic or deal with issues beyond their control.

### **4.3.3 Scope of the analysis**

The scope of the ALEP analysis is to a large extent determined by the objectives. This is true for different dimensions of the planning:

- The choice of geographical area to be studied – system boundary (see chapter 4.1.4)
- The size of the analysis resources allocated to different parts of the energy system
- Which analysis models are being used for the comprehensive and subsystem studies

When you formulate and decide on the objectives it is important to be aware of the limitations of the local decision-makers influence.

### **4.3.4 The choice of approach**

Different approaches for the comprehensive analysis can be chosen. If the comprehensive analysis dominates the ALEP, a *strategic approach* has been chosen. In a *project oriented approach* the main work is concentrated around the subsystem and component studies, and the comprehensive analysis helps the planner to co-ordinate the different projects.



The choice of approach is of strategic importance for the ALEP project. It helps to attain a good result in the most efficient manner, both in the comprehensive analysis and in the ALEP project as a whole. It also helps to drive (or accelerate) the learning process. Before starting the comprehensive analysis, we strongly recommend making a decision on their intended approach.

The strategic approach is focused around the comprehensive study. Around two thirds of the analysis work is allocated to the comprehensive study. It is the main work of the ALEP project. The comprehensive energy system model has an extensive system boundary. It models interdependencies between subsystems and long term developments, but uses simplified descriptions of subsystems. The comprehensive analysis generates information exceeding that of individual subsystem projects. Thus the comprehensive analysis will be strategic for the selection and orientation of detailed studies. Detailed projects on the other hand have the advantage of increasing the degree of detail and credibility of the comprehensive study. Comprehensive analysis and detailed studies can be realised in parallel. Information flows in an iterative process between the two levels. All analyses and models use a common, and validated, database. One should be prepared to commit sufficient resources, and to firmly guide the project through a political steering group or the like.

In the project oriented approach LEP is started with subsystem studies. On the basis of existing subsystem projects, the planner aims to co-ordinate the projects through a comprehensive study. The content and scope of the comprehensive study is thus guided by the focus of the detailed projects, but the study is designed broadly enough to describe the entire energy system. Besides the detailed projects, the comprehensive energy system model contains only a small number of additional subsystems (using simplified descriptions of subsystems) but also includes long term aspects and interdependencies between subsystems. As a result of the comprehensive analysis one may come to the conclusion that some subsystem projects should be enlarged or that additional projects should be started. The results from the ALEP project are nevertheless based mainly on the detailed studies. The comprehensive analysis is built on the data and inputs of the subsystem studies and should at least include the description of the present situation and one or two scenarios. The subsystem projects require the major part of the budget.

### **4.3.5 A pilot study**

If the strategic approach is chosen, a useful starting point is to run a pilot study.

In a pilot study all phases of the comprehensive analysis are run through in a short time using the comprehensive model with a simplified RES. This is possible if you use aggregated data with lower quality than used in the main study. It is often also necessary that the planner guides the work and discussions in the groups, to avoid too much focus on one of the single phases (e.g. the input data).

The main aim of the pilot study is to increase the understanding of the methods and models used, and to start the learning process coupled with the analysis of results. It is essential to reach results as soon as possible. It is the preliminary results which stimulate the discussion of the reference and working groups. They discuss the selections made in the strategy phase concerning objectives, scenarios, constraints and other inputs, before too much of the main work of the project is completed.

### **4.3.6 Structuring the problem**

For a successful project it is important to structure the problem well before beginning the main analysis. There are a number of factors which should be taken into account. Since ALEP is more than just technical analysis, there is a need for structuring of both technical and organisational aspects.

## The Technical Energy System

The Technical Energy System comprises all energy technologies in the community and all flows of energy to these technologies from outside the community, between the technologies and from the technologies to the end users. We structure, or represent, the Technical Energy System in the comprehensive analysis - and in the energy system models - by using:

- Reference Energy System (RES)
- Load and duration curves
- Geographical Information System (GIS)

These "models" for representation also help reduce the complexity of the energy system under study.

There are four factors in the environment of the Technical Energy System that influence the choice of energy technologies and energy flow paths. The factors are:

- Energy sources: the price and availability of energy carriers on international, national and regional energy markets, and the availability and cost of extraction of energy carriers from natural resources within the system boundaries;
- Useful Energy Demand: demand for energy services in different sectors and different geographical regions of the community;
- Technological progress: new, or improved technologies, for conversion and energy conservation, become available as new options for the system
- Physical environment:
  - \* Physical Constraints on the use of certain technologies, e.g., availability of natural heat sinks or heat sources, or the use of solar radiation.
  - \* Environmental Regulations, e.g., emission restrictions on individual plants, or on parts of the Technical Energy System, or on the whole system. These may also be expressed as emission fees or taxes.

Data and prognoses, for the development of these factors, are the most important input to the comprehensive analysis.

### Input data

The comprehensive analysis requires input data for the present situation (see chapter 4.1 above), and the development of the four factors in the environment of the energy system.

In the comprehensive analysis input data can be used as follows:

- (1) For model work non-aggregated data will be used as inputs to the energy system models:
  - the present use of energy carriers, e.g. fuels, electricity, district heat ...
  - the present demand of heat, tap water, steam, electricity ...
  - existing capacities of energy technology, e.g. plants, boilers, network ...
- (2) Outside the model aggregated data is used:
  - as the starting points when you include constraints to the model, e.g. a reduction of CO<sub>2</sub> emissions with x% compared to the present level.
  - as reference levels when you analyse the results from the model runs. It is, for example, useful to use the information of the present primary energy supply for the local energy system, when you analyse the results from the model runs for a certain period in the future.
  - for the presentation of input data and results.

The evaluations made in the description of the present situation can give useful information for all phases in the comprehensive analysis.

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## System boundary

The system boundaries for the local energy plan are important to define. It separates the Technical Energy System which will be included in the analysis from the system environment. In chapter 4.2 the system boundary is discussed further.

## Time horizon

The energy planner also will have to decide on the time horizon of the analysis. Two considerations may guide the decision: On the one hand, most investments in energy systems are long-term investments with a usual planning period of 20-30 years. On the other hand, recent changes in political, economic and even technical boundary conditions indicate that even a short period of 5-10 years may be difficult to assess in regard to major determinants of change. As a recommendation we suggest choosing a shorter time horizon for the detailed studies and a longer time horizon of up to 30 years for the comprehensive study.

## The system of actors/organisations in the energy system

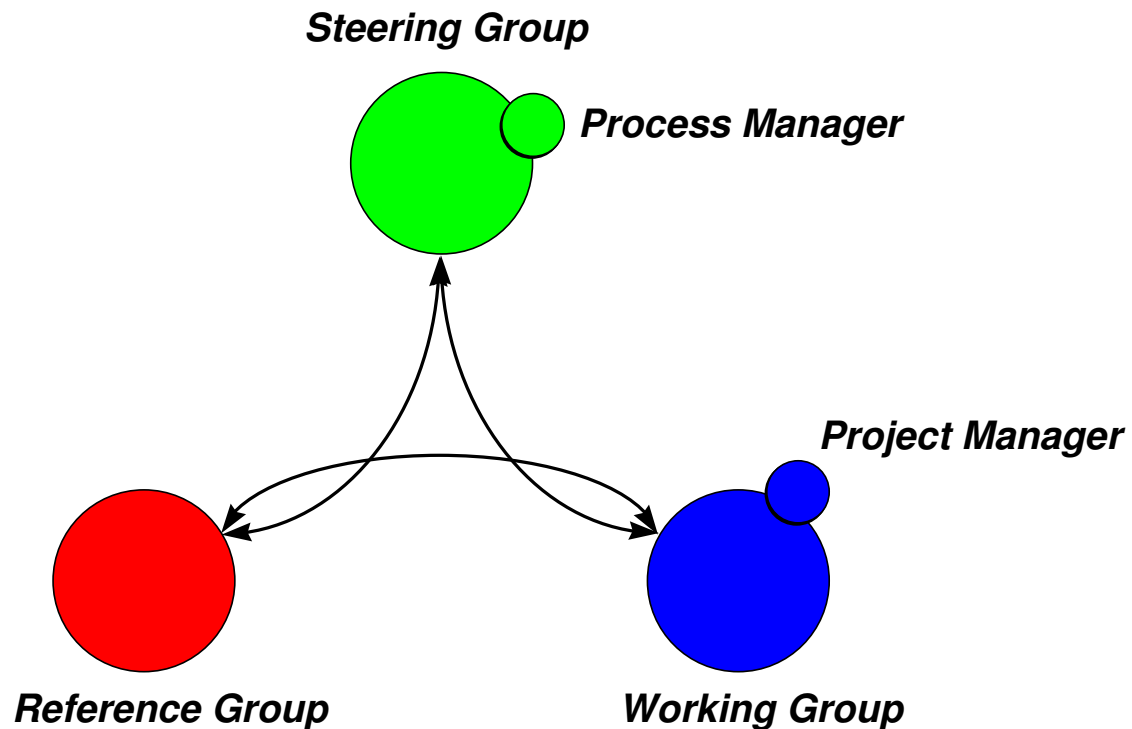
The ALEP planning approach is focused on technical aspects of planning and the integration of social and political processes. A planning approach which neglects the political aspects of planning often fails because of lacking consensus. Therefore the planning process must be embedded in an organisational set-up which includes all interested social, political and economic interest groups. Only early involvement and motivation of these groups will ensure that ambitious objectives can be achieved. Examples of actors within the planning process are:

- political decision-makers,
- representatives from utilities,
- representatives from the municipal or regional administration,
- industrial energy consumers, chambers of commerce,
- environmental groups.

The institutional organisation defines the roles of the actors directly or indirectly involved in the project. The institutional organisation should be tailored to the existing decision mechanisms within the area of investigation. These mechanisms may be quite different in European countries; therefore no general recipe for an institutional framework can be given.

As a general rule an organisational framework should be established which contains the following functions:

- Steering function: Setting goals and strategic directives, defining the political framework, resolving conflicts, suggesting decisions, approving the final report, approving contracts for external consultants. The steering group is not identical with the decision makers (e. g. municipal council).
- Process management (affiliated with the steering function): directing, controlling and promoting the process, communicating and solving problems, contacting relevant people, moderating meetings.
- Reference function: discussing and developing scenarios and strategies, providing data and knowledge, discussing models and model results, suggesting action plans, approving of final report.
- Working function: development and operation of the energy system model, analysing results, preparing reports.
- Project management (affiliated with the working function): supervision of project time and budget, leading and co-ordinating work, guiding all phases in the sense of ALEP.



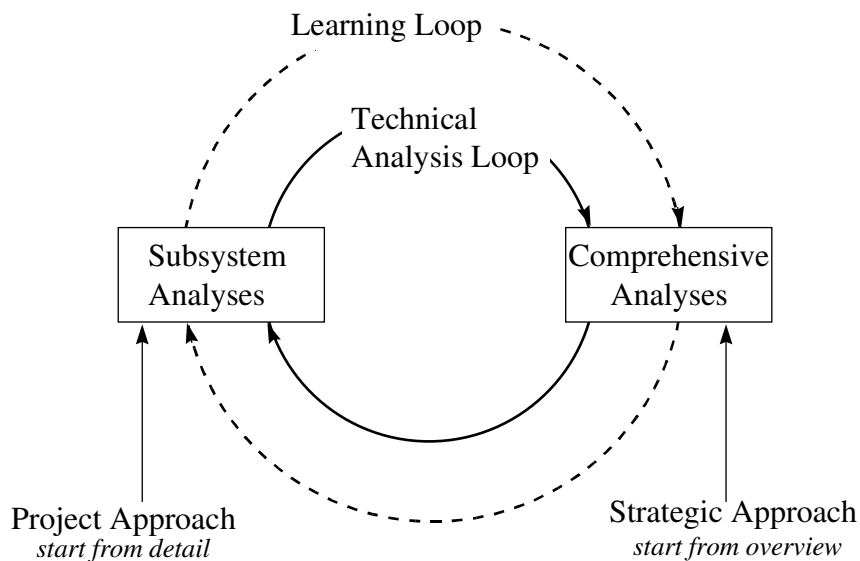
**Figure 4-15:** Example of an organisational set-up for ALEP

The figure above shows an example of an organisational set-up; other constellations containing for example only two groups are also possible. The steering group is not involved in the day to day business of the project. The process manager provides day to day support on behalf of the steering group. The involvement of the steering group is most important at critical points and at milestones of the project. The steering group plays a leading role, especially in the definition of goals and objectives at the beginning of the project and the decision phase at the end of the comprehensive study. The involvement of key persons from the very beginning is absolutely necessary to secure successful implementation. The reference group will be included in the project at the request of the working group as dictated by the progress of work.

#### Including a learning process in the ALEP

A learning process on the various social and technical aspects is quite important for the success of ALEP, because ALEP requires the understanding of problems and possible conflicting goals associated with the local energy system by the different interest groups. The learning process improves the ability of the parties to take an active role in the planning process. However, organisations can only learn through their individual members. The learning process for the individual members of the groups has four components:

1. learning about the technical system and the options for finding adequate solutions to problems,
2. learning about the complex interdependencies of economy, energy system, environment and society,
3. learning and understanding the objectives of other groups,
4. learning and mastering communication.



**Figure 4.16:** Two-fold loops of learning and technical analysis

The two-fold loop above shows the principle of the simultaneous processes of learning and technical analysis. The technical analysis loop consists of iterative considerations at different levels of detail and feed back of results (see also chapter 3.1 and 3.4). Simultaneously the learning loop improves the technical, communicative and organisational knowledge of the group members and their ability to understand and support the planning process. Two different approaches are possible (see chapter 4.3 for „strategic approach“ and „project oriented approach“). The strategic approach starts with a comprehensive analysis of the energy system. Although the strategic approach seems more logical and straight-forward, in practice it is often specific individual projects that provide the starting point for local energy planning. In this case the work proceeds from project oriented subsystem analysis to overall strategic considerations. The persons responsible for ALEP must be aware of obstacles to learning and create a communicative atmosphere within and between the individual groups where the learning process can be cultivated.

#### 4.3.7 Recommendation for the development of the local energy system

The comprehensive analysis provides the basis for a recommendation for the long-term development of the local energy system. When all work with the comprehensive analysis has been finished, choices and decisions have to be made. In the process of preparing those decisions one should ask:

1. What goals must the development achieve (see above);
2. Which measures are the best according to the targets;
3. Which are the best strategies for implementing these measures.

This means that the comprehensive analysis must result in a recommendation for concrete decisions to be made to reach the goals. In other words, it is not enough to conclude the comprehensive analysis with a set of scenarios showing different pictures of the future energy system. The challenge is to take the analysis further and make a choice regarding how the energy system should develop in order to meet the principle objectives.

The recommendations for the local energy system must be backed up by relevant strategies, distribution of responsibilities, etc., which are further described in chapter 4.7 below.

#### 4.4 The interaction between the comprehensive and the subsystem studies

The interaction between the comprehensive analysis and the subsystem studies is an important part of the work in an ALEP project. The co-ordination between the two should be reciprocal.

*The potential for energy conservation in Göteborg has been studied both in detailed subsystem analysis and as a component in the comprehensive analysis. It is valuable to exchange information between the studies. Typical information which could flow from the comprehensive to the detailed study is the future mix of energy production alternatives for specific user sectors, e.g. single family houses, future energy prices, e.g. district heating price, optimal energy conservation levels as a function of heating system and building type, etc. Information could also flow in the opposite direction, from the detailed to the comprehensive analysis.*

*If it turns out from the detailed study that, in some types of buildings, the optimal energy conservation levels are more or less robust with respect to assumptions about important parameters then it may suffice to just use the calculated energy conservation levels from the detailed study and simply reduce the net energy demands in the comprehensive analysis accordingly. The analysis of optimal conservation could then be left out of the comprehensive analysis. This greatly simplifies the comprehensive analysis and could facilitate better descriptions of other aspects of the total system.*

It is important to have an interaction of the comprehensive analysis with ongoing planning projects for subsystems and components. This is true regardless of the chosen approach for the comprehensive analysis (see chapter 4.3.3). Ongoing activities can affect the comprehensive analysis in a number of ways, and vice versa:

1. Use the same objectives and prerequisites for the comprehensive analysis and the subsystem studies

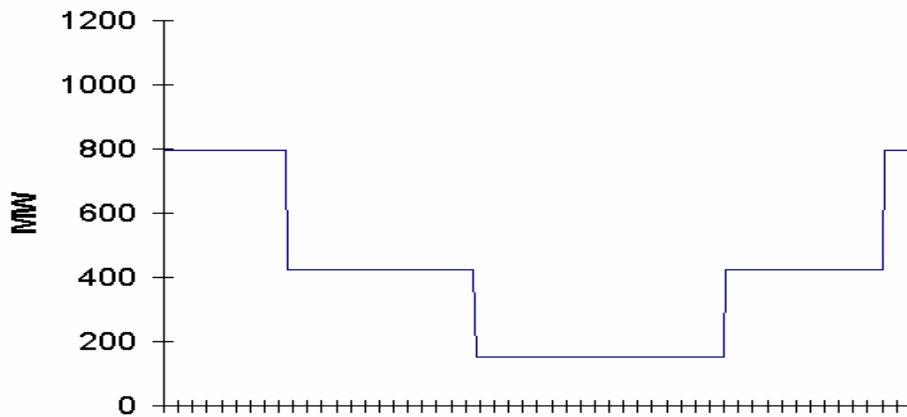
It is desirable to use the same objectives and prerequisites for all parts of the ALEP. Otherwise it will be difficult to draw general conclusions from the material and to co-ordinate the comprehensive and the detailed studies. However, this is easier said than done since some of the detailed studies may already be in progress prior to the start of the ALEP. In this case it may suffice to interpret the results intelligently, or to make a few additional calculations, in order to facilitate co-ordination.

2. How to deal with results that are contradictory

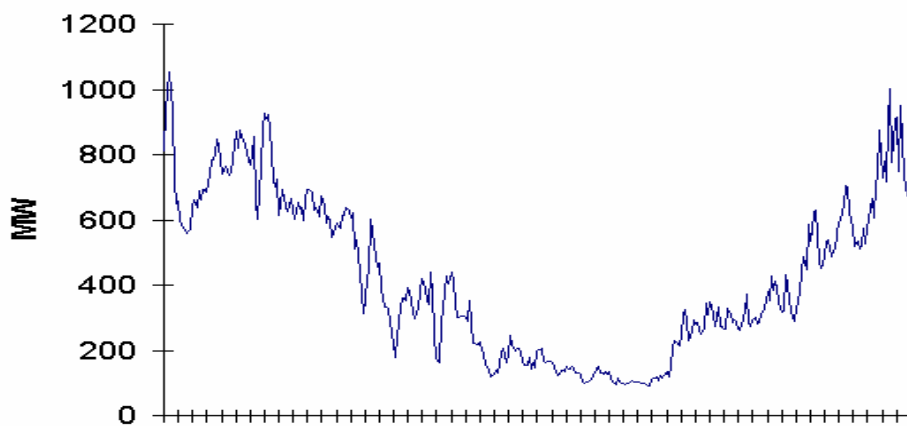
Two studies may produce different results even if the same assumptions have been used. If this happens it is important to understand the reasons and to present a clear explanation.

The example below gives an illustration of such a contradictory problem.

*In the Göteborg ALEP project the district heating production was analysed using both a comprehensive computer model, MARKAL, and a detailed production simulation model, MARTES. The results from the two models were not exactly the same, e.g. regarding the suggested size of a future CHP plant. This can partly be explained by the different degree of detail in the used load curve, (see figures below). The simplified load curve of MARKAL was the basis of the determination of the size of the CHP plant, since the load level during spring and autumn is constant. However, the load level during the winter is too short to make CHP production at that power level economic. The load curve of MARTES does not affect the size of a CHP plant in the same way.*



**Figure 4-17:** Load curve for district heating production, MARKAL



**Figure 4-18:** Load curve for district heating production, MARTES

The subsystem and component analyses have different purposes, for example:

- (1) To give a more detailed analysis of the development of a certain part of the energy system than is given by the comprehensive study. One example is the detailed analysis of the district heating production in Göteborg above.
- (2) To aggregate input data for the comprehensive analysis, and then - the reverse - to give the results from the comprehensive analysis a more detailed description.
- (3) To include knowledge and expertise from the subsystems within the comprehensive analysis.

We refer to conventional text-books on LEP to discuss methods for subsystem and component analysis.

## 4.5 Data requirements and data provision

### 4.5.1 Data acquisition

Data collection and preparation is a crucial part of planning. To factually work on data acquisition a clear picture of the individual analysis steps that are to be performed is necessary. Knowing precisely the data requirements requires in-depth knowledge of the system and the needs, options, and possible constraints. It also means that the steps of analysis – or more generally, the methodology – to be applied in the planning process have been decided upon.

### 4.5.2 Information systems

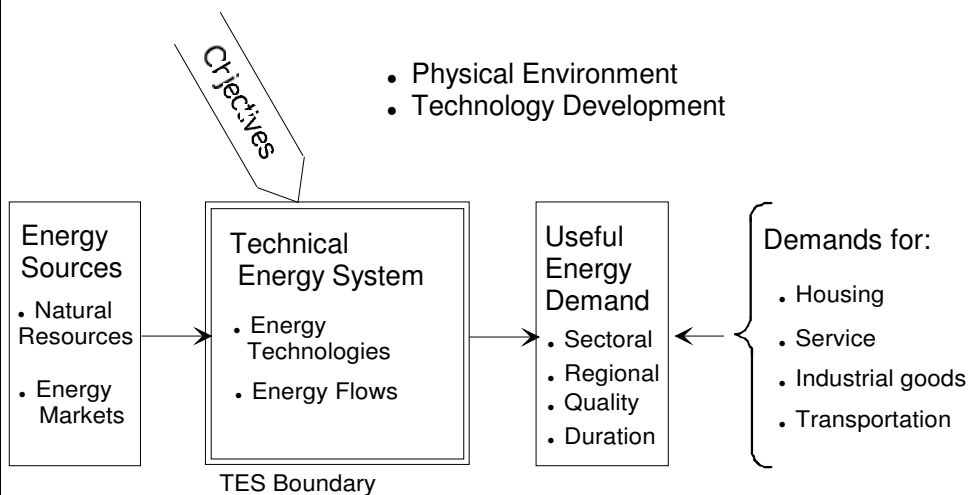
Databases for use by component analysis tools have already been mentioned. Data organisation, i.e. features of data input, storage, selection, display and retrieval, is usually an integral part of the software. In general, the tools make use of spreadsheet, database, or other standard software packages. Tools should facilitate data-set display or printout.

One should be very cautious in building on an omniscient information system providing all pieces of information necessary for the comprehensive study. However, frequently in communities the municipal administrations and statistical offices have useful databases. Other information can be obtained from statistical, market research, or other surveys, or from studies performed for comparable areas, for the larger regions or the country as a whole. Databases that also contain geographical data would be useful for facilitating visualisation of the various system elements by means of a geographical information system (GIS).

*If the databases are used in the daily work of administrations, then it can be assumed that the data is reliable and kept up-to-date, as required for the analysis. It has already been pointed out that further efforts by the planner or the Work Group is necessary to fill information gaps with additional assessments. The planner should make use of existing information systems to the farthest extent possible, but he should refrain from developing a pertinent system for use in the analyses that follow.*

#### Sources for data acquisition in Sweden

*Statistics and data for the energy sector are relatively easily accessible in Sweden. Here we present some of the most important sources, structured according to the description of the technical energy system shown in the figure below.*



**Figure 4-19:** *The Technical Energy System*

#### Energy sources

*The present prices on international, national and regional energy markets can be found in:*

- *national analyses made by e.g. the Swedish National Energy Administration*
- *analyses made by different branch organisations*
- *local market surveys.*

*Prognosis for the development of prices of energy carriers are presented by:*

- *the Swedish National Energy Administration (often not specifically presented as a fuel price prognosis, but rather found as input for their normal investigations.)*



- *branch organisations.*

*Availability and cost of utilisation of energy sources from resources within the system boundaries:*

- *local sources, e.g. industries with waste heat, industries producing by-products, e.g. sawdust, municipal waste for incineration, etc.*
- *branch organisations.*

*Taxes and environmental fees:*

- *summaries made by the Swedish National Energy Administration*
- *summaries from the Swedish Fiscal Administration*
- *branch organisations.*

### ***Useful energy demand***

*Data on the demand for energy services in different sectors and different geographical regions of the community can be found both at the national office for statistics and at local sources, such as municipal administrations/companies and energy utilities. The following is a briefing of the data sources for the different demand categories. For all sectors the goal is to find data on:*

- 1. the existing building stock, e.g. the number of single family houses with oil fired boilers*
- 2. the use of energy, e.g. the number of MWh used in single family houses heated by oil*

*The connection between 1) and 2) is the specific energy use, expressed in kWh/m<sup>2</sup>.year. Sometimes both 1) and 2) are available, sometimes only one of them. In this case, general data about specific energy use can be utilised. Such data is available in certain statistical products, e.g. MASTERFILE.*

*The following examples deal with how data on building stock and energy use can be found for different user categories:*

*Single family and multi family houses – heating: The number of buildings and/or area with different means of heating are available in the Swedish National Housing Inventory (FoB), ENERGIPAK and MASTERFILE. The energy consumption for buildings heated by electrical, district heating and natural gas can be found in the utility's customer database.*

*Single family and multi family houses appliances, etc.: This is also available in the utility's customer database. (The use of natural gas for cooking is negligible in Sweden.)*

*Commercial buildings – heating and appliances, etc.: Large property owners keep data about their buildings, e.g. in facility management files and data bases. The energy companies have data about the total use of electricity, district heating or natural gas; however there is generally not separation between heating and other uses. ENERGIPACK and MASTERFILE contain statistics about private buildings; MASTERFILE also includes estimates for publicly owned buildings.*

*Industry: Total use of different fuels and electricity per municipality is available from SCB's industry statistics. The energy companies have data on the total use of electricity, district heating and natural gas; however they are not divided between heating and other uses. The number and area for the majority of industries is available in MASTERFILE.*

*It is in general far more difficult to find data on commercial buildings and industry than on residential buildings.*

Source	Single family houses	Multi family houses	Commer- cial build- ings	Indus- tries	Updated
FoB	x	x			every 5 <sup>th</sup> year
Energipak (SCB)	x	x	(x)	(x)	every 6 <sup>th</sup> year
Masterfile	x	x	x	x	every 6 <sup>th</sup> year
Energy company registers	x	x	x	x	every year
Large property owners		x	x		every year
SCB's energy statistics	x	x	x		every year (survey of 20,000 buildings)
SCB's industrial statistics				x	every year

**Table 4-2:** A summary of sources for statistics regarding "the useful energy demand" in Sweden

<p><b>Information on technologies:</b></p> <p><b>Existing equipment</b></p> <ul style="list-style-type: none"> <li>• Large scale energy conversion plants: Data (performance, costs etc.) is available from the owners.</li> <li>• Distribution system: Data (performance, costc etc.) is available from the owners</li> <li>• Small scale energy conversion plants: Market surveys etc.</li> <li>• Energy conservation technologies: Market surveys etc.</li> </ul> <p><b>New equipment</b></p> <ul style="list-style-type: none"> <li>• Large scale energy conversion plants: Official sources, national investigations, technology data bases, manufacturers</li> <li>• Small scale energy conversion plants: Market surveys, etc.</li> <li>• Energy conservation technologies: Market surveys, etc.</li> </ul> <p><b>Information on environmental issues:</b></p> <ul style="list-style-type: none"> <li>• Emission statistics are available from official sources, e.g. The Swedish Environmental Protection Agency and the County Administrations. Measurements are continuously being taken at large plants.</li> <li>• Regulations for allowed emissions are available from official sources (e.g. Web-Site of environmental ministries)</li> </ul> <p><b>General remark:</b></p> <p><i>If data is missing it may be necessary to initiate a detailed study (see chapter 4.4 above).</i></p>
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### 4.5.3 Data documentation

If the subject and the objective of the analysis is defined, a step-by-step approach to develop the database to be used for the local model must be followed. Data from a variety of sources is to be assembled in this database. A database documentation system is needed for drawing up the single data elements, quoting the referenced material, outlining the calculation steps and assumptions made, and finally presenting the data as model parameter values. Data documentation is necessary to produce information that can be discussed, put in question; improved, etc. Documentation of the input data is also a prerequisite for the model results to become acceptable and will be useful to the working group in later work phases.

## 4.6 Analysis and presentation of results

### 4.6.1 Use of scenarios

Generally, one run of the model used for a specific ALEP project makes use of one set of input data and generates one set of related output information.

However, software tools allow for parametrisation, i.e. the presentation of one or more pieces of output information as a function of varying values of one or more parameters of the input data. This feature helps - with the steps of analysis and when discussing results with the working groups - to visualize effects of an especially important or doubtful parameter value on the result. For example, the variation of the maximum allowed CO<sub>2</sub> emission used in the comprehensive study resulted in different patterns in the resulting primary energy mix; or, in the component analysis, by cost increments used to stepwise change the investment costs for a CHP plant, the effect on the specific heat and electricity costs could be shown.

In general, to hedge against uncertainties of far-reaching projections or otherwise doubtful input data, different paths of future development involving more complex changes to the model database may be analysed, i.e. variations of more than one model parameter value are necessary. For example, it will usually not suffice to vary the price of coal at one point in time - rather the period values throughout the time frame will have to be changed for an assessment of a "price scenario". Furthermore, taking into account the interdependency of prices of the various energy carriers, an alternative price path for coal should trigger (different) price changes for other energy carriers as well.

Consistent hypotheses of the prices of relevant energy carriers over the study time frame have to be assessed in separate model runs and the results analysed thereafter as discussed in Chapter 4.7. Each hypothesis must be based upon predicted global economic developments, as well as conditions specifically connected to the area of investigation. This is perhaps the most difficult step in scenario analyses.

It is also common practice to consider hypotheses of the development of energy demand. Different supply options for newly developed areas, of performance of local industries, and effects of overall economic development, such as the discount rate for investments, characterise the hypotheses. Furthermore, each hypothesis must be *consistent*, i.e. projections for the various demand sectors must follow the same underlying assumptions. Such hypotheses are appropriately assembled in „*scenarios*“, each resulting in a model database and output information of a model run, and the set of scenario results allows conclusions to be drawn on uncertain future developments.

### 4.6.2 Elements of scenarios

The following specific technical terms have become familiar to modellers working with comprehensive models:

**Scenario:** A scenario is the description of a potential development of the analysed system during the time frame. We refer to the case studies in chapter 5 for scenario examples.

**Context:** All development underlying a scenario that are not subject to the control of local authorities are denoted as the context or the *system environment*. Assumptions regarding four factors in the system environment in principle make up the context. This is discussed further in chapter 4.3 above.

**Strategy:** All developments underlying a scenario that can potentially be achieved through efforts of local authorities particularly for this scenario are denoted as the strategy, for example the intended expansion of district heating.

**Context parameters:**

Context parameters characterise the conditions of the existing system boundaries.

**Strategy parameters:**

describe the measures of the strategy.

**Reference scenario:**

For the reference scenario, both the context and the strategy project the trends of the past into the future. No fundamental changes are assumed to take place during the time frame chosen for the comprehensive study. The reference scenario serves as the basis for evaluating alternative scenarios.

Although the concept of scenario techniques has its origin in the area of comprehensive studies, it is considered useful for component studies as well. For both categories, this concept facilitates a top-down approach to structuring and documenting data, performing data acquisition and communicating within the project team.

### 4.6.3 Formal and logical plausibility checks

During the course of the ALEP project the Working Group and the Reference Group are involved in the systematic evaluation of the results of the model runs. Frequently, computation, scenario analysis, and modification of input data are repeated until useful results are obtained. This iterative process requires some time depending on the size and complexity of the model, and the experience of the working group.

The very first results of LP model runs may include so-called infeasible solutions. Infeasible solutions are generated, when conflicting boundaries are set.

In order to generate feasible solutions and to separate useful results, formal and logical plausibility checks are provided by the energy models. Formal plausibility checks trace formal input errors such as typing, unit or dimension mistakes. Logical plausibility checks eliminate logical deficits in the input elements, determined by incomplete problem definition.

A powerful instrument for plausibility checks is the information embodied in shadow prices, slack periods and reduced costs of an LP-solution (see fig. 4-21 for an example).

### 4.6.4 Example for building and selecting scenarios: The Göteborg case study

Five different scenarios have been analysed in this planning project. The scenarios are defined by a number of assumptions describing the context of the energy system.

The following scenarios have been calculated and analysed:

- Reference scenario (or Base scenario): This scenario is based on the assumptions considered most probable. It is assumed that the price of electricity increases by 50%, up to 320 SEK/MWh, and that the seasonal differences decrease significantly compared to the base year 1993. In 1996 additional industrial waste heat becomes available (from the Preem refinery). For the emissions calculation we assume that imported electricity is produced in coal fired condensing power plants. If gas fired CHP production is introduced by the LP model, we limit the allowed capacity to 350 MW electricity.
- "Unlimited" CHP expansion: Here the size of a possible gas fired CHP plant has a high limit. Apart from this the assumptions of this scenario are identical to those of the reference scenario.
- Low electricity price: In this scenario the electricity price is assumed to remain at the present level. Other than the price, the same assumptions as the reference scenario are used.
- High real yield requirements: The real interest rate is used for the calculation of present values, etc. Here we assume 12 %, instead of 5 % as in the reference scenario. All other assumptions are identical to those of the base scenario.

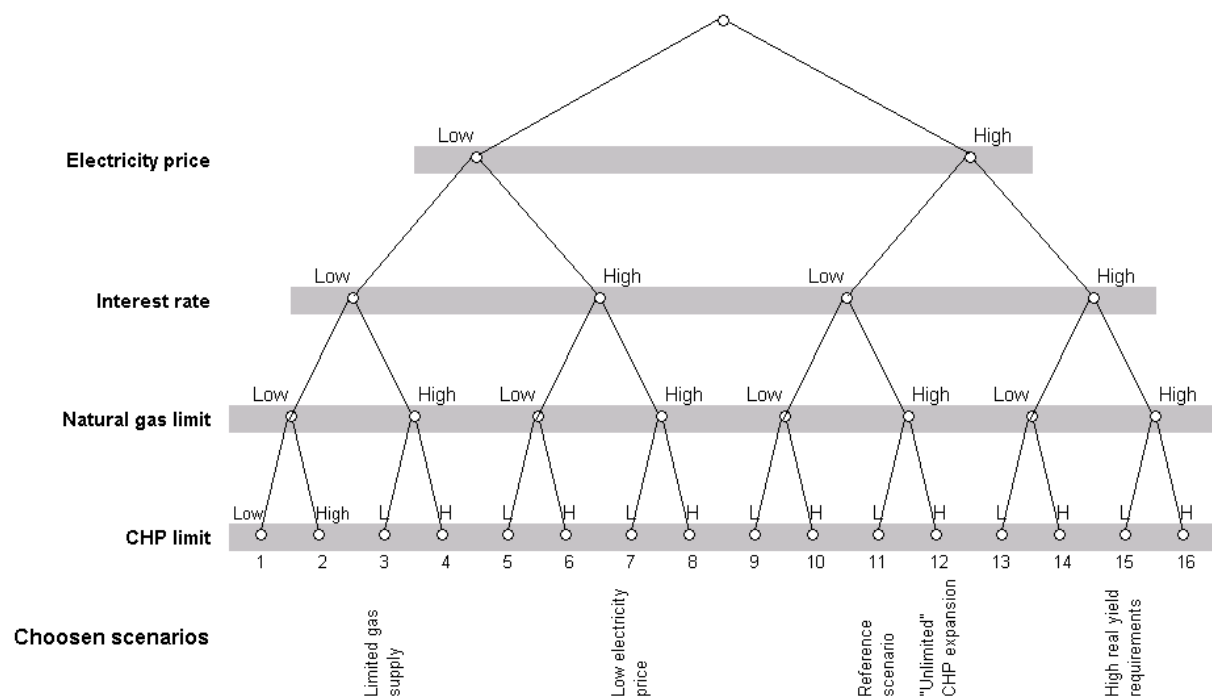
- Limited gas supply: Most scenarios show a large expansion in the use of natural gas. This would make Göteborg very dependent on natural gas, which is presently only available from one supplier. Therefore we have designed a scenario where the supply of gas is limited to 3 TWh/yr, to illustrate a situation where dependence on natural gas is not allowed to reach the same level as some of the other scenarios.

These five scenarios have been chosen since they illustrate various development trends which differ greatly in some cases. When analysing the results it is important to observe how different parameters are influenced by the various scenario assumptions. Comparison of the scenarios indicate the robustness of different strategies.

#### 4.6.5 „Meaningful“ scenarios

In scenario analysis, useful results are filtered from those considered not useful. This evaluation requires that the working group have experience in both mathematical modelling and energy economics. After the separation of useful results from a set of scenarios has been completed, it is essential to find a suitable format for cross-scenario presentation.

It is advisable to select one of the scenarios as the reference scenario (or base case) for scenario analysis and presentation. All other scenarios are discussed in relation to the reference scenario. In most cases the reference scenario has already been selected in parallel to the scenario definition. It is however neither necessary nor important that the reference scenario be the scenario with the highest likelihood of occurrence.



**Figure 4-20:** The five scenarios chosen for the Göteborg case study

Due to the normally large amount of information contained in the scenario results, it is necessary to find an adequate way to extract relevant information and a gradual access to the presented material. A very useful approach is the creation of summary tables for cross-scenario presentation showing some selected main indicators, such as primary energy consumption, total system cost, emissions for several pollutants etc., in order to provide an overview.

Those summary tables allow a quick survey of the main differences between the scenarios. For more detailed analyses, especially with respect to the technology mix, more in-depth investiga-

tions for individual scenarios are necessary (see chapter 5.4 for more information on the Göteborg case study).

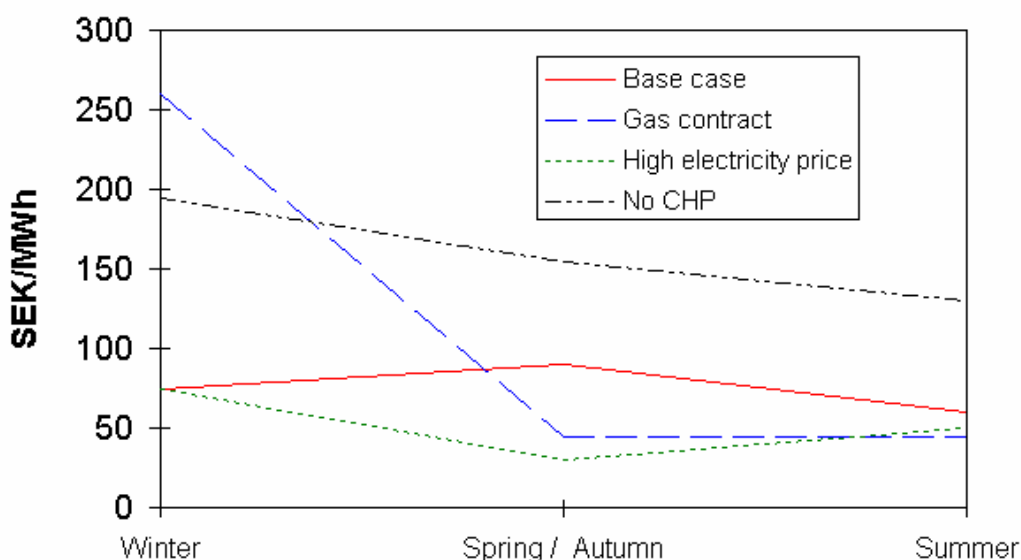
### Result of specific interest: Shadow prices of district heating in Göteborg

The ALEP approach often includes the use of optimised computer models such as MARKAL. Such models typically produce so called shadow prices for various energy products, e.g. district heating. The shadow price can be presented for different time intervals, e.g. winter, spring/autumn and summer. The shadow price is an indicator of the cost for the next kWh of energy that is to be supplied. This information is very useful for the understanding of the production cost by season, and for pricing strategies of the utility.

The shadow price for district heating production is a parameter which is interesting to analyse in a scenario analysis. In the Göteborg energy plan the shadow prices for district heating for a large number of scenarios were compared. Figure 4-21 shows the shadow price for each season. The scenarios are:

- **Base case:** No restrictions on when natural gas can be used, slightly higher electricity price than the present
- **Gas contract:** Winter, spring and autumn use no more than 35% above the average level, slightly higher electricity price than the present.
- **High electricity price:** Much higher electricity price than the present, no restrictions on the use of natural gas.
- **No CHP:** No new CHP plants allowed, no restrictions on the use of natural gas, slightly higher electricity price than the present.

(Natural gas is a fairly new fuel for Göteborg. During an introductory period there were no time-dependent or temperature-dependent restrictions on the use of natural gas, i.e. the seasonal profile of gas consumption was unconstrained.)



**Figure 4-21:** Shadow price for district heating production for each season

Figure 4-21 shows that there are significant differences between the scenarios. In the base case the shadow price remains fairly constant over the year. To a large extent CHP production determines the shadow price during winter and spring/autumn. Since the electricity price is higher during the winter than during spring/autumn, the resulting district heating cost is slightly lower.

The introduction of a natural gas contract that specifies the consumption profile has a drastic effect on the shadow price. Since the need for natural gas is higher during winter (due to high

heating demand) the restriction on winter consumption to not exceed the average consumption by more than 35 % leads to a lack of gas. The very high shadow price of district heating is a consequence of this. However, for all seasons except winter the shadow price is lower than in the base case. This can also be explained by the natural gas contract. One way to be able to use more gas during winter, when the price is very high, is to increase the average consumption of gas. This could be expressed in a low gas price during all seasons except winter. This results in low shadow prices for district heating during these seasons.

The high electricity price scenario makes CHP production more competitive and thus the cost of district heating is reduced. This can be seen through the low shadow prices.

A situation without CHP production leads to a less energy efficient supply system. It is then not possible to take advantage of the more competitive electricity produced with CHP plants in order to lower the overall cost of district heating.

#### 4.6.6 Robust recommendations and „if-then“ hints

In order to derive recommendations from the scenario analysis, **robust strategies** are to be distinguished from „if-then“ strategies. A robust strategy is defined by those elements which appear in (more or less) all scenarios, whereas an „if-then“ strategy is based upon the choice of a few conditional elements appearing in specific scenarios only.

*Two examples from the first ALEP study that were carried out in Jonkoping, Sweden in 1981:*

*(1) The competition between conservation and supply:*

*The comprehensive ALEP results show the robustness of energy conservation. As a result, the city council decided to boost the budget for energy conservation in buildings owned by the municipality by 5,5 million SEK.*

*(2) The optimal choice of fuel for D.H. production:*

*The comprehensive ALEP results show the robustness of building a D.H. system, but a big debate arose over which solid fuel to use in the CHP plant: hard coal or peat. The ALEP results show that the optimal choice is very sensitive to the assumptions used. The city decided to invest in fuel flexibility.*

#### 4.6.7 Derivation of recommendations

From the discussion of the scenario results recommendations can be derived for measures to be proposed by the Reference Group. In cases where the conclusions are not clear and recommendations for measures cannot be derived, the scenario computations must be repeated with a modified model structure and input data or/and a higher resolution.

The measures which are finally recommended and adopted by the Reference Group should first be separated into organisational and investment measures. They should then be categorised according to the time frame (ad-hoc, medium-term, long term measures) and characterised for possible interactions with each other – see chapter 5.4 as an example.

Finally priorities must be set by the Reference Group for the recommended measures in order to arrive at an action plan for implementation. Without such a prioritisation, implementation of measures will likely be rather unrealistic, since no clear signals are given to the executive bodies.

Ranking along priorities is a complex process of judgement and balancing of different criteria. Normally elements such as

- investments
- emissions of various pollutants and greenhouse gases
- technology development effects
- labour force effects

- social impacts
- external effects

and other items are to be considered in the assessment.

**Example: Shortened "action plan" for Göteborg**

**Production and Distribution Systems:**

*A natural gas-fired combined cycle plant (~250 MW electricity)*

- *Continue the planning for a new CHP plant. Responsible: Göteborg Energi AB*

*The waste incineration plant - electric capacity more than 20 MW.*

- *Utilise the power production possibilities at the waste incineration plant optimally. Responsible: GRAAB*

*Integrate private and municipal owned heating systems not connected to the main D.H. system:*

- *Continue the expansion of the main district heating system. Responsible: Göteborg Energi AB*

**Emission reduction:**

*The City of Göteborg and Göteborg Energi AB are front-runners in the use of low emission fuels, low emission combustion technology, and flue gas cleaning technology:*

- *Develop flue gas cleaning technologies further. Investigate NO<sub>2</sub> emissions from energy production plants. Responsible: Göteborg Energi AB*
- *Apply emission standards for new wood fired boilers in residential areas. Responsible: The consumer board*
- *Change from CFC to refrigerants which are less harmful to the ozone layer. Use environmental friendly cooling production. Responsible: Göteborg Energi AB*

*The transportation sector is one of the largest single sources of emissions:*

- *Demand that only vehicles with a higher environmental standard can be used in the central part of the city. Responsible: The transportation board*
- *Apply environmental standards when procuring transportation services. Responsible: All concerned committees and boards*

**Renewable Energy Resources:**

*Biomass fuels are of increasing interest and can be integrated into Göteborg's energy production and supply systems.:*

- *Study the possibility of using biomass as fuel in existing coal fired heating plants. Responsible: Göteborg Energi AB*

*Energy production at the waste incineration plant could be increased through the use of construction waste and waste from forestry:*

- *Expand the existing waste incineration plant. Responsible: GRAAB*

*The sewage treatment plant produces a large quantity of sludge, from which methane gas can be extracted and used in vehicles, central heating plants, or both:*

- *Utilise the available methane gas from the sewage treatment plant. Responsible: GRAAB, the transportation board*

*Göteborg has several medium-sized wind power plants:*

- *Participate in the building of further wind energy plants. Responsible: Göteborg Energi AB, the building committee*

**Energy Conservation:**

*It is important for Göteborg to utilise the existing potential for energy conservation.*

*Reducing the overall electric and heating energy use by 2% per year:*



- *Create task plans for more efficient use of energy. Increase investments in energy conservation measures. Evaluate the results of energy conservation annually. Responsible: The property management agencies*

*Göteborg Energi must report to the City Council how much electricity, natural gas and district heating it delivers annually:*

- *Evaluate how the use of energy develops. Responsible: Göteborg Energi AB*

*The best time to influence the property owner is during initial planning for construction or during building is being renovated:*

- *Provide an information and advisory center for developers, builders, consultants and contractors. Responsible: Göteborg Energi AB*

#### **Research and Development:**

*Göteborg Energi's Board of Directors has authorised the Company to invest a specific budget for various research and development projects:*

- *Cheaper systems for connecting single family houses to D.H. Responsible: Göteborg Energi AB*
- *Research & development efforts. Responsible: Göteborg Energi AB*

#### **4.6.8 The documents**

The presentation and publication policy for an ALEP-project is not a trivial matter, since decisions for specific energy strategies often involve a number of sensitive issues affecting various aspects of society. Release of information and presentation of results, therefore, have to be planned deliberately.

There are various recipients, expecting different types and details of information released from the ALEP -project:

- |   |   |                                  |
|---|---|----------------------------------|
| – the Working Group                     | } |                                  |
| – the Reference Group                   | } | <i>inside the ALEP -project</i>  |
| – the Steering Group                    | } |                                  |
| – universities, scientific laboratories | } |                                  |
| – consultants (mainly energy planners)  | } |                                  |
| – utilities                             | } | <i>outside the ALEP -project</i> |
| – manufacturing industry                | } |                                  |
| – the public                            | } |                                  |

It is advisable to decide from the outset which information should be released and at which phase of the project to those expecting the information. The project management group should normally be given the responsibility of disseminating the information. The Reference Group and Steering Group should monitor the dissemination activities.

Written documents may comprise four categories:

- an Executive Summary (< 10 pages)
- a Main Report (100 - 150 pages)
- Material Documentation during the ALEP project
- Working Papers and interim reports.

It is advisable to provide sufficient working time for such material and make use of them for internal and external communication as well.