HANDBOOK FOR PERFORMING FEASIBILITY STUDIES OF ALTERNATIVE ENERGY SYSTEMS

November 2008

SENTRO

Sustainable **E**nergy systems in **N**ew buildings – market in**TRO**duction of feasibility studies under the Directive on the Energy Performance of Buildings

Report no.: SENTRO/D4/2008/WP4
EC-contract: EIE/06/102/SI2.445679

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Intelligent Energy Europe

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Project description

The buildings sector accounts for 40 % of the EU's energy requirements. An estimated potential of one-fifth of the present energy consumption in this sector could be saved by 2020. To translate this potential into reduced energy consumption, the Energy Performance of Buildings Directive (EPBD) 2002/91/EC is intended to promote the improvement of energy performance of buildings. An important aspect (Art. 5) of the EPBD is that all member states are obliged to ensure that the feasibility of alternative energy systems is considered within national building codes for new buildings over 1000 m^2.

At present, barriers such as higher cost, lack of knowledge, experience and confidence are hindering alternative energy systems. If Article 5 is to have a substantial impact, feasibility studies of alternative energy need to become commonplace.

The SENTRO project aimed at developing and promoting an "optimal" approach in order to effectively incorporate the feasibility studies of alternative energy systems (art. 5 EPBD) in the common building practice.

The project started with an inventory on how European member states comply with the requirements of conducting a feasibility study for alternative energy systems for new buildings. The inventory also encompasses which policy they pursue to actively introduce this requirement. Subsequently, in the seven SENTRO countries (Denmark, France, Lithuania, Poland, Slovenia, Sweden and the Netherlands), an inventory has also been made of specific building practices as possible barriers for the implementation of Alternative Energy Systems (AES). After this inventory phase, tools have been developed to ensure that assessment of alternative energy systems will become an integral part in the common planning process of new buildings. These tools, such as universal checklists for requirements, handbooks and flowcharts, cover technical, financial as well as organizational aspects. Core of the project has been the testing of these tools in a field trial in the participating countries. Towards the end of the project, the experience has been disseminated through courses and conferences to policy makers and key actors in the building process.

Results (deliverables) from the SENTRO-project are:

- Information concerning the status of the feasibility study part of the EPBD in all EU-27 MS
- Insight into the barriers which are hindering the use of alternative systems and insight into possible solutions to overcome these barriers
- Supporting methods and checklist for embedding feasibility studies in common building practice
- Lessons learned from the field trial of these tools and evaluation of this element of the EPBD

Project partners

Ecofys Netherlands BV Netherlands	ECOFYS
SenterNovem Netherlands	SenterNovem
Building and Civil Engineering Institute ZRMK, Slovenia	ZRMK INSTITUT
Danish Building Research Institute, Aalborg University Denmark	SBi
Lithuania Energy Institute, Lithuania	LEI
Ecofys Poland Sp. Z.o.o., Poland	ECOFYS
Agence de l'environnement et de la maitrise de l'energie (Ademe), France	ADEME
SP Technical Research Institute of Sweden, Sweden	SP

Executive summary

The Energy Performance of Buildings Directive (EPBD) has imposed obligatory consideration of the technical, environmetal and economic feasibility of alternative energy systems (AES) for large new buildings. Most countries have transposed the requirements into their national legislation. However, operational legislation, technical guidelines and support tools are usually not yet in place. The objective of the EIE SENTRO project (http://www.sentro.eu/) is to develop an approach for effectively incorporating the introduction of AES feasibility studies into the common building process.

Part of the approach consists of this handbook, that is intended to be a guide on how to perform a feasibility study and to help actors to embed feasibility requirements in the common planning and building processes. First, a checklist is presented that has been developed in order to facilitate discussion between decision makers (investors) and other key actors involved in the building project. The checklist, - an Excel spreadsheet tool - should be used at an early stage to identify the most promising AES. The feasibility of these promising AES (two or more) must then be investigated in more detail. This handbook covers technical, economic, environmental and organisational aspects to ensure that a complete package of barriers is dealt with.

As support for raising awareness, appendix B of the handbook presents some good practice examples of feasibility studies performed in different countries up to now. In addition, appendix D lists frequently asked questions about alternative energy systems. Finally, appendix E of the handbook provides a list of tools in place that can be used when performing the feasibility studies.

Contents

Appendices:

1 Introduction

As of 4th January 2006, the EPBD requires all EU countries to include, within the legal and administrative framework of their building codes, minimum energy performance requirements, energy certification, calculation procedures, feasibility study requirements, and requirements for inspection of boilers and air conditioning systems.

Until now, the focus has been on calculation and certification methods for the energy use of new and existing buildings. Less attention has been paid to requirements to consider the feasibility of alternative energy systems (AES) for new large buildings (part of Article 5 of the EPBD). This introduction therefore explains the feasibility study requirements of the EPBD with respect to this handbook.

1.1 Article 5, EPBD

The requirements of the feasibility study are included in Article 5 of the EPBD.

Feasibility studies in Article 5 of the EPBD (2002/91/EG)
[..] For new buildings with a total useful floor area over 1000 m^2, member states shall ensure that the technical, environmental and economic feasibility of alternative energy systems such as:
- decentralised energy supply systems based on renewable energy,
- CHP,
- district or block heating or cooling, if available,
- heat pumps, under certain conditions,

are considered and is taken into account before construction starts

Background European legislation
The feasibility study requirements in Article 5 of the EPBD are included in order particulary to promote energy savings that can be achieved by energy-efficient supply systems and renewable energy systems, as opportunities for these systems are generally not explored to their full potential. Measures which reduce the energy demand (e.g. insulation) of a building are largely covered by other articles in the EPBD.

Member states are free to decide how they incorporate the obliged feasibility consideration into their national legislation. It can be carried out once, by the member state, through a study which produces a list of energy conservation measures for average local market conditions that meet cost-effectiveness criteria. Before construction starts, specific studies may be requested if the measure, or measures, is deemed feasible.

Some countries have already carried out a national study for average local market conditions. In Portugal and Spain, for example, this has led to obligations for solar thermal systems. In the Netherlands, such a study has provided the base for the Energy Performance Standard. However, based on experiences in front-runner countries (e.g. the Netherlands, Denmark, Sweden (Beerepoot, 2007), it is already known that, to achieve an optimal energy concept, it is necessary to take the local conditions and building characteristics into account. This means that individual consideration of opportunities for AES per building or per new building area is needed.

1.2 Aim of the SENTRO-project

SENTRO is a European project within the Intelligent Energy – Europe (IEE) programme. The project is called Sustainable Energy systems in New buildings - market introduction of feasibility studies under the Directive on Energy Performance of Buildings. The main aim of the overall project is to develop and promote an “optimal” approach in order effectively to incorporate feasibility studies of alternative energy systems in new large buildings in the common building process. This handbook is one of the elements of the SENTRO project.

1.3 Handbook including a checklist

The handbook aims to be a guide on how to perform a feasibility study and help actors to embed the feasibility study in common planning and building processes. This integration is necessary to ensure that an optimal effect of the EPBD - namely, substantial growth in the use of sustainable energy systems - will be achieved. Accurate communication about technical, financial, organisational and environmental requirements and opportunities are key elements for a successful implementation. The overall aim is to identify barriers and potentials for the implementation of alternative energy systems in order to overcome the barriers and use the potentials for successful implementation.

For Whom?

The handbook is structured in the same order as a feasibility study could be performed in practice, and is primarily aimed at two different target groups; *decision makers* and *consultants*.

An overview of the approach to embed the feasibility study requirements in the building process is aimed at the target group of ***decision-makers*** (*local authorities, real estate project developers, designers, installers*), and they are recommended to read particularly Chapters 2, 3, and appendices B and D.

Chapters 4 – 7 will give more detailed information on how to perform a feasibility study, and are primarily intended for ***consultants*** who will perform the required feasibility study for large buildings. Appendices A, C and E are also more aimed at supporting consultants in their work with article 5 of the EPBD.

What is in the Handbook?

In the SENTRO project **an approach** is developed and tested effectively to incoporate feasibility studies of alternative energy systems in the common building process. The approach considers how to perform a feasibility study. However, it does not provide any answers of what is feasible. An evaluation of the feasibility of an AES is largely a subjective matter. It will be seen differently by each key actor (municipality, real estate developer, installer etc.), whose views will be affected by environmental ambitions and economic preconditions.

The proposed approach of a possible implementation of AES feasibility studies consists of a checklist for a brief pre-feasibility study and of a method for a more detailed feasibility study of those AES regarded as being of interest.
First of all, unrealistic AES options must be filtered out, for which the checklist (detailed description in next chapter) can be used. The aim is to identify at least two interesting AES options considering the local conditions and building characteristics.
A more detailed feasibility study will then be performed for these AES of interest. The results must be available when the final decision is made (often at project stage) on the building's energy system.

Article 5 of Directive on Energy Performance of Buildings (2002/91/EC) requires consideration of technical, environmental and economic feasibility of AES. Close related to technical and economic preconditions are organisational aspects which in addition must also be considered. As a consequence, a detailed feasibility study is divided into four parts: one technical, one economical, one organisational and one environmental.

- First, a technical evaluation is performed to see if it is relevant to use alternative energy systems, having less environmental impact than conventional sytems. This involves determining the necessary capacity of the alternative energy system, and thus the required space, construction and installation requirements. The energy system's performance parameters are used in order to calculate the expected yearly energy use in the building's operation phase (Chapter 4). The results from the technical evaluation are used in order to make an economic and an environmental evaluation.

- The economic evaluation considers different price scenarios for both investment costs (technique, installation) and operational cost (maintenance, energy prices and the development of interest rates). In addition, a first insight in possible financing schemes have to be available (Chapter 5).
- A feasibility study also consists of an organisational evaluation of which activities are needed to implement and to operate the AES sucessfully. For instance if the capacity and skill of the in house employees match the new requirements of the selected AES (Chapter 6).
- The environmental evaluation is made for different mixes of electricity and other energy sources, and for different scenarios of future changes in the environmental impact of different energy sources: for example in district heating systems (Chapter 7).

All the collected and calculated results must contribute towards an optimal consideration of AES when deciding on the final energy system. (see the overview in Figure 1.1 and appendix A).

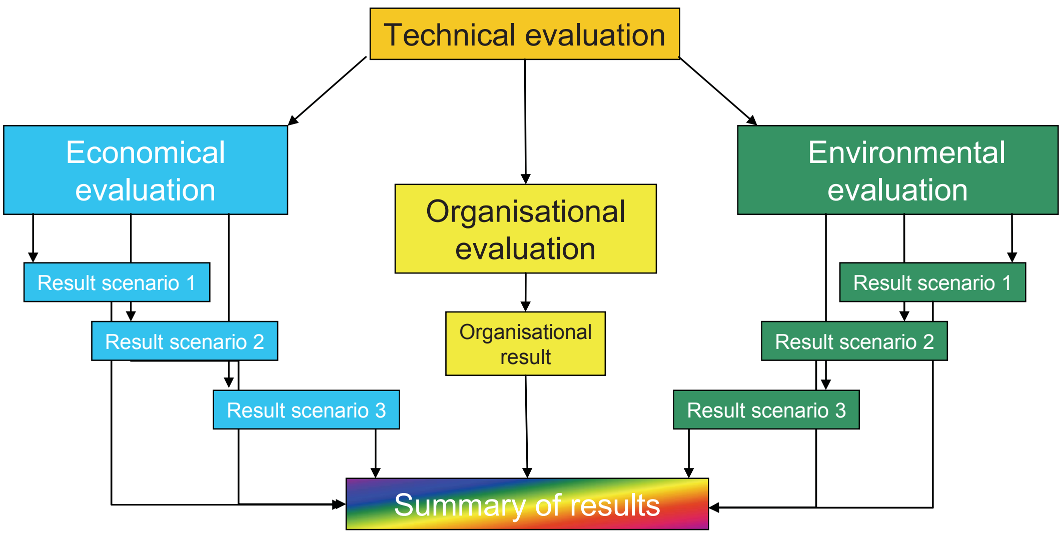

Figure 1.1 Flow chart overview of different evaluations in a feasibility study.

The approach explained in this handbook is of general format, and suitable for use in/by most European countries. However, national regulations may have been stated so that the approach cannot be used directly as described within this handbook. For this reason, country-specific handbooks will be developed within the SENTRO project.

Definitions of terms

Explanation of several terms as they are used in this handbook:

- ***Approach*** is used to refer to the overall method of incorporating AES feasibility studies in the common building process. The approach uses the checklist and the handbook as supporting tools (Tables 2.1 and 2.2).

- ***Checklist*** is used to refer to a pre-feasibility study.

- ***Feasibility study*** is used to refer to detailed determination of the feasibility of AES. It is intended to show whether the AES is technically, economically and organisattionally feasible. It also provides information on the environmental impact of the AES.

- ***Alternative Energy System (AES)***, as defined in art 5 of the EPBD, this means systems based on renewable sources as well as energy efficient systems.

1.4 Overview within SENTRO-developed support tools

In the SENTRO-project various support tools have been developed. An overview of these tools including their target groups is presented in Table 1.1.

Table 1.1 Overview within SENTRO-developed support tools

SENTRO tools	for whom?	when?	where to find in the handbook?
Documentation for raising awareness - Shining examples - FAQs	Policy makers, clients	Planning / program stage	Appendix B and Appendix D
Checklist – Filtering out unrealistic options	All key actors involved in the building project team	Program / proposal stage	Chapter 3 and spreadsheet tool on www.sentro.eu
Handbook – Request for and performing of feasibility study	1. Decision makers (local authorities, investors etc) 2. Advisors, consultants	1. Planning stage – request for FS 2. Proposal and project stage – performing the FS	1. Chapter 2 and 3 2. Chapter 4 - 7
Calculation methods – Overview of software tools for performing feasibility studies	Advisors, consultants	Proposal and project stage	Appendix E and spreadsheet tool on www.sentro.eu

2 Embedding feasibility studies of alternative energy systems into the common building practice

2.1 Boundaries and starting points of the developed approach

The SENTRO project started by making inventories of (1) how European member states comply with the requirements of conducting a feasibility study for AES, and (2) barriers and possible solutions for the implemention of AES in the seven SENTRO countries. Based on the results of these inventories, it has become clear how investigation of the feasibility of AES should preferably be integrated in the building process. The approach is illustrated by Tables 2.1 and 2.2.

Three main situations can be distinguished in realising AES in buildings:
1) new large individual utility or domestic buildings
2) new housing areas, and
3) renovation of existing building(s).
A combination of these three basic situations is also possible. As the focus of Article 5 of the EPBD is on new buildings, the approach is concentrated on the first two cases. The third case is beyond the scope of this handbook, unless the building is totally stripped, in which case it can be regarded as a new building.

The approach is more or less the same for the first two cases. This handbook explains the approach, and the tools, for a new individual building. The development of a new housing area differs from a new single building in terms of more opportunities for collective energy systems and greater freedom in the choice of energy infrastructure. As a consequence investigation of the feasibility of AES is more complex in this case, and has to be carried out at the very beginning of the building process. Decisions about the energy infrastructure, for example, are usually made at the planning stage.

Background European legislation
The feasibility study requirements in Article 5 of the EPBD are included in order particulary to promote energy savings that can be achieved by energy-efficient supply systems and renewable energy systems, as opportunities for these systems are generally not explored to their full potential. Measures which reduce the energy demand (e.g. insulation) of a building are largely covered by other articles in the EPBD.

This is the reason why the approach developed within the SENTRO project also focuses on AES, although also bearing in mind that building-related measures, such as insulation, ventilation, and use of daylight, must always be integrated in the overall energy concept. The modular/flexible structure of the checklist makes it possible also to take these measures into account in an advanced version of the checklist.

Importance of good overall concept
Feasibility study requirements of Article 5 of the EPBD are included particularly to promote energy savings which can be achieved by energy-efficient supply systems and renewable energy systems. However, building-related measures, such as insulation, ventilation, use of daylight etc., should always be integrated to their maximun extent before considering AES.

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2.2 The construction process, and when to perform activities to determine feasibility of AES

In general, the building process exists of six stages:

- Planning stage
- Programming stage
- Proposal stage
- Project stage
- Physical construction stage
- Operation stage.

The stages are schematically presented in Table 2.1. The figure also includes the findings of the investigation, carried out as part of the SENTRO project, of the actions needed in the building process for implementation of feasibility studies of the provision of alternative energy systems in buildings (Hansen, 2007). It also includes descriptions on when to use the parts in this handbook.

Note that, of course, building processes differ in the various EU countries. However, in general, it is possible to distinguish six different stages as defined in the table.

The results of the inventory carried out as part of the SENTRO project (Hansen, 2007) show that the most important stages regarding the choice of energy systems are the planning, proposal and project stages. However, the programming stage is also important, since it includes an option for the introduction of alternative energy systems into the design concept of both the building envelope and the building's services. It was also pointed out that consideration of feasibility of AES should be initiated early in the building process, preferably in the planning stage of the building process, since some options of alternative systems may be decided or excluded by urban planning considerations. According to this, the feasibility studies should be carried out during one or several of these stages getting more and more detailed and focussed during the process. These stages are in more detail described at the end of this paragraph.

Solution space to reach high quality and cost-optimal buildings
The space to find suitable solutions to realize an optimal energy concept in the building is funnel-shaped (marked blue). This illustrates that when, for example, AES is considered only from the project stage there are fewer opportunities to realize a good AES concept compared to consideration of AES right from the planning stage. Of course, the ability to realize a high-quality building, including its energy concept, is also closely related to the required cost. Little space to find a suitable solution indicates higher cost and vice versa. (Prins, 2006; WBCSD, 2007)

Awareness of the AES must be created at an early stage of the planning and programming phase, which can be done by putting the topic on the agenda of project meetings. As a support to raise awareness, descriptions of the basics of AES as well as good national practice examples, described in appendix B and C of this handbook, can be used. Appendix D also gives answers to frequently expressed objections towards AES.

Depending on how the feasibility requirement of Article 5 of the EPBD is applied, there are several paths to follow for raising awareness.
1) When there is a direct obligation, the key actors have to fulfil the legislation.
2) When the application is implicit, key actors have to be made aware that AES are valued in the energy performance calculations.
3) When there is no obligation (yet), the next step is to achieve commitment that the feasibility of AES must be investigated.

In all cases, it is recommended that key players ask for a feasibility study at an early stage of the process.

Planning stage
During the first stage, i.e. the planning stage, decisions are made regarding the energy infrastructure of the construction area. Municipality heating plans can have a considerable influence on the actual possibilities of incorporating alternative energy systems. If, for example, the municipalities decide to extend the district heating system to new construction areas, it may improve the situation for extending the use of alternative energy sources to include such as waste heat,

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biomass (incl. waste incineration), heat pumps or geothermal energy. The municipalities therefore play a significant role in influencing the possibility of using alternative energy sources. At this stage, the urban planning is settled by the municipality, which might specify requirements for the building envelope that can exclude some choices of alternative energy systems. The planning stage should therefore include feasibility studies of the potential for inclusion of alternative energy systems at district level or at building level; so that considerations regarding the use of alternative energy systems at building level are well thought out.

Programming stage

At the programming stage, the client or developer defines the owners' and future occupants' needs and requirements. It should be appropriate, at this stage, to start the work of the feasibility study, such as gathering information on available alternative energy systems that may be an option for further evaluation during the coming proposal and project stages. At the programming stage, the project partners involved could use the checklist for finding the most promising options that should be examined in more detail during the proposal stage. The checklist should result in selection of at least two alternative energy systems.

Proposal stage

In the proposal stage, which follows, the clients decide upon the aesthetic, functional, technical and financial features of the building project, together with the principles of operation and maintenance, as well as financing. This is where the energy demand and production should be optimised. Alternative concepts for the building, including energy systems, should be considered and evaluated using the handbook and other available tools on the market. The building's annual energy use should be calculated, in order to arrive at an optimised design of the building envelope. The two to three energy concepts (including the alternative energy systems that have been found most suitable) should be evaluated in terms of their technical, economical, organisational and environmental aspects.

Project stage

It is at the project stage of the building process that energy systems should be compared and a decision made as to which system should be used in the building under consideration. The final version of the feasibility study should be submitted at this stage, together with the other project documents for application for the building permission.

Table 2.1 Schematic flow chart of the building process stages, main actors and their description[1].

Building Process	Actors	Description
Planning	- Municipality - Energy suppliers - Developers	Urban planning incl. energy infrastructure, heating plans, and constraints on number, size and use of buildings in the area.
Program	- Client or developer - Consultants	Defines the occupants' needs and requirements in the building programme
Proposal	- Client or developer - Architect - Consultants	Defines the basis on which the client makes his decisions on the specific performances of the project in question The proposal stage may include consideration of a number of alternative concepts
Project	- Client or developer - Architect, - Engineers - Consultants	Describes the project in unique terms to allow it to form a basis for final approval by the authorities and for tendering, contracting and construction
Construction	- Contractors - Installers	The building is constructed incl. energy systems, so that a use permit can be given
Operation	- Owners - Occupants - Installers	The building is in use

1) Note that the process and the terminology differ from country to country, so the description in Figure 2.1 does not necessarily fit the practice in all the participating countries.

Space to find suitable solutions to realize a high quality building including an optimal energy concept within acceptable costs

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Space to find suitable solutions to realize a high quality building including an optimal energy concept within acceptable costs

2.3 Actors involved in the feasibility study

An investigation has been performed as part of the work of the SENTRO project on how European member states comply with the requirements of performing a feasibility study for alternative energy systems for new buildings (Sijanec Zavrl, 2007). It identified key actors involved in the execution phase of implementing EPBD Article 5, and the results are illustrated in Table 2.2. They are those who play an important role in the integration of feasibility studies in the building process as well as in facilitating the decisions for investments in alternative energy systems.

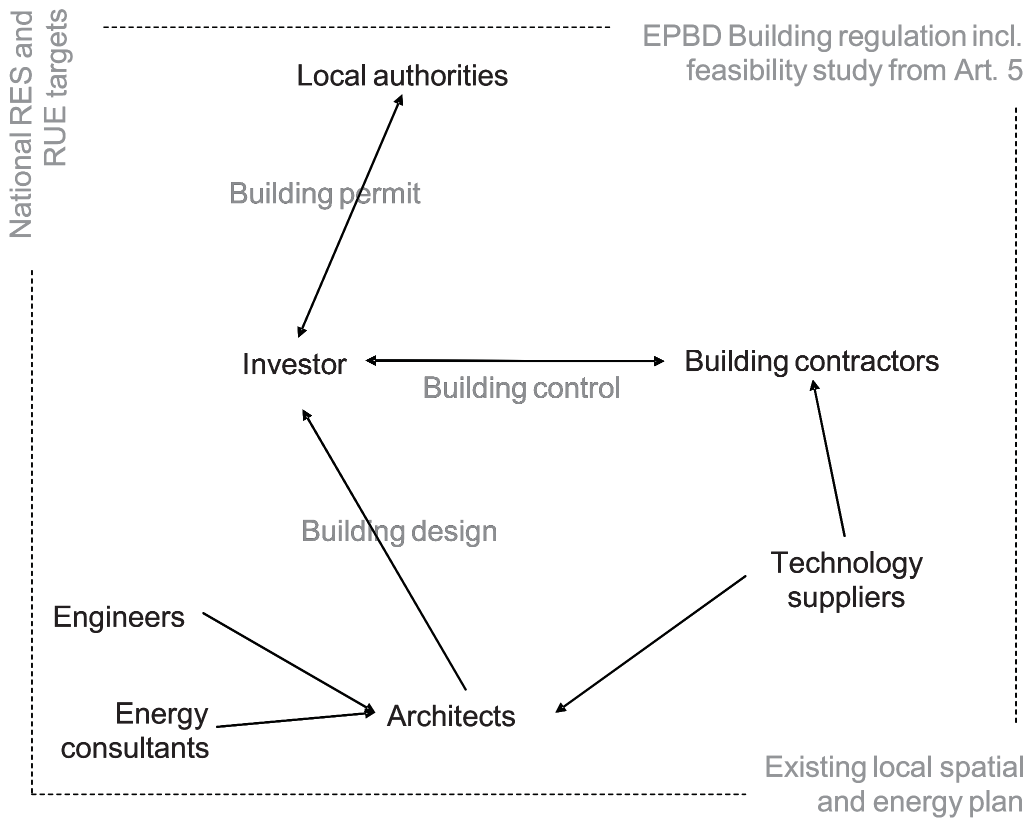


Figure 2.1 Key actors for the introduction of feasibility studies of alternative energy systems. With the boundary conditions that have to be considered (an example).

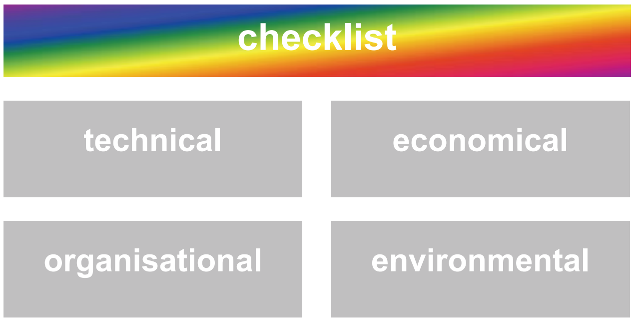
Architects play an important role in actual implementation of feasibility studies, since their responsibility is to investigate various solutions and to create an optimum building design corresponding to the client's needs and to the local and national requirements and targets.

Sufficient technical expertise and adequate tools are needed for comprehensive technical, environmental and economical analyses that will be performed by engineers and energy consultants. Technology suppliers will complement the EPBD calculation methodology. Local authorities will be responsible for checking the building design against the comprehensive investigation of alternative energy systems.

The execution phase involves building contractors, technology suppliers and building inspectors. These actors will reflect the market response to the EPBD efforts in increased implementation of low-emission energy technologies.
Due to the general problem with economical feasibility of implementation of alternative energy systems, it is clear that the national and local targets of rational use of energy and more use of renewable energy sources, supported with incentives programs for selected energy technologies, will play a key role in meeting the targets of EPBD Article 5.

Integrated design processes are becoming more and more common, especially when low-energy buildings are constructed. Here, the key actors may be involved by 'partnering' (see Chapter 6.3), which means that energy consultants will play a larger role within the feasibility study than shown in Figure 2.1.

3 Checklist



This chapter contains the description of the checklist. The checklist is one of the supporting tools within the proposed approach to perform feasibility studies of alternative energy systems. The aim is that by using the checklist at least two interesting alternative energy concepts are identified.

3.1 Objective

The objective of the checklist is to make a pre-feasibility study of which systems that are promising for further investigations early in the building process (see Figure 3.1). By using the checklist, it should be possible to choose a few alternative energy systems for further investigations together with the conventional system. It is recommended that at least two promising energy systems should be chosen for further investigations. Beside this, the use of the checklist also identifies a number of challenges for further action in the next stage of the process, e.g. regarding lack of knowledge or lack of data.

Figure 3.1 Flowchart overview of using the checklist.

3.2 Method description

Four evaluation parameters are considered for each alternative energy system: technical, financial, organisational and environmental. Each evaluation parameter is weighted with weighting parameters that are set on the first page in the Excel spreadsheet tool. The default values are set with the following weightings:

- Technical: 0.3
- Financial: 0.2
- Organisational: 0.1
- Environmental: 0.4

The default weighting is intended to highlight the fact that environmental issues are one of the reasons for stipulating the EPBD directive. This means that environmental aspects are the most important ones. Once the weighting parameter is set, the same weighting will be used for all alternative energy systems. If the weighting parameters are set to 0.25 for all parameters, it means that they all are equally important. The evaluation parameters are, in their turn, weighted between different aspects that are relevant to consider in order to tackle barriers for each specific alternative energy solution. Each aspect is evaluated with scores from 1 to 3; 1 means that it will need a high effort to achieve success, while 3 means that it will need only a low effort.

The scores are based on rules of thumb. It may be necessary to change some of the parameters in order to adapt to local conditions. It is the intention that the design team should need only one or two hours to fill in the checklist and obtain a relatively good overview of which systems that should be further investigated in a detailed feasibility study. The scores should therefore be set simply on previous experience, and no background investigations or calculations should be needed. This may lead to some systems, of which the design team has previous poor experience, being constantly dropped. On the other hand, there is nothing to say that only suggested alternative energy systems can be further investigated, or indeed that those not suggested by the pre-feasibility study cannot be further investigated, so it might be more pragmatic to concentrate on systems with which the design team feels comfortable, unless supplementary consultants can be involved in the project.

	Decentralised energy supply							
A1	**Solar thermal systems (hot water and/or heating)**	Low effort demand to realise sucess = 3 points	Medium effort demand to realise sucess = 2 points	High effort demand to realise sucess = 1 point	SCORE to fill in,	SUBScore (%)	Weighting	Total Score (%)
Technical parameters	hot water demand	premises with restaurant, sportsactivities, hotell or hairdresser, Residental builidings	premises with kitchen facilities, ordinary schowers, partly residential	day offices	3			
	space heating demand	demand during summmer season	demand during autumn and spring	demand during mid-winter	3			
	sutaible roof	roof with large open area towards south with possibilitie to place the collector in 30 to 45 degree angel, no shading from surrounding, possibilities to integrate the collector into the roof or other building envelope parts	roof towards west or east, possibilities to install the collector on the roof, partly shaded	no suitable roof, in shadow	2	89%	0,3	
Financial parameters	system price	lifecyclecost (LCC) price of kWh equal to reference system (i.e. electricity, oil or gas)	lifecyclecost (LCC) price of kWh 2 to 3 times higher than reference system (i.e. electricity, oil or gas)	lifecyclecost (LCC) price of kWh 5 or more times higher than reference system (i.e. electricit, oily or gas)	1			
	availability of subsidy schemes	subsidies of 30% or more	subsidies over 15%	no subsidy	2	50%	0,2	
Organisational par.	building permit (yes/no)	easy to get	possible to get	difficult and expensive to get	3			
	system maintainance	minimum need of maintainance	need maintainance every third year	need maintainance several times each	3			
	reliable system supply	runs for 10 yeras without change of spare equipment	runs for 5 yeras without change of spare equipment	high probablity to fail	3			
	knowledgeable installer	easy to find certfied installers	possible to find installers with good qualifiactions	difficult to find installers	1	83%	0,1	
		high impact = 3 points	medium impact = 2 points	low impact = 1 points				
Environmental par.	Effect on global warming	replace more than 20 % of energy that otherwise should have been produced by a conventional system	replace more than 10 % of energy that otherwise should have been produced by a conventional system	replace 5 % of energy that otherwise should have been produced by a conventional system	2	67%	0,4	72%

Figure 3.2 Part of the checklist, showing evaluation of solar thermal systems by rules of thumb in a 1-3 point system.

3.3 How to use the checklist

Each evaluation parameter is followed by a number of aspects that should be assessed, with scores from 1 to 3. The evaluator writes the scores in the white boxes and the summary scores will be calculated automatically. If nothing is known about a particular aspect, the evaluator should give it three points in order not to underestimate the possibilities of the system and thereby exclude a more detailed feasibility study. This means that the design team will investigate systems that are not well known, and thus increase their knowledge of them.

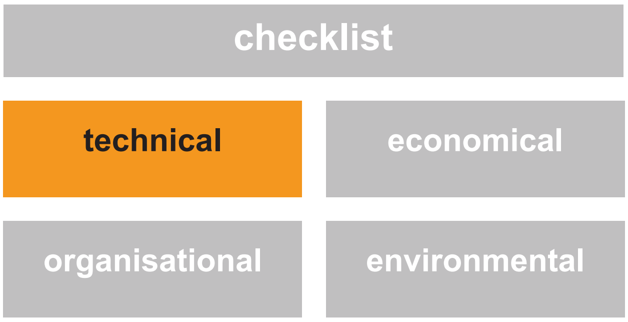
For technical aspects, the lowest score should describe the difficulty of realising the AES. If it impossible to realise a particular technical aspect, the whole alternative system solution fails and further assessments should be done for other systems. In the same way, technical aspects that will not cause any problems in implementation are not considered.

The summary sheet summarises the scores for different aspects from the three other sheets. The design team can choose one or two systems that have high scores, and thus promising potentials. Note that some of the systems are independent of each other, and may therefore need separate assessments. For example, it is possible to use a solar thermal system together with district cooling.

	SENTRO WP4- CHECK LIST FOR FEASIBILITY STUDIES					
		Score Technical parameters	Score Financial parameters	Score Organisational parameters	Score Environmental parameters	Probability for sucess in comparison of efforts
	Weighting to fill in, (0 - 1)	0,3	0,2	0,1	0,4	
	Decentralised energy supply					
A1	Solar thermal systems (hot water and/or heating)	89%	50%	83%	67%	72%
A2	Solar electricity systems (photovoltaics, PV)	33%	33%	58%	33%	36%
A3	Biomass energy systems (hot water and/or heating)	50%	100%	40%	100%	79%
	CHP and District or block heating or cooling					
A4	CHP (micro) at building level	67%	67%	50%	100%	78%
A5/A6	District or block heating	50%	56%	67%	100%	73%
A7	District or block cooling	67%	83%	83%	67%	72%
	Heat pumps					
A10	Geothermal energy systems (heat pumps for heating and/or cooling)	72%	89%	92%	100%	89%
A11	Heat pumps other than geothermal	67%	33%	75%	100%	74%

Figure 3.3 Summary sheet of the checklist showing evaluation of all AES systems with predefined weighting of technical, financial, organisational and environmental parameters.

4 How to consider technical aspects



Technical aspects of the feasibility study are described in this chapter. The outcomes of the technical evaluation, taken into account space and construction characteristics and the simulation of the energy demand, form the basics of the economic, organisational and environmental evaluation.

Various steps are needed in order to compare different energy concepts (including alternative energy systems) from a technical point of view. First, the different alternative energy systems' technical performance parameters must be collected, in order to calculate or model expected total energy use for the building/buildings under consideration. Along with the actual energy performance of the different systems, the physical space requirements for the alternative energy systems must be considered. Finally, the results from the technical evaluation can be used in the economic, organisational and environmental evaluation (see Figure 4.1).

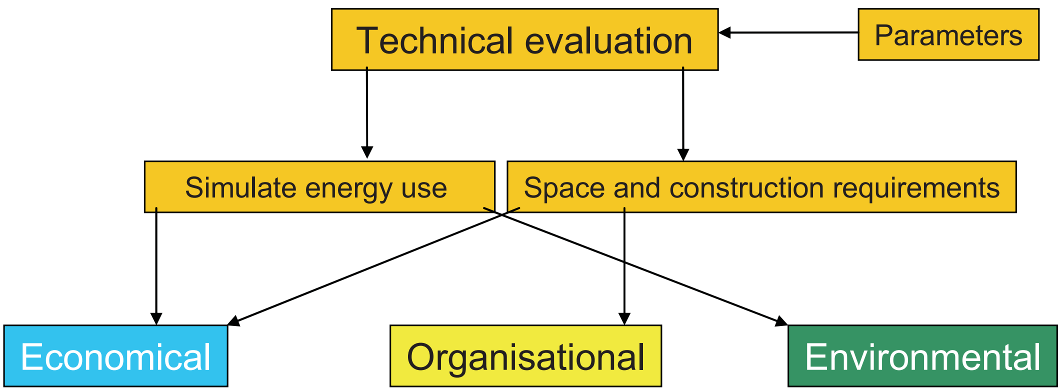


Figure 4.1 Flow chart overview of the technical evaluation in the feasibility study.

4.1 Technical parameters

In order to perform an evaluation of the different energy systems' technical performance, various parameters values must be collected. Information regarding the technical systems' efficiencies, power, performance, size and lifetime must be found (see example in Table 4.1). Depending on the type of system, there are different parameters of interest. Different options of efficiencies or SPFs of different available equipment on the market could also be compared for the same type of AES.

Table 4.1 The following technical parameters for different systems are needed for input to the energy simulations.

System	Technical parameters			
Solar thermal	Collector energy output (the total energy output during one year)	Efficiency	Lifetime	Size
Solar electricity	Power (electricity)	Efficiency	Lifetime	Size
Biomass	Power (heat)	Efficiency	Lifetime	Size
CHP (at building level)	Power (electricity/heat)	Efficiency	Lifetime	Size
District or block heating	Power (heat)	Efficiency	Lifetime	Size
Geothermal heat pumps	Power (heat)	SPF/COP[1]	Lifetime	Size
Heat pumps other than geothermal	Power (heat)	SPF/COP[1]	Lifetime	Size

[1] Two indicators for efficiency:

The Seasonal Performance Factor (SPF) is defined as: $$SPF = \frac{Delivered\ Heat_{whole\ year}}{Power\ input_{whole\ year}}$$

The Coefficient of Performance (COP) is defined as: $$COP = \frac{Delivered\ Heat}{Power\ input}$$

COP is measured at fixed conditions of temperatures etc.

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4.2 Simulation of energy use for different systems

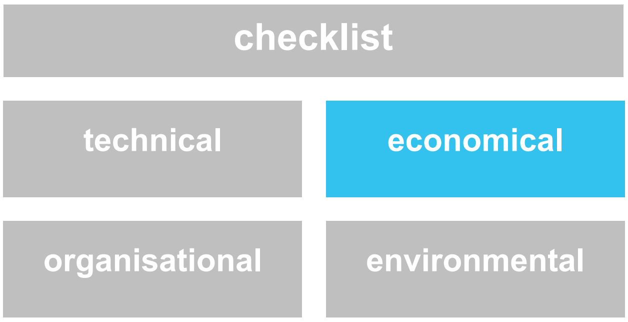
When all the necessary information for the considered alternative energy systems has been collected, an energy simulation of the complete building system is required. This should be done in order to compare a traditional system with the two alternative energy systems. The simulations should be performed on the total annual energy use for the building. It is vital that the simulations include the energy aspects of activities during the forthcoming use of the building. See Appendix A for suitable simulation tools. For this, it is essential to have an experienced person for performing these calculations. It is also important to have well-defined input values and boundary conditions, in order to achieve good quality and comparable results for the different systems under consideration. Bear in mind, too, that the simulations include many assumptions, so the results will be only an estimation of the future energy performance of the building.

4.3 Changes in space and construction requirements

Different energy concepts and systems may need different designs of the building and a different amount of space for the hardware. The space required will influence the building plan, and this aspect is also included in the checklist.

Space requirements must also allow for possible environmental factors (smell, noise etc.) and safety regulations.

5 Calculation of financial conditions and financing opportunities



This chapter deals with two aspects of the economical part of the feasibility study. The financial factors are of great importance, since the outcome of the financial calculations will often determine the choice of energy system.

The first financial aspect deals with the financial calculation method. There are several financial calculation methods, which can all lead to different financial results for the same situation. The methods are explained and their differences illustrated. The second financial aspect deals with the different options for financing.

5.1 Financial calculation methods

The financing factor is an aspect of great importance when choosing between different energy systems. There are varying methods of calculating the economic consequences of an alternative system, and the choice of method tends to affect which system is the most profitable from a financial point of view. For example, some methods permit inclusion of costs for environmental effects, while other calculation methods do not take account of environmental costs. Other aspects include selection of initial values for the calculation, such as calculation period, internal rate etc. There is also a governmental aspect: taxes and grants, for example, for different types of energy sources. Since many of the future factors (such as energy prices and interest rates) have to be estimated, it is important to consider a number of different scenarios of future economic development, which will provide a better base for the final evaluation of the economic aspects of the alternative energy system. The procedure for the financial evaluation is illustrated in Figure 5.1.

A very important aspect are the partners involved from the beginning of the process. In larger projects for utility buildings or housing developments it can be of importance to involve energy companies and/or energy service contractors in a very early stage. These can offer solutions which could normally be financed by the initial project partners. European tender procedures however can disturb this type of early process involvement.

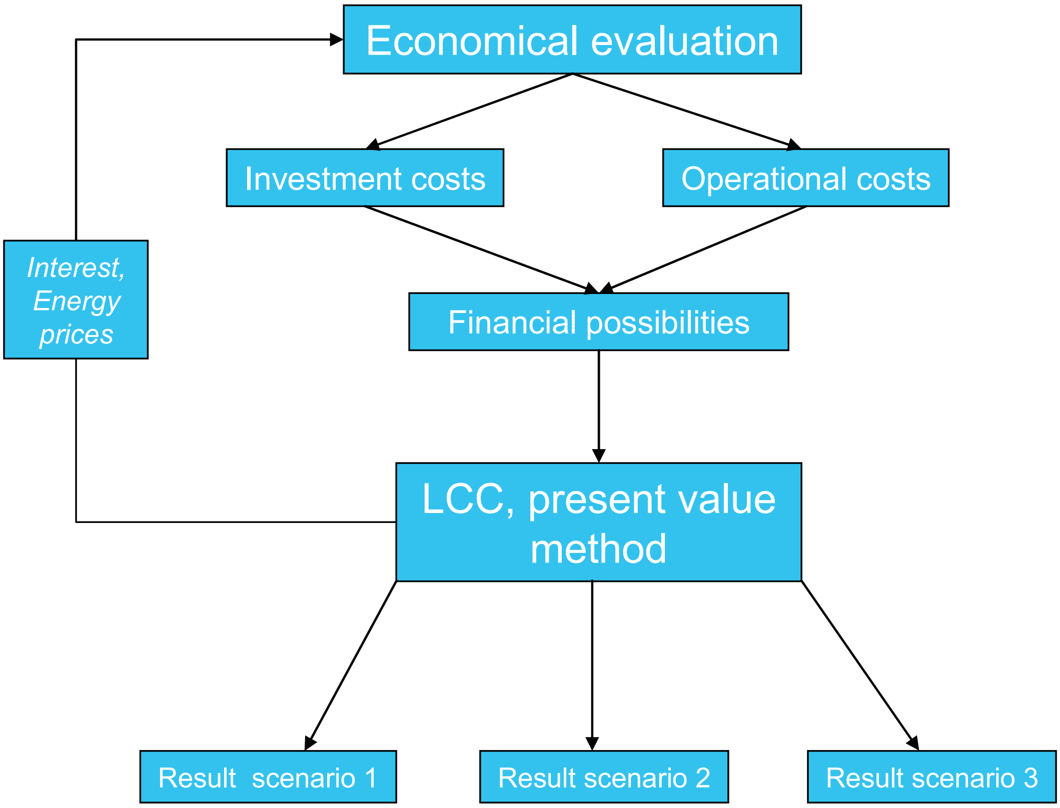


Figure 5.1 Flow chart overview of the financial evaluation in the feasibility study.

Differences in investment costs for the evaluated systems

The following factors must be considered when calculating investment costs of the considered alternative energy systems:

- Possibilities for external subsidy. Investigate if there are any possibilities for external subsidies for any or both of the systems. These could be, for example, grants from authorities.
- Differences in costs for space. Investigate the costs for the different space requirements of the systems in the building.
- Differences in construction costs. Investigate the influence of the different systems on the costs during the design process.
- Differences in cost limits for investment costs. Investigate the maximum limit of investment.

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- Avoided cost compared to the reference standard energy supply
- Avoided cost comparing the two systems with each other

Differences in operation and maintenance costs for the evaluated systems
Factors to take into consideration when calculating operation and maintenance costs could be:

- Local prices for energy sources, including possibilities of long-term agreements with energy suppliers
- Possibilities for external subsidy of energy costs
- Possibilities for sale of excess energy
- Environmental fees for emissions (today and during the entire lifetime)
- Labour cost and materials for maintenance
- Income/costs for extra space which affects income from rents and how the building can be used.

Evaluate the systems with different inflation, interest rate and energy price increase scenarios
There are different ways of calculating the costs of energy-saving actions. Examples of methods of calculation include:

1. The present-value method
2. Annual cost per kWh (saving costs)
3. Internal rate of return method
4. Pay-off methods
5. Life cycle cost, LCC

Methods 2-5 are variants of Method 1, the present-value method.

<u>Present-value method</u>
Future yearly expenses/costs and incomes/savings (actually payments in and out) are converted into their values as of today. The present value depends on the costs of capital, increases of energy prices and the period of calculation that have been chosen. The present value of future payments in and out, minus the original investment cost, is referred to as **capital value**. If the capital value is above zero the investment is profitable.

A factor called **present sum factor, p_0**, can be used in order to calculate the capital value and consider the effects of energy price increases. The greater the difference between the actual cost of capital and the actual differences in energy and maintenance costs, the smaller the present sum factor, which makes the energy-saving measure less profitable. The difference between the actual cost of capital and the actual difference of cost is sometimes called the **true rate of interest**. The criterion of profitability according to the present value method is:

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The capital value must be greater than zero. This can be expressed in the following equation:

Capital value = p_0 ·(changes in annual energy and maintenance costs)
- investment costs

Table 5.1 Present sum factors, p_0, of the differences between real rate of interest and real energy price incresae (%) and the calculation period (years in use). (Adalberth and Wahlström, 2008)

% / Years	0	1	2	3	4	5	6	7	8	9	10
1	1,00	0,99	0,98	0,97	0,96	0,95	0,94	0,93	0,93	0,92	0,91
5	5,00	4,85	4,71	4,58	4,45	4,33	4,21	4,10	3,99	3,89	3,79
10	10,00	9,47	8,98	8,53	8,11	7,72	7,36	7,02	6,71	6,42	6,14
15	15,00	13,87	12,85	11,94	11,12	10,38	9,71	9,11	8,56	8,06	7,61
20	20,00	18,05	16,35	14,88	13,59	12,46	11,47	10,59	9,82	9,13	8,51
25	25,00	22,02	19,52	17,41	15,62	14,09	12,78	11,65	10,67	9,82	9,08
30	30,00	25,81	22,40	19,60	17,29	15,37	13,76	12,41	11,26	10,27	9,43
40	40,00	32,83	27,36	23,11	19,79	17,16	15,05	13,33	11,92	10,76	9,78
50	50,00	39,20	31,42	25,73	21,48	18,26	15,76	13,80	12,23	10,96	9,91

Annual cost per kWh (saving costs)

The energy cost which leads to a capital value that equals zero is also called the saving cost. If the value of this cost is lower than today's variable energy cost, the investment is considered as profitable. When the terms in the equation above are divided by p_0, the right-hand side will show the annual costs of the investment project. Capital value equal to zero corresponds to that changes in annual energy- and maintenance costs is equal with the annual cost of the investment. The annual cost per kWh equals the saving costs.

Internal rate of return method

The actual cost of capital, which results in a capital value that equals zero is called the **internal rate of return**. If the internal rate of return exceeds the chosen actual cost of capital, the investment is considered as profitable.

Pay-off method

If the capital value equals zero, the equation above could be transformed to p_0 = Investment cost / (changes in annual energy and maintenance costs). The result

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shows the pay-off time expressed in years. If the pay-off time is shorter than the expected length of life of the investment, it is considered as profitable.

<u>LCC method</u>
The LCC-method is a variation of the present-value method. Instead of maximizing the capital value, it tries to minimise it and calls it LCC. In addition, the lifetime environmental effects of a product can be included. This method estimates the life cycle cost of an energy-saving measure. The energy measure and/or “zero-alternative” measure which gives the lowest life cycle cost is considered as the most profitable.

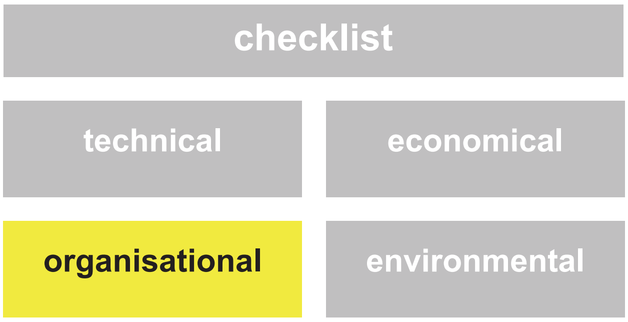
5.2 Options for financing

Another financial factor is that the actor that makes the decision on the building’s system solution is (often) not the one that will bear the costs for energy use. This is the case, for example, with a construction company which sells the building after completion.

Consider possible opportunities for financing
Investigate all possible opportunities for financing.

- Favourable loans. Investigate the possibilities of obtaining favourable loans, e.g. for energy-saving measures.
- Investigate the possibilities to financial support from manufacturers of energy-saving equipment.
- Own money.
- Outsourcing: Hire energy service companies that will make the investment and take care of all or part of the benefits of the savings
- Specific lease and/or hire construction for using the installation.

6 How to consider and tackle organisational aspects



In this chapter is described which organisational issues are of importance for a successful implementation of alternative energy systems. Four aspects of the organisational part of the feasibility study are discussed: timing and ambition set, knowledge, organisation of the building team and marketing advantages.

6.1 Timing and ambition set

It is relevant to effectively incorporate the consideration of the opportunities of alternative energy systems in several stages during the building process. First of all, it is important that awareness of the use of alternative energy systems is established early in the process (planning/programming phase). This can be done during the discussions setting the energy performance of the building. It is also recommended that the investor (e.g. local authority, real estate developer) asks for a feasibility study. This can be done by a quick scan (using tools such as the checklist), and/or by employing additional expertise at the beginning of the process. It is essential to include – being as specific as possible - the intentions and aims of the energy performance in the building programme. The organisational evaluation procedure is illustrated in Figure 6.1.

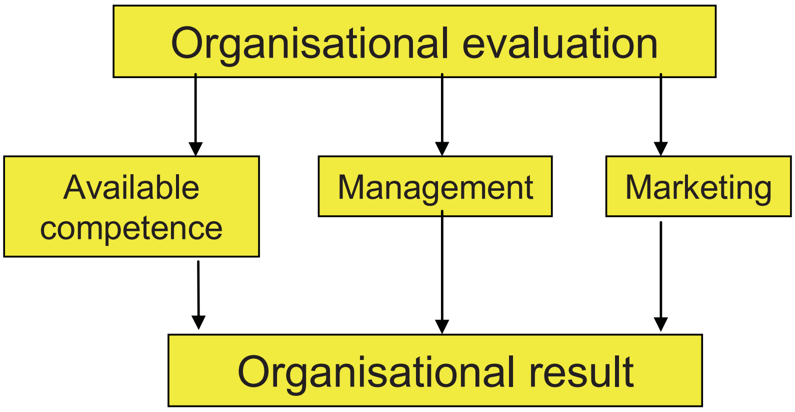


Figure 6.1 Flow chart overview of the organisational evaluation stage of the feasibility study.

6.2 Available and required personal

When introducing alternative energy systems and new technical systems in the building, additional demands will arise on the different actors involved in the building process. This includes the competence of those involved in the proposal and project stages, as well as during the construction of the building and operation and maintenance phases.

Training and new employment

Lack of knowledge of alternative energy systems is one of the most serious barriers for introduction of alternative energy systems. In most situations, those making choices will tend to choose common practice and familiar systems, which will mean that new options and energy alternatives are unlikely to be chosen. It is therefore important that new and upcoming alternative energy systems should be covered in the training of engineers and architects, and also in the training of those involved in the work of building projects. This includes not only information on the different alternatives, but also on how to consider the new options from technical, economic and organisational points of view.

Requirement for external expertise

Some consultants will specialise in alternative energy systems, in the same way as architects have, for example, specialised in the passive house concept. This will mean that a certain number of consultants will become experts in the field of analysing and evaluating new alternative energy sources. However, although there will be consultants and architects with the required knowledge, it is also important for the building client and developer to have some insight and general awareness of different options.

Out-sourcing of operation and management

Two main options are available for dealing with operation and maintenance of the technical systems: within the own organisation, or outsourcing. If the property owner decides on in-house operation and maintenance responsibility, the maintenance staff must be trained in the new systems and on how to operate and maintain them. For some alternative energy systems, e.g. district heating and district cooling, there is no special need for education of the property-owner's staff: maintenance and operation are performed by the energy supplier itself. However, for other alternative energy systems, there is a need for training of the property-owner's own maintenance staff. For more complex systems, it might be better to choose the other option, i.e. to outsource the work to an external company. This might be beneficial for the property-owner, particularly in the short term, hiring an external company with the required knowledge, equipment etc. When the technical system is new, there is always a need for adjustment and inspection during the first years. After some time, when the systems are running properly, it might be worthwhile considering bringing responsibility back in-house.

6.3 Long-term based project organisations in the building process

Communication is very important in the building process in order to achieve the set goals in time and with a high quality building. This applies both to internal communication inside the developer's own company and to communication between the other partners in the building project. One obstacle to the introduction of alternative energy systems is that the normal project organisation includes short-term relationships. In order to be able to introduce new energy alternatives into the building projects, there is a need for long-term relationships between all the relevant actors involved in the building process. One way of achieving a long-term based organisation, which will have more effective communication and a more construction-focused process, is to develop a design team at the early stages of the building process. This can be called an Integrated Design Process (IDP), or Partnering. The purpose of these kinds of project organisation is to have shared goals, shared activities and shared finance. Most of the partners are involved early in the process, so that the input from different point of views is gathered right from the beginning. The emphasis will thus tend to be more on constructing a building with a good indoor environment and low energy use than on lowest costs, which is the normal way in most building projects. Using IDP reduces the probability of construction faults that need to be corrected in later stages of the process, and may also reduce total construction costs.

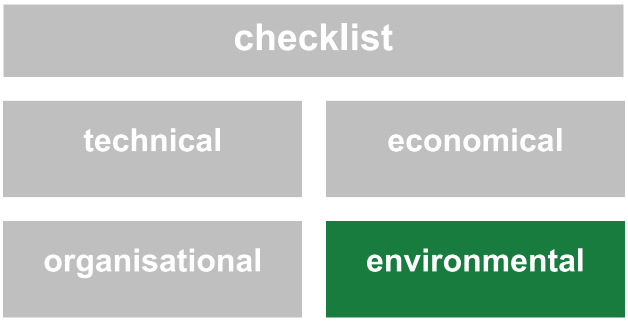
Other, usually more traditional ways of project organisation, demand careful building specifications. These building specifications must include all the relevant conditions for optimal performance of the alternative energy systems. The instructions must be clear for the contractor and installer. It is strongly recommended that additional expertise and guidance should be brought in when it is expected that this will be needed during realisation of the building. Furthermore, it is strongly recommended that, when selecting actors (architects, contractors, installers) who will be involved in the design and the building process, they should be asked about their experience of alternative energy systems. Alternatively, they can be required to consider and, where so decided, to incorporate alternative energy systems.

6.4 Positive marketing advantages with an environmentally beneficial building

One of the strongest driving forces for market introduction is increased general awareness (Hansen et al, 2007). This has led to increased concentration by companies on environmental matters. Companies have also put more effort into defining environmental policies, thus highlighting the increased needs for using alternative energy sources in order to help to achieve the environmental targets for society. Since the general level of environmental awareness in society has also risen, there has been an increased demand for energy-efficient buildings with low environmental impact. This might become a marketing advantage to interest future buyers.

Another driving force is that the alternative energy system will probably generate a higher score in the labelling of buildings under the Directive on Energy Performance of Buildings (2002/91/EC). It is expected that in the coming decade a building with lower operational costs will get a better market price.

7 How to estimate environmental aspects



In this chapter is described which environmental aspects can included in the feasibility study of alternative energy systems.

7.1 Environmental impacts from energy sources

Over the lifetime of a building, the major part of the environmental impact is caused by energy use for daily operation. Efforts to decrease the energy used in the operational phase will therefore have the greatest positive effect on the environment. When different energy systems are compared, the degree of impact depends on the type of heating system used, the effectiveness of the system and the choice of energy source. The environmental impact from the energy source begins long before the energy is used in the building (see Figure 7.1), starting from extraction, production and transportation of the energy source to the building or the energy plant. Further environmental impact occurs at transformation (e.g. combustion) of the energy source, either in the building directly or in a central energy unit that serves several buildings' heating/cooling demand. Further impact is also associated with construction of means of transport or delivery, and/or of energy plants.

7.2 Annual energy use by energy sources

State the annual energy use needed for heating, cooling and domestic hot water production. Divide the annual energy use into the different energy sources used by the evaluated systems. Examine which production units will be used to obtain the energy. For example, district heating is often a mix of different production units which have different impact on the environment. It is recommended to use data from the production unit for the specific (local) district heating system intended to be used.

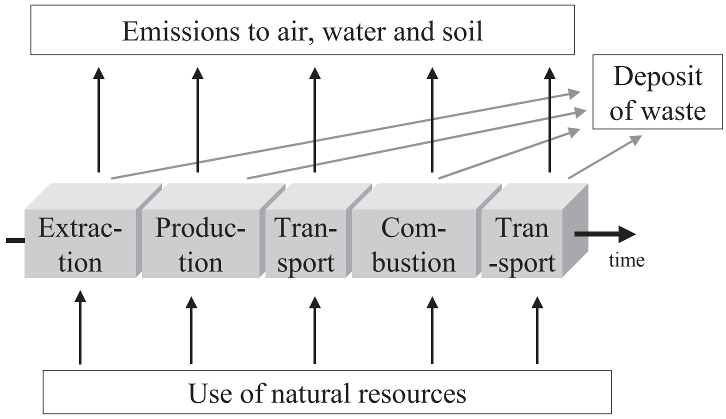


Figure 7.1 Environmental impact during an energy source's life cycle (Wahlström, 2003)

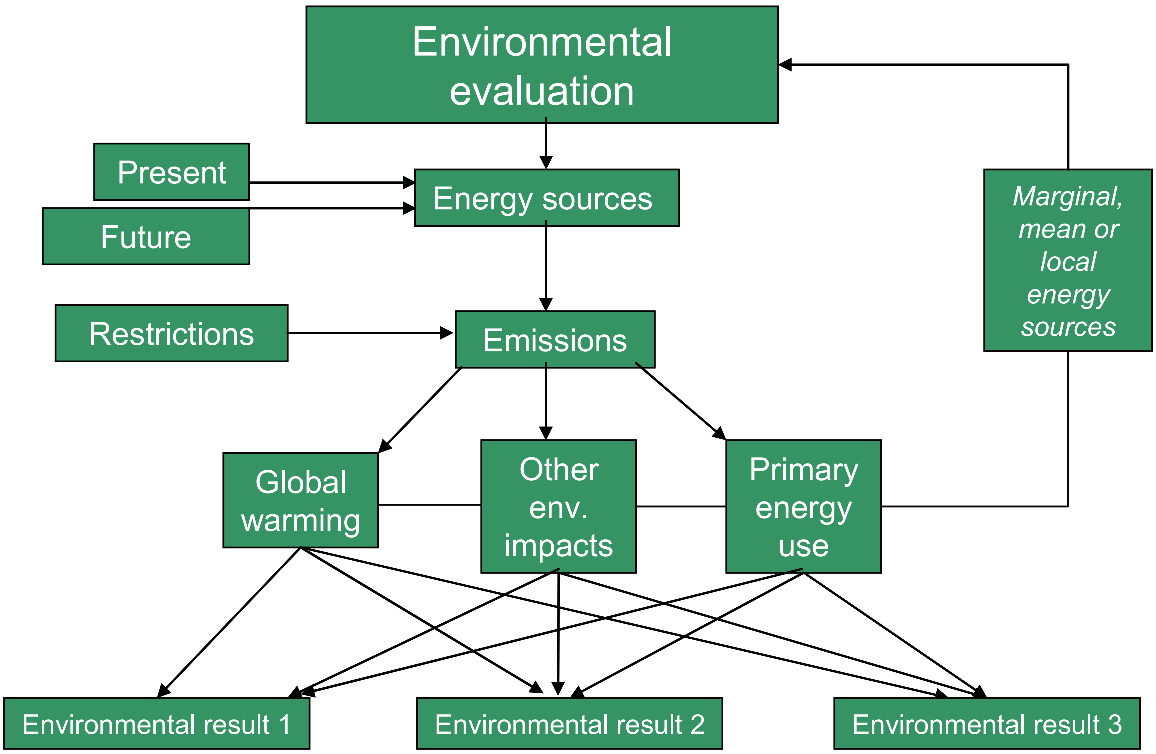


Figure 7.2 Flow chart overview of environmental evaluation in the feasibility study.

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When it comes to electricity, there are three common ways of defining the system boundary for the mix of production units:

1. *Average mix* consists of the percentage composition of production units within the system boundaries, e.g. in Europe, the nation or the region. The average mix will describe the actual contribution from the building to the environmental impact.

2. *Marginal electricity* consists of the production unit that is started up last as the load rises, i.e. used only to meet peak load demand. This is generally the most costly production and might also have the most negative environmental effects. The definition describes how the environmental impact will decrease with electricity-saving measures.

3. *Environmentally labelled mix* consists of specified production units with low environmental impact.

Another way of looking at the energy use should be considered as during the life time of the building energy system the boundary conditions change. Most of the models for calculation in feasibility studies are based upon a comparison of technologies in the existing infrastructure. During the life time electricity generation will become more efficient with less emissions and a higher rate of renewable electricity (over 10 – 20 % in 2020). A scenario for calculating the emission during the life time may be developed and used.

It is important clearly to state which system boundary has been chosen in the study, as the system boundary for electricity may have a decisive effect on the result. It is recommended that, when estimating the environmental aspects, possible changes that could occur within the lifetime of the building's services or the building, should be considered. For example, the mix of production units for district heating could change in the future.

7.3 Environmental effects of the emissions from the studied systems

The energy use of the systems will cause emissions to air, ground and water, and can be in gaseous, liquid or solid form. Emissions to air are considered to be the most important environmental aspect in the process of energy production, and should therefore be focused on.

Estimate the emissions per useful kWh for the different energy sources used by each of the evaluated systems. Emissions of interest include CO_2 and other greenhouse gases, as well as other emissions such as NO_X, SO_X, CO, particles etc. Tools for calculations of emissions are described in the Appendix.

Evaluate the effect on global warming and effects on the local environment from emissions from the evaluated systems. This can be done by a life cycle assessment (LCA). The data from emissions must be converted to contributions to environmental impact. This is performed in three main steps (Figure 7.3):

1. *Classification.* Group the emissions to air into categories reflecting their impact on significant environmental effects, e.g. global warming, acidification and so on.

2. *Characterisation.* Weight the contributions to different impacts within each category through multiplication by characterisation factors. Sum the contributions to a single characterisation indicator.

3. *Weighting.* Weight the different characterisation indicators into one or just a few indices. This weighting is based on subjective evaluations. Most weighting methods try to represent and describe how society sees and assesses different environmental categories. Useful LCA tools are listed in the Appendix.

If effect only on global warming is considered, the environmental evaluation will stop after the second step. Calculate the possible greenhouse gas effect as the sum of the Global Warming Potential (GWP), i.e. as grams of CO_2-equivalent in a 100-year perspective. The calculation formula, with the respective substances' greenhouse gas effect characterisation factors is as follows (Wahlström, 2003):

$$CO_2 \cdot 1 + N_2O \cdot 310 + CH_4 \cdot 21 \qquad \text{(gram } CO_2\text{-equivalents)}$$

There are several computer programs that directly calculate the CO_2-equivalents per useful kWh from different energy sources. They include the necessary LCA data in data bases, and users do not need to understand the LCA methodology in detail. Such programs reduce the effort for performing the environmental assessment.

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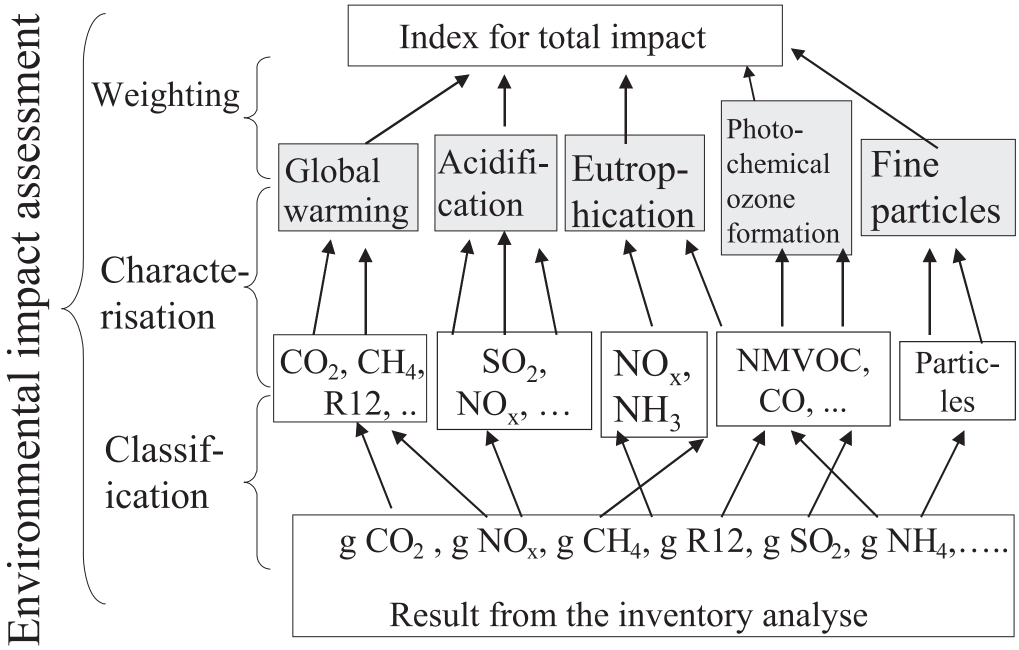

Figure 7.3 Environmental impact assessment with life cycle assessment. (Wahlström, 2003).

7.4 Local restrictions of emissions

Investigate local restrictions of emissions, and evaluate the different energy systems' emissions in relation to them.

7.5 Calculation of primary energy use

The primary energy use can be a valuable measure when comparing different types of heating systems for the same building. It can be defined as the total gross energy needed to produce one kWh of useful energy in the building. A primary energy factor is used in the calculation, and includes all the transformation losses in the complete energy chain, all the way back to the natural resources used.

As primary energy factors differ depending of the system boundary for the energy source considered, the factors may differ in different countries for the same energy source. In some countries, political aspects may also be considered, and so a political energy factor must be used instead of a primary energy factor in the country, to reflect the primary energy used.

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Appendix A: Example of summary and presentation of feasibility study for final assessment

Chapters 4-7 of this report have described the various stages that should be included in a feasibility study for the use of alternative energy systems. Such studies can be carried out and presented in many different ways, and this appendix gives an example of how a study can be carried out, summarised, and the results be presented in such a way as to enable the design team to produce a final verdict on which AES that is suitable for the building or buildings under consideration. Regardless of how the study is performed, it is important to bear in mind that the four different aspects that have been described in the guide should be presented in such a way that the design team can evaluate the technical, economic, organisational and environmental benefits and drawbacks of various alternative energy systems.

The appendix concludes with a table showing the indictors that should be included when performing the feasibility study, which can be used as a guide for the work.

A.1 Description of the case study

A development consisting of 33 apartment buildings, with a total of 264 apartments and a heated floor area of 33 000 m^2, is planned for construction outside a large town in southern Sweden. This is a new area, and will need a new energy supply system. The Swedish Building Regulations state that specific energy use for space heating, domestic hot water production and electricity for building services systems must not exceed 110 kWh/m^2, and that the results of a feasibility study must be submitted as part of application for building permission.

A.2 First selections of AES by using the checklist

The design team (in this case, the developer and the designer) uses the checklist in order to decide which alternatives should be considered.

Experience from nearby areas has shown that contributions from solar heating can be worth while, but as the new area is partly shaded by a hill, it is not regarded as sufficiently cost-effective here. For the same reason, photovoltaic systems can be ruled out, with very doubtful cost efficiency, despite their considerable environmental benefits.

A central pellets-fired boiler plant could be a good alternative, with substantial environmental benefits. However, it would need several tonnes of pellets per year, which would involve considerable goods vehicle traffic to and from the boiler plant. In order to avoid disturbance of the local environment in this way, it would be necessary to build a special road to the boiler plant. The boiler plant would also require regular attention and chimney sweeping, which would require almost one person's full-time employment besides the ordinary operational staff. This alternative, too, was ruled out.

The area is relatively close to a district heating system, which means that district heating could be an energy supply alternative. This alternative needs further investigations.

Micro-CHP plants are little used in Sweden, as it is generally more suitable to supply district heating systems from a large CHP plant. Natural fossil gas is today most common fuel used in small CHP installations but the area is not close to a gas supply, and so this alternative, too, was ruled out.

Rock heat pumps are not an alternative, as drilling of boreholes in the area is banned. The amount of ground surface area available for ground-source heat pumps is not regarded as sufficient, and nor are exhaust air heat pumps on their own regarded as capable of supplying the necessary power - power, not to be confused with energy. However, an exhaust air heat pump in combination with a ground coil for additional heat take-up could be a good alternative. The alternative of an exhaust air heat pump combined with an outdoor air heat pump was also considered, but was not regarded as having sufficient capacity at the design outdoor temperature.

The design team has therefore decided to continue on the basis of district heating and exhaust air heat pumps with an extra ground coil.

A.3 Investigation of technical aspects

As, at this stage, no detailed plans are available, rough calculations and outline investigations of how the alternative of district heating and exhaust air heat pumps could be designed have been made with the help of equipment suppliers. The developer also wants the new alternatives to be compared with a conventional arrangement in order to see how much better they are. Comparison has therefore also included a central oil-fired boiler for the area, although this is not a plausible alternative for Swedish conditions.

The calculations show that the alternatives of district heating or an oil-fired boiler would not meet the requirements of the Building Regulations without heat recovery. These alternatives are therefore combined with an exhaust air heat recovery unit in the form of a heat exchanger preheating the incoming supply air.

The technical evaluation gives the following results:

1. District heating with heat recovery
   a. A culvert would have to be constructed for pipes to the existing district heating system.
   b. There needs to be a district heating substation in each building.
   c. There needs to be a central heat recovery unit in each building.
   d. District heating energy use is calculated as 100 kWh/m^2, or 3300 MWh per year for the entire area.

2. Exhaust air heat pumps
   a. A central exhaust air heat pump in each building, in combination with a ground heat coil for additional heat uptake.
   b. The expected annual COP is calculated as 2.2, with 85 % of the buildings' heat requirement being met by the exhaust air heat pump, and the remainder by direct electric heating.
   c. Use of energy for electricity for heating calculated as amounting to 54 kWh/m^2, or 1770 MWh per year for the entire area.

3. An oil-fired boiler with heat recovery
   a. A culvert would have to be constructed from a centrally sited oil-fired boiler to all 33 buildings.
   b. A central unit for heat recovery in each building.
   c. The fuel oil is assumed to have a calorific value of 9900 kWh/m^3, and the boiler to have an efficiency of 85 %
   d. Energy use for the buildings is calculated as 100 kWh/m^2, or 393 m^3 of oil per year.

A.4 Investigation of organisational aspects

The various heat production systems require different levels of operational attention and maintenance. Operation and maintenance for the district heating substations would be provided by the district heating utility, which owns them. However, the heat recovery units require operation and maintenance, such as replacement of filters. Exhaust air heat pumps, too, require a certain amount of annual maintenance, as does the oil-fired boiler. The developer already has an operations organisation with the necessary competence to operate and maintain heat recovery units, exhaust air heat pumps and an oil-fired boiler, with the difference between them consisting only of the amount of work required.

Both district heating and exhaust air heat pumps can be regarded as environmentally welcome alternatives, and selection of either of them would provide a positive marketing benefit for the developer. Choosing an oil-fired boiler for an area of new residential buildings would be a marketing disaster, and would make it difficult to find tenants for the properties.

A.5 Investigation of economic aspects

The investment and energy costs for the various alternatives have been estimated, and are shown in Table A.1 and Table A.2.

Table A.1 Investment costs of the various energy supply systems

Alternative	**District heating with exhaust air heat recovery**	**Exhaust air heat pumps in each building**	**Oil-fired boiler with exhaust air heat recovery**
Equipment	Connection to district heating system will be free of charge	33 units for EUR 35 000 each. Total: EUR 1 155 000	One oil-fired boiler with 33 substations. EUR 582 000
Heat recovery	33 units for EUR 16 000 each. Total: EUR 528 000		33 units for EUR 16 000 each. Total: EUR 528 000
Digging and making culverts for piping	EUR 475 000		EUR 254 000
Maintenance, main unit		EUR 15 000/year	EUR 11 000/year
Maintenance, heat recovery	EUR 14 000/year		EUR 14 000/year

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Table A.2 Energy prices for various energy sources

Energy source	Price
District heating	EUR 0.06 /kWh
Electricity	EUR 0.08 /kWh
Oil	EUR 617 /m^3

The present value of the investment has been calculated using the present-value method. The equipment is assumed to have a life of 20 years, and so a calculation period of 20 years has been used. With such a potentially long time for economic conditions to change, calculations have been made for three different scenarios: for 0 %, 5 % and 10 % difference between the real rate of interest and the real increase in the price of energy, using the present value factors as shown in Table A.1. The results of the economic analysis are shown in Figure A.1.

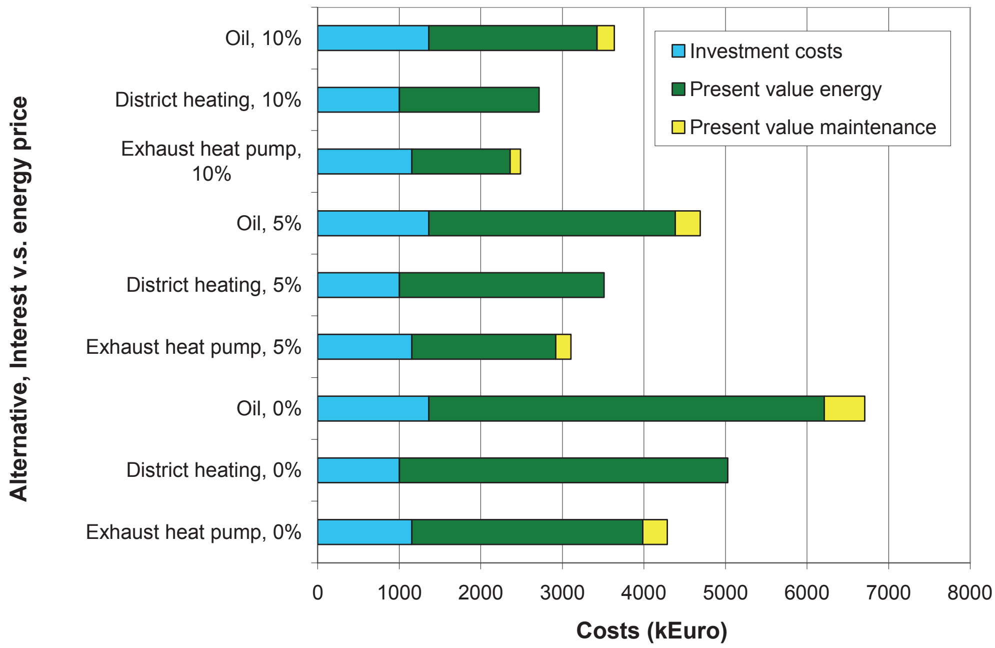

Figure A.1 Present value of the total investment for the two AES and the oil-fired boiler, for three different future economic scenarios.

Figure A.1 shows that the oil-fired boiler is the least profitable in a life-cycle perspective, regardless of the three different future economic conditions scenarios. The greater the difference between the real rate of interest and the real increase in the price of energy, the closer the cost similarity between district heating and exhaust air heat pumps.

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A.6 Investigation of environmental aspects

In order to be able to evaluate the environmental aspects of the various alternatives, their effects in terms of greenhouse gas emissions have been calculated. Emissions, expressed as CO_2 equivalents, have been calculated for each useful kWh supplied to the buildings, using the EFFem environmental assessment program (Wahlström, 2008). The values used are shown in Table A.3. Possible greenhouse gas effect has been calculated for three different ways of seeing electricity: as an average value of Swedish production units, as an average value of European production units, and for marginal production methods. District heating has been calculated using data for the actual production mix for the system concerned. As electricity is used in connection with district heating production, district heating also has different weightings depending on how electricity production is seen.

Table A.3 Emissions of CO_2-equivalents per kWh for different heating sources and electricity production methods

Electricity production	**Electricity** (CO_2-kWh/KWh)	**District heating** (CO_2-kWh/KWh)	**Oil** (CO_2-kWh/KWh)
Swedish mix	40	100	350
European mix	360	132	350
Marginal production	650	160	350

The Swedish governmental investigation of the directive on energy end-use efficiency and energy services has resulted in political weighting factors that are intended to reflect the environmental impact of the primary energy use various forms of energy and energy carriers, i.e. their use of natural resources (SOU 2008:25). The report suggests what are known as mean weighting factors, intended to be used when assessing existing energy use, as well as proposals for efficiency improvement weighting factors that are intended to be used when assessing changes in energy use. It is these latter factors that must be used when assessing performance etc. of new buildings. The values are shown in Table A.4.

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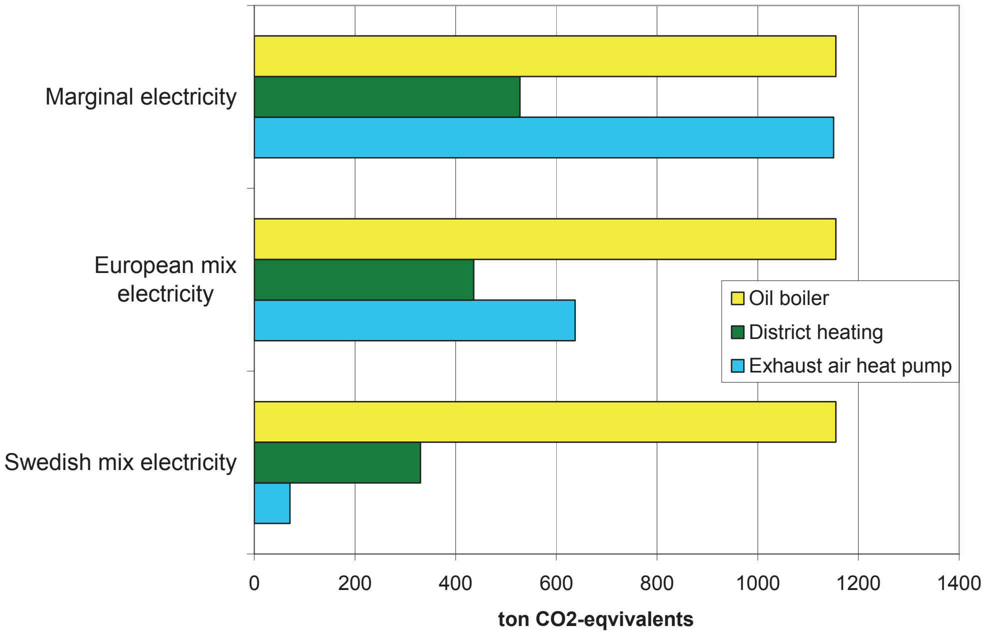

Figure A.2 Emissions of CO_2-equivalents for the various energy supply system alternatives.

Table A.4 Weighting factors for various forms of energy and energy carriers, as given in the report of the Swedish investigation into the directive on energy end-use efficiency and energy services (SOU 2008:25).

Energy, energy carrier	Average weighting factor	Efficiency improvement weighting factor
Electricity	1,5	2,5
District heating	0,9	1,0
Fossil (oil/natural gas)	1,2	1,2
Biofuels (pellets/logs)	1,2	1,2

Figure A.3 shows the effect of application of the weighting factors on the effect of the various alternatives on the use of natural resources.

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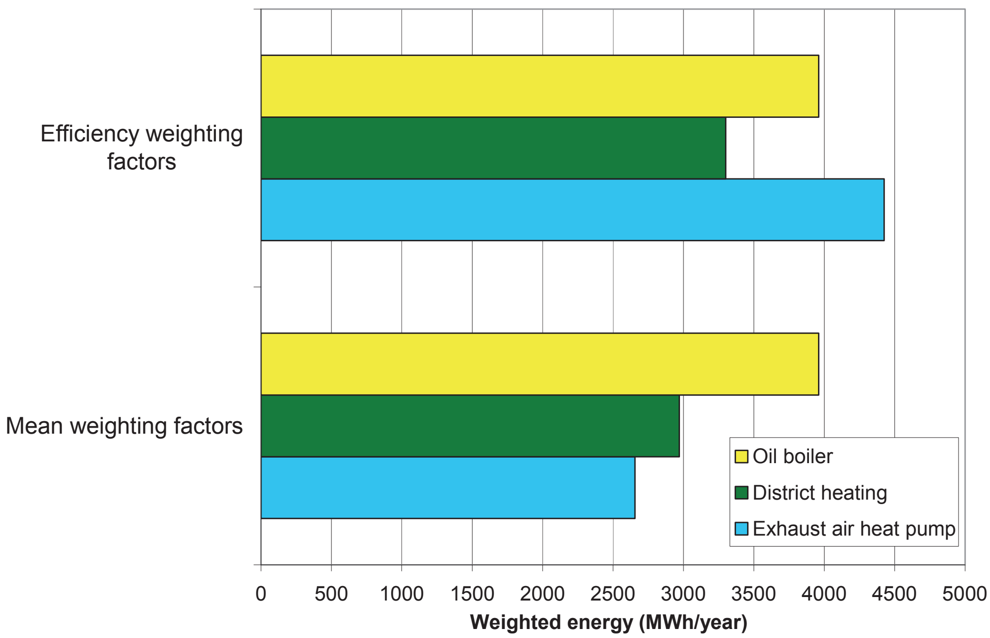

Figure A.3 Weighted energy use, intended to reflect primary energy use of the various alternative energy supply systems.

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A.7 Model form of indicators that could be used in a feasibility study

The results of the feasibility study have to be related to the national indicators. In particular, the energy performance standard and energy label of applying a certain alternative energy system for the energy supply of the building have to be presented.
A model form of indicators to be used when preparing a feasibility study has been produced in France. It is shown below in Table A.5, with details of the indicators that should be considered when performing a feasibility study.

Table A.5 Summary results of the feasibility study investigating supply energy sources, in accordance with the implementation order of 18th December 2007.

Short description of the different options, whether fully analysed or not: - baseline solution: the one that is selected by the building owner or developer - Option 1: solar thermal - Option 2: …..

	Indicator	Unit	Name of the indicator	Baseline	Indicator	Option 1	Option 2	Option 3	……..
Obligatory indicators		€	Additional cost of the option investment cost compared to the baseline cost		3.a				
	1.a	KWh/m2 MWh/y	Energy consumption (primary energy)		3b				
	1.b	Kg CO2/m2 T CO2/y	CO_2 emissions due to energy consumption (excluding refrigerant)		3.c				
	1.c	A,B,C,…	Energy class according to the energy label		3.d				
	1.d	A,B,C…	CO_2 emissions class according to climate label		3.e				
	1.e	€/year	Annual running costs		3.f				
		year	Payback of option compared to baseline		3.g				
			Other aspects (advantages and drawbacks) of option compared to baseline		3.h				
Optional indicators		kWh/m^2 MWh	Addition of savings over 30 year		3.i				
		Kg CO_2/m^2 T CO_2	Addition of saved emissions over 30 year		3.j				
		€/m^2 €	LCC over 30 year		3.k				
		€/m^2 €	Annual LCC		3.l				
		%	Return on investment rate of the option compared to baseline		3.m				

Reasons for not considering certain options - Option 2 is not ….

Reasons for selecting the baseline

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Appendix B: Some examples of practice

B.1 Swedish example

This chapter has been provided by Cecila Segerholm, SP Technical Research Institute of Sweden.

B.1.1 Description of the Hamnhuset project

Hamnhuset (Harbour House) is situated at Sannegårdshamnen, Gothenburg. The building is under construction and will be finished in the summer of 2008.
The intention of the project is to build an energy-efficient house which should be evaluated on the basis of life cycle costs. Another goal is to build a house without heating radiators, making the best use possible of internal energy from lighting, occupants etc.

Hamnhuset consists of two blocks, with a courtyard between them, and providing a total of 116 apartments. The houses have four or five floors. A garage is situated in the basement.

B.1.2 Content and outcome of LCC calculations

The life cycle costs of different construction methods, installation systems and energy-saving actions were calculated. Some of them turned out not to be profitable, and were excluded from further calculations.
A total final LCC calculation was made for the most favourable choices, with LCCs for two other houses being calculated and compared with Hamnhuset.

- Parameters that were compared in the LCC calculation:
  - Mounting of balcony slabs: comparing traditional method versus a product that reduces thermal bridges.
  - Insulation of the edges of floor slabs: comparing extra insulation versus normal insulation.
  - Construction of infill walls: comparing extra insulated walls versus standard walls.
  - Design of ventilation and heating installations. Different ventilation alternatives combined with different standards of wall insulation, and with or without radiators were calculated (seven alternatives).
  - Heat recovery from sewage: heat recovery from domestic waste water (shower, kitchen, wash) and domestic soil (all sewage) compared with no recovery.

- Control of lighting: Different light fittings combined with different control methods were studied (three alternatives).
- Solar collectors: Production of domestic hot water was calculated with and without solar collectors.

- Input data for the LCC calculation
  - Time period
  - Discount rate
  - Annual adjustment of costs
  - Cost of capital
  - Amortisation
  - Program for calculation

  The results depend on which values the figures above are given. Sensitivity analysis of the LCC calculations were performed with different values of the above annually cost adjustments, discount rate and the cost of capital. The results showed that, in this project, changes in these parameters very rarely produced a determining factor for the results.

- Account of results of the LCC calculation
  The results of the LCC calculation are shown in diagrams and graphs of three types.

1. The monthly costs
   The monthly specific costs for the investment (cost/m^2) during the first year are shown in Figure B.1.1. This forecast cost is comparatively reliable as a short-term forecast, valid for today's rates of interest, energy prices etc.

2. Diagram of costs, 30-year graphs
   The diagram of costs shows the running costs over the next 30 years, Figure B.1.2. If the lines in the diagram diverge during the time period, it indicates that there is a difference between the alternatives. The difference in slope shows how profitable (or unprofitable) the investment is during the time period.

3. Diagram of pay-back, 30-year graphs
   This type of diagram shows when an investment is paid back, Figure B.1.3. The diagram does not provide any information on the level of the monthly cost or of the yield of deposits.

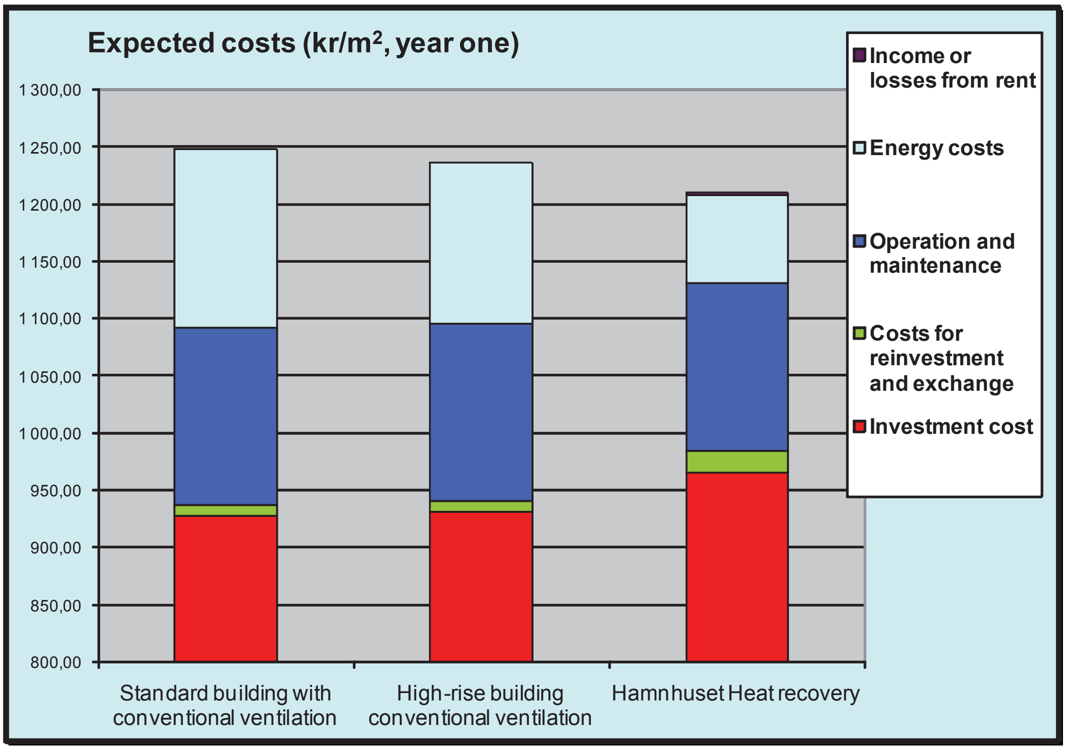

Figure B.1.1 The monthly costs for three types of houses

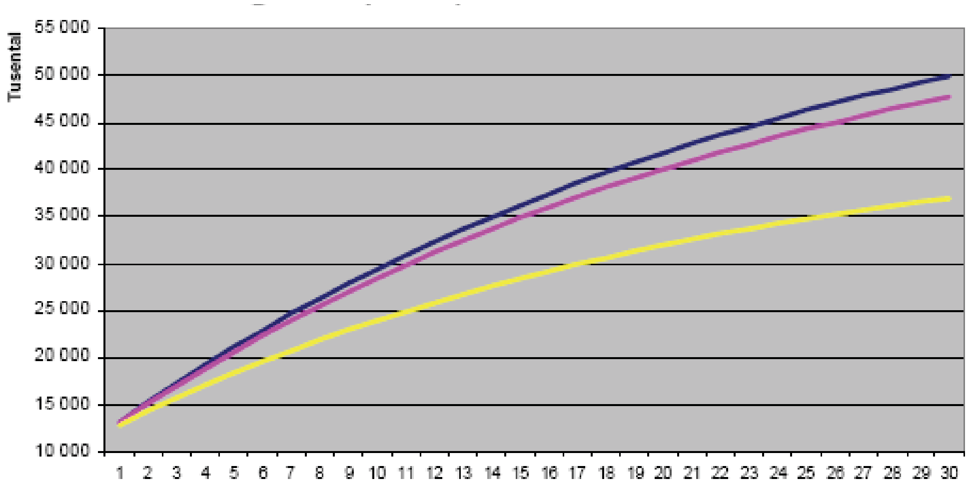

Figure B.1.2 Costs 30 years ahead. Blue line: standard building with conventional ventilation. Pink line: High-rice building with conventional ventilation. Yellow line: Hamnhuset with heat recovery.

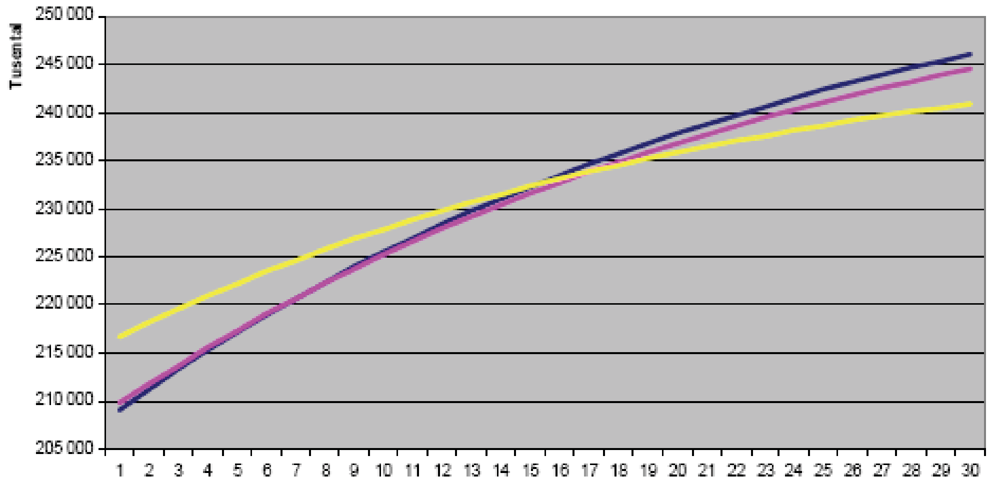

Figure B.1.3 Payback during 30 years. Blue line: standard building with conventional ventilation. Pink line: High-rice building with conventional ventilation. Yellow line: Hamnhuset with heat recovery.

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- Overall LCC of Hamnhuset
  Finally, an overall LCC calculation was made, bringing together the total cost of Hamnhuset from all energy-saving measures that were selected. Three types of houses were compared in the overall LCC calculation, as follows:

  1. Standard house (normally insulated) with radiators and a standard ventilation system (mechanical exhaust air ventilation, supply air through ventilators behind radiators)

  2. A house better insulated than the standard house, with radiators and a standard ventilation system.

  3. A passive house, where all favourable alternatives from the first calculations have been chosen. This means a well-insulated house where thermal bridges are reduced as much as possible. It also has a ventilation system with heat recovery from the exhaust air, and no radiators.

B.1.3 Results

After the feasibility study, the following energy solution was chosen for Hamnhuset:

- Highly insulated walls with a low U-value.
- Optimally placed low-energy windows with solar protection
- A large solar thermal system with 193 m^2 of collector area on the roof
- Heat recovery system for the ventilation
- District heating for preheating of air distribution if needed after the heat recovery unit, and district heating for additional heating of tap water that cannot be provided by the solar thermal system.

B.1.4 Conclusion

The LCC calculation of Hamnhuset shows that it is theoretically possible to achieve the target objectives. The total energy-saving measures contribute to such low running costs that the investment in a passive house is profitable, compared to a traditionally built house.

B.1.5 Reference

Älvstranden Utveckling AB (2007) LCC beräkningar (Staffan Bolminger)
Online: http://www.alvstranden.com/images/uploads/File/pdf/LCC-berkningar,%20Hamnhuset.pdf *(in Swedish)*

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B.2 Dutch example

This chapter has been provided by Suzanne Joosen Ecofys.

B.2.1 Description of project

De Boschkens is a new housing estate project in the woody village of Goirle in The Netherlands, to be completed in 2009. The project consists of approximately 400 family dwellings (several different types) and a school. Space heating, space cooling and domestic hot water are provided by a group heating and cooling system in combination with individual heat pumps at each connection. If this project is successful, the concept will be extended to another four hundred houses during 2009-2012. The choice of heat pumps implies that houses will not be connected to the gas grid. The total project will be the largest heat pump project in the Netherlands.

B.2.2 Content and outcome of feasibility studies

- *2001-2002: Ambition to develop a sustainable new area of family houses*
  At the start of the building process, the municipality of Goirle stated its ambition to achieve a reduction in CO_2 emission of 30 % compared to the Dutch energy performance standards of 2004 (EPC 1,0).

- *2002: Feasibility study on sustainable energy options.*
  The outcome of the study was that heat pumps would be the best option for a project such as De Boschkens. Heat pumps were chosen, since this would be one of the most cost-efficient ways of achieving the aims of this housing estate project.

- *November 2002: Feasibility of heat pump concepts*.
  Three heat pump concepts were considered (individual, collective and cluster heat pumps), against two scenarios(heating only, and heating together with cooling).
  - First, technical feasibility was considered, taking into account the three different heat pumps and the thermal balance of the aquifer layers.
  - Second, environmental and financial aspects were considered and quantified per household (see Table B.2.1).

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- Third, organisational aspects were covered by suggestions for an action plan.

Based on financial and environmental parameters, individual heat pumps are the best option.

Table B.2.1 Financial and environmental aspects of different alternatives.

Aspect	Individual heat pump	Collective heat pump	Cluster heat pump	Reference situation
Environmental				
CO_2 emissions, with and without cooling	600 ton	1300 ton	1200 ton	1200 ton
On Site Energy Performance	7.6	6.4	6.5	6.5
Financial				
Additional investment benefits, heating only	- € 100	- € 950	- € 800	€ 0
Additional investment benefits, heating and cooling	€ 900	- € 400	- € 200	€ 0
Additional exploitation benefits per year, heating only	- € 1	€ 40	- € 15	€ 0
Additional exploitation benefits per year, heating and cooling	€ 65	€ 100	€ 50	€ 0
Internal rate of return, heating and cooling	28.2 %	12.9 %	7.2 %	-

- *2002-2004: Tendering and contract negations with the energy partner.* This partner was found through a restricted call for tenders. Energy company Eneco won the bid to construct and run a collective heat and cold storage system in combination with individual heat pumps. Before the contract was signed, two obstacles were successfully tackled:
  - A new aquifer layer had to be found, after the first option proved not to be adequate.
  - A change in the Dutch subsidy scheme resulted in a new organisational structure. In order to profit from new subsidy schemes, the heat pumps will be owned by the energy company instead of the house owners.
- *July 2004: Contract with energy company*
- *2005 – 2012: Realisation of concept*
- *2007 – 2014: Occupation of the houses*

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B.2.3 Actors involved

During the first phases of the project, the municipality of Goirle decided to form a small steering committee with power of decision mandated by the city council. Actors involved during the first phases were project developers, housing organisations, architects, consultants and energy companies.

B.2.4 Conclusion

In 2007, 25 % of the 400 dwellings have been completed. Targets were set at the same time as starting the building process. In the Netherlands, the plans of the community on renewable energy are important for development of the site. The feasibility studies were carried out during the planning and programming stage of the process.

B.3 French example

This chapter has been provided by Hubert Despretz, Ademe.

B.3.1 Construction of 28 dwellings for social housing in Besançont

This small residential programme 1979 m^2) is divided into four small buildings. An energy feasibility study was conducted in 1999 by "Image et calcul" Consulting, examining and comparing six different combinations of building envelope insulation performance and systems. The building owner, Habitat 25, a social housing organisation, has selected additional insulation compared to minimum regulatory requirements, with a geothermal heat pump for heating (and cooling) and a solar system with electricity for domestic hot water.

Two heat pumps are connected to ten vertical boreholes, 100 m deep. Heating is provided by floor heating, which can also be used for cooling by reverse action of heat pumps.

DHW is preheated by 52 m^2 of solar collectors integrated into the roof of one building, in two sections of 26 m^2 each (see picture) and connected to a 3 m^3 water tank with a 24 kW additional electric resistance heater.

<u>Building design and construction stages</u>:

Initial programme and sketch	06/1995
Feasibility study	11/1999
Building permit	05/2001
Start of construction work	06/2002
Beginning of occupation	08/2003
Monitoring	2005

B.3.2 Content of feasibility study done

A number of technical combinations of solutions have been evaluated from the point of view of energy consumption costs, as shown in Table B.3.1.

Table B.3.1 Technical aspects and energy costs for different options.

Options	0 -Initial base case	1 - Reference solution	2	3	4	5
Enveloppe performance level	Regulatory reference	Ref-7 %	Ref-15 %	Ref - 15 %	Ref-15 %	Ref-23 %
Energy source	Electricity	Natural gas	Electricity with heat pump			
Heating system	Individual	Group central heating system				
Emission	Electric heater	Radiators	Heated floor			
DHW prod.	Individual electric water heater	Central gas fired boiler	Solar absorbers+ central additional electric resistance			
Total energy cost (€/m2)	10.22	7.45	5.79	4.88	4.83	4.52
Investment cost (€ TTC/m2)		49.5			163	162

Although the investment is far more important in solutions 4 or 5 than in the reference case, the procured comfort, elimination of radiators (room gain) and the possibility, if needed, of providing some cooling have decided the building owner for the more energy-efficient one. The study has also revised the various financial incentives which have cancelled out the additional cost of the innovative solution.

B.3.3 Outcome of the study

The solution that was adopted and monitored in 2005 leads to the following results:

Table B.3.2 Economic balance

Costs (€/m2)	**Reference***	**Planned***	**Actual 2005**
Investment cost	1504	1648	1697
Energy consumption	6.83	4.06	6.01
Maintenance	0.62	0.46	1.82
*** 1999 value**			

Table B.3.3 Energy consumption and production

kWh/m^2, year	Reference	Planned	Actual 2005
Heating consumption	174.6	21.2	17.3
Domestic hot water	74.7	33.4	37.1
System ancillaries	5.3	3.7	6.1
Total energy consumption	254.6	58.3	60.5
Contribution of renewable energy to total needs			53 %

Table B.3.4 Environmental indicators

CO_2 emissions (kg/m^2, year)	47.0	5.7	6.4
Primary energy consumption (kWh EP/m^2, year)	263	150	156

B.3.4 Conclusion

The completed and occupied group of buildings has delivered a performance as planned, which has led both the social housing organisation and the energy consultant to repeat the technical solution on several occasions.

B.4 Slovenian example

This chapter has been provided by Marjana Sijanec Zavrl, BCEI ZRMK.

B.4.1 The case of planning of integral energy retrofitting of kindergarden in Gornja Radgona

In many countries, energy retrofitting of older public buildings serves as an illustrative showcase of potentials for energy and environmental retrofitting. In principle, both the owner and the state are interested in optimal solutions from the point of view of investment and energy services costs on the one hand, while on the other hand, in most cases, the buildings in question can serve as demonstration objects for new concepts, designs and technologies that are available to most of the public. They also provide information from the users of energy services in retrofitted buildings.

Energy retrofitting of public buildings – typically, schools, kindergartens, homes for the elderly – can reduce primary energy in the proportion of 10:1, at the same time as indoor comfort and working conditions usually are substantially improved at the same time. However, retrofitting is not limited only to energy conservation, because in many cases new "bio-insulation" materials are used in order to replace less sustainable or less environmentally friendly solutions. In such cases, retrofitting is therefore integrated with many aspects since planners are introducing a broader spectrum of environmental criteria for improving performance and extending the lifetime of the building.

Manka Golarja kindergarten in Gornja Radgona consists of two single-floor buildings, each of about 900 m^2_{net} of heated area: the older building at Kocljeva Street 2 (Building X in Figure B.4.1)) that was built in 1975, and a newer building at Kocljeva 4 Street (Building L in Figure B.4.1)) that was built in 1982. The energy retrofit includes energy conservation measures, and proposes the use of renewable energy, with the overall aim of approaching the standard of a passive energy building. As a result of the significantly reduced energy demand, it will also be necessary to replace energy systems in the buildings. With the implementation of new energy conservation measures and renewable energy technologies, while respecting the principles of sustainable building, the renovated kindergarten will achieve better economic, social and environmental performance for its operation.

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Figure B.4.1 Location of kindergarten's buildings in Gornja Radgona

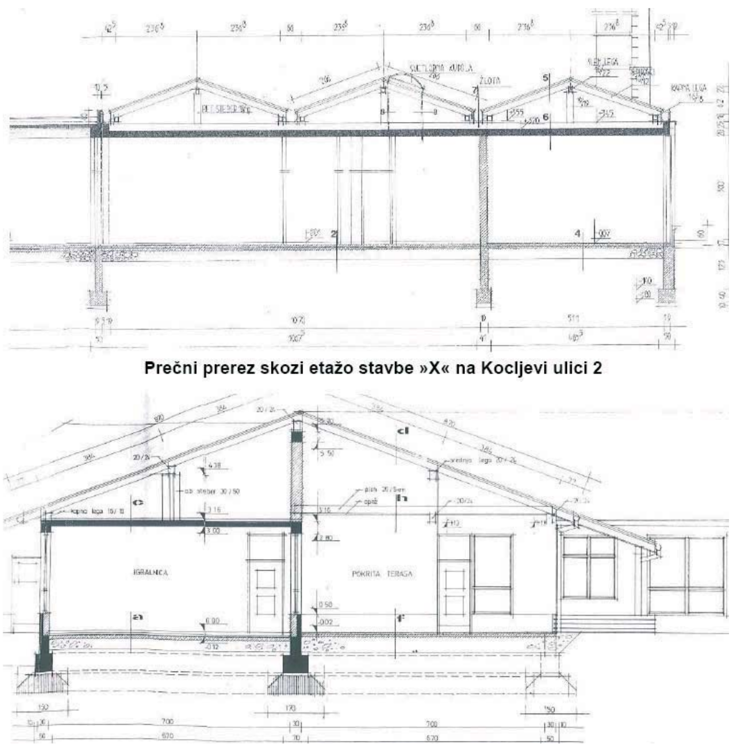
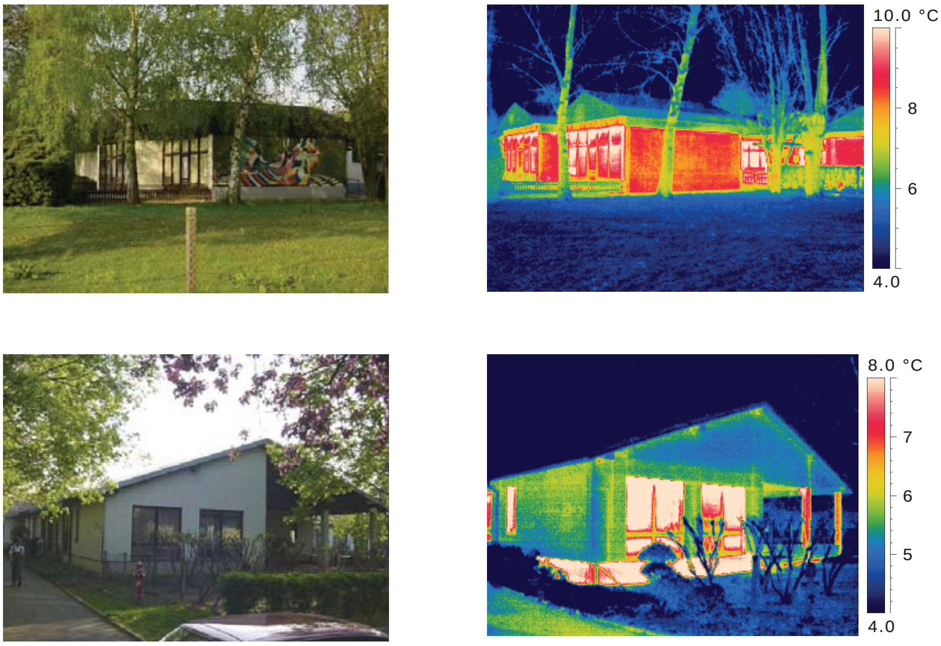
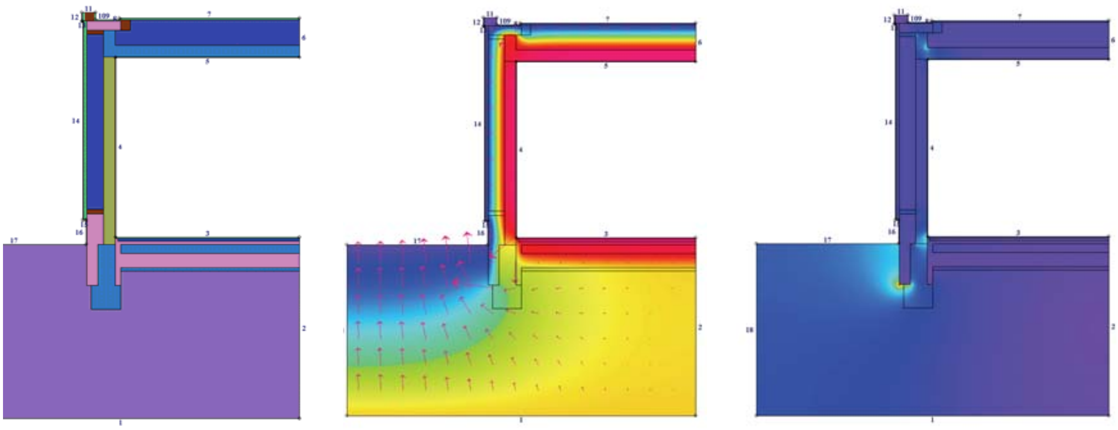


Figure B.4.2 Typical vertical cross-section of single-floor buildings



Figur B.4.3 IR photos of building exteriors, showing insufficient thermal insulation

Planning of this kind of energy retrofitting – i.e. "passive technology""- demands interrelated knowledge from architecture, civil engineering and energy sciences, together with contemporary multi-criteria optimisation of proposed solutions, based on knowledge of interactions between the proposed measures. This showcase illustrates inter-disciplinary cooperation of different expertises, showing how the results of planning are comparable with good practice of construction/retrofitting of public buildings in foreign countries.



Figur B.4.4 Evaluating solutions for heat bridges in building envelope with dynamic heat transfer simulations

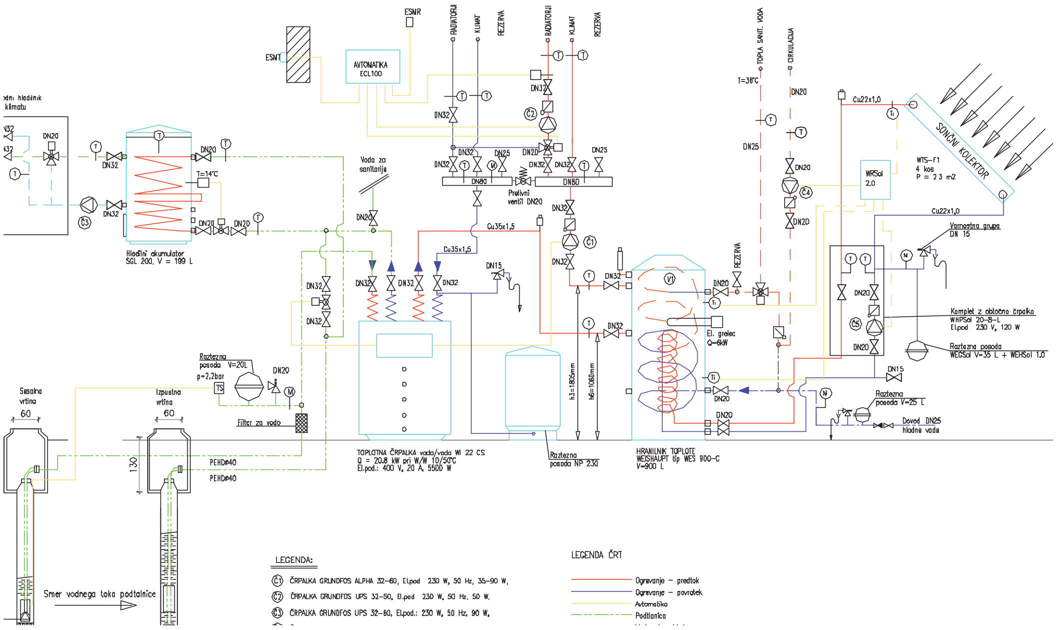


Figure B.4.5 A groundwater heat pump provides active heating and passive cooling, with additional heat contribution from solar panels

The basis for the project consists of an earlier study on energy retrofitting of the kindergarten, ordered by the investor, the municipality Gornja Radgona. The study has investigated three basic scenarios of investment: 1) a reference scenario with minimal investment without change of technologies already in place (at 160 €/m^2); 2) meeting the minimum new energy performance standards for energy retrofitting, (at 300 €/m^2), and 3) an advanced scenario for integral retrofitting with passive technology design guidelines (at 500 €/m^2).

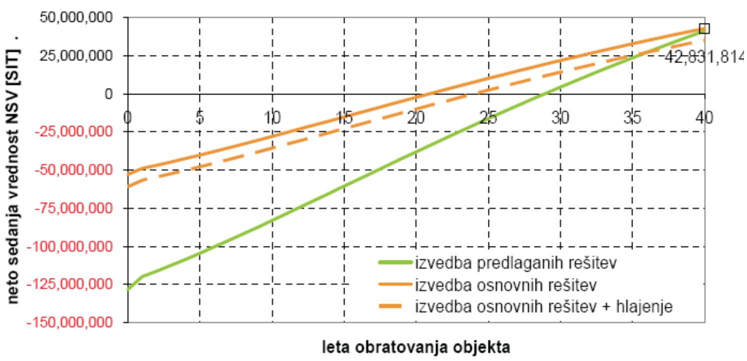


Figure B.4.6 Long-term economic evaluation of different retrofitting scenarios

The long-term economic evaluation of the scenarios indicated that the second and the third scenarios have identical long-term financial results. This means that, for the same financial cost, if either of the scenarios is implemented, the users will gain better living/working conditions at all times of the year.

Evaluation of retrofitting measures on the building envelope and energy system shows that annual energy demand for heating will be reduced from 100 to 120 kWh/m^2, year, or 14 to 18 kWh/m^2, year – a reduction in ratio of 7:1.

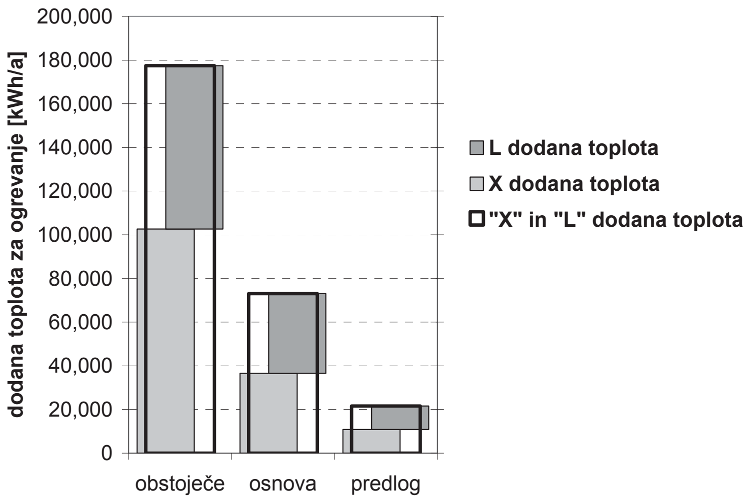


Figure B.4.7 Annual energy demand for heating is reduced in ratio 7:1

Changes in total energy use and in the mix of fuels will reduce annual CO_2 emissions from 100 ton/year to 60 ton/year, and total primary energy use in the kindergarten's buildings from 300 kWh/m^2, year to 140 kWh/m^2, year.

B.4.2 References

Kovič Silvija, Miha Praznik: PGD/PZI, Elaborat celostne energetske prenove Vrtca Manka Golarja v Gornji Radgoni, december 2006, Gradbeni inštitut ZRMK d.o.o. Ljubljana

Miha Praznik: Energy Retrofitting of Education-purpose Buildings- –The case of planning of integral energy retrofitting of Kindergarden in GORNJA RADGONA, 24. april 2007, Konferenca slovenskega E-Foruma, Cankarjev dom, Ljubljana

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Table B.4.1 Summary of indicators from the feasibility study

Indicator from feasibility study	Reference scenario	Basic renovation level[2]	Advanced renovation level, including AES and PHR[3]
Investment Total [€/m^2]	160	300	500
Building vs. systems share in the investment	60 : 40	85 : 15	70 : 30
Overal thermal transmitance of the building envelope. [W/m^2K]	0.69 0.61	0.25 0.26	0.19 0.17
Annual heat losses [MWh/year]	280	155	95
Annual heat demand [MWh/year]	180	75	20
Factor of heat demand reduction	9	4	1
Improved thermal insulation of the envelope	NO	YES	YES
Mechanical ventilation system installed	NO	PARTLY	YES
Active cooling of living space in summer	NO	NO	YES
Annual CO_2 emissions [t/year]	100		60
Annual primary energy use [kWh/m^2, year]	300		140
Use of fossil fuels in energy supply	YES	YES	NO
Use of heat from the environment (ground heat)	NO	NO	YES
Active use of solar energy	NO	NO	YES

1 – no changes, only regular maintenance

2 - building standards level, usual technologies for technical improvement

3 - passive house renovation and integration of RES

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B.5 Lithuanian example

This chapter has been provided by Egidijus Norvaisa, LEI.

B.5.1 Example of solar and biofuel energy system investigated for a children's sanatorium

This paper is not intended to present an example of a feasibility study, but to present the analysis results of an already implemented alternative heating system operation. According to the analysis made in WP3 of the SENTRO project, lack of knowledge and practical examples are significant barriers to the implementation of alternative energy systems in Lithuania. The real economic and operational indicators described here provide understanding of possible investments, O&M costs and the effectiveness of such systems in local conditions. This information could be very helpful for actors considering installing one of the systems described here. However, the economic, technical and environmental analyses are necessary for each particular building project in order to estimate the possible benefits of intended alternative systems.

This descriptino relates to the reconstructed heat supply system for a children's sanatorium in the small town of Kacergine. The new integrated system of biomass and solar energy has replaced the old oil-based system and significantly increased the efficiency of heating and hot water production, while reducing energy generation costs and CO_2. The sanatorium has nine buildings, with a total heated floor area of 2319 m^2. Reconstruction included installation of a 600 kW boiler burning wood and wood waste, together with 77,3 m^2 of solar collectors, as shown in Figures B.5.1a,b and B.5.2. It is the only system of such a type actually operating in Lithuania in a public building.

Figure B.5.1a,b Boiler house and solar collectors in Kacergine sanatorium.

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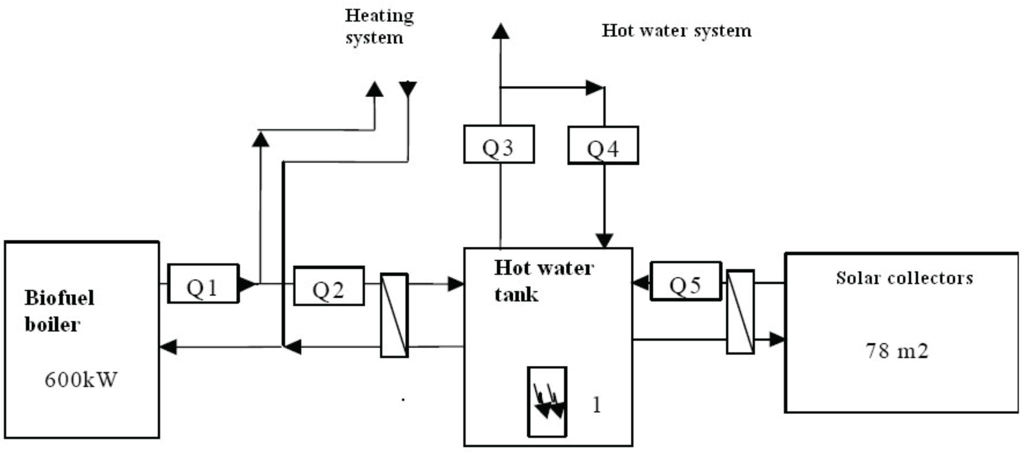

Figure B.5.2 Schematic diagram of the reconstructed heating system.

System performance was monitored over the 2004-2007 heating seasons. The new boiler house generated 751 MWh (2004-2005), 831 MWh (2005-2006) and 694 MWh (2006-2007) of heat energy in the three years, with a fuel efficiency of 0.79-0.81 over the period.

The solar collectors delivered 3-5.3 MWh of heat energy in the summer months and 0.2-1.5 MWh in the winter months. The data from the heat meters shows that the solar collectors supplied 29 MWh (2004), 32.9MWh (2005), 30.9 MWh (2006) and 24.8 MWh (2007) of heat energy as hot water, i.e. the solar collectors heated 16.3-18.7 % of the total hot water demand in the sanatorium. The energy produced in the solar collectors is shown in Figure B.5.3.

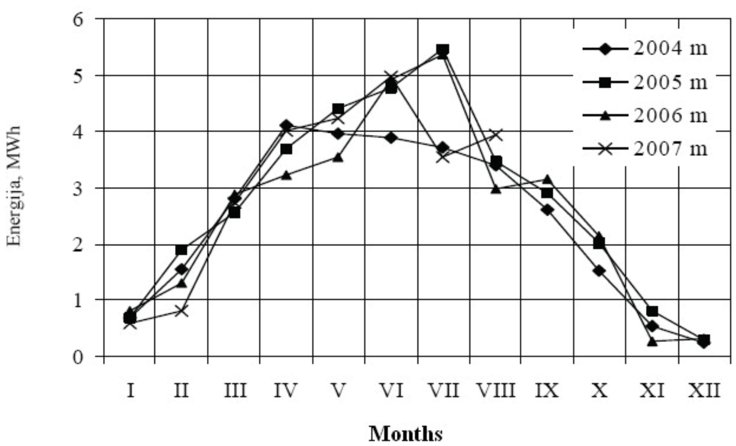

Figure B.5.3 The heat (hot water) generated in the solar collectors (2004-2007).

The average heat production cost from the wood waste boiler house is 14 LTct/kWh, the share of fuel cost in the total cost is 5.9-6.4 LTct/kWh (Table 1).

The real pay-off time of the boiler house is 5.7 years (according to the operational data). The costs of heat generation, compared to the old boiler, has been reduced to about one third. The investment for the new boiler house was 1127 Lt/kW, but the average investments for biomass boiler houses in Lithuania are 500 Lt/kW. However, the heat insulation in the sanatoria buildings is very low, and the comparative heat consumption in the period analysed was 318 kWh/m^2. The buildings are in need of renovation, which could decrease heat energy consumption by 30-50 %.

Table B.5.1 Heat generation price in 2005-2006 (boiler house).

Heat generation	MWh/year	831
Boiler capacity	kW	600
Investment	Thous. Lt / Lt/kW	676.4 / 1127
Fuel costs	Thous. Lt/year	36.4
Electricity, water costs	Thous. Lt/year	12.7
O&M costs	Thous. Lt/year	24.5
Heat price	Lt/kWh	0.1427
Fuel price	Lt/kWh	0.059-0.064

* 1 Euro is 3.45 Lt

The average heat production cost from the solar collectors is 42.3 LTct/kWh (Table B.5.2), which is more than the current price of electricity (33 LTct/kWh). However, the collectors are in shadow for part of the day: in principle, heat generation could be 25 % higher, which would reduce the heat production cost to 34.2 LTct/kWh. The average annual heat energy generation from one square meter is 400 kWh/m^2. If solar collectors are optimally sited, heat generation under Lithuanian climate conditions could reach 520 kWh/m^2. The real pay-off time of the solar system in this object is 17 years. Financial support from the government is necessary in order to encourage installation of such systems.

Table B.5.2 Economic indicators for the solar collectors.

Heat generation (average)	MWh/year	30.8
Solar collector area	M2	77.3
Investment	Thous. Lt / Lt/kW	190 / 2459
O&M costs	Thous. Lt/year	0.5
Heat cost	Lt/kWh	0.427

Changing from light fuel oil to wood waste has reduced CO_2 emissions by 237 tonnes per year, or to 0.267 t/MWh. The solar collector system has reduced the CO_2 emissions by 9.14 tonnes per year, or 0.25 t/m^2 (assuming that solar energy replaces the electricity).

The educational aspect of this object is also very important. Every year the sanatorium is visited by hundreds of children, who learn about the renewable energy sources: biomass and solar.

B.5.2 References

The system described here is based on the study "The analysis of efficiency of the biomass and solar energy generation in the kinder sanatorium in Kacergine",. (http://www.ukmin.lt/lt/veiklos_kryptys/energetika/istekliai/doc/Kacergines_studija.pdf, in Lithuanian) made by "AF-TERMA" (www.afterma.lt).

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Appendix C: Description of alternative energy systems

Article 5 of the Directive on Energy Performance of Buildings (2002/91/EC) prescribes feasibility studies of the following alternative energy systems:

- decentralised energy supply systems based on renewable energy,
- CHP,
- district or block heating or cooling,
- heat pumps.

Note that these AES systems are often combined with each other and other traditional energy systems. Other AES that are not mentioned here might be suitable solutions.

C.1 Decentralised energy supply systems based on renewable energy

Solar thermal systems

In a solar thermal system, energy from the sun is converted into heat in a closed hydronic water circuit. The obtained heat could either be used for heating in the domestic hot water system or in a combined system for both space heating and domestic hot water heating. A solar thermal system consists of a solar circuit, a thermal storage and an additional back up heater (gas-fired or direct electric). There are several types of solar collectors the main systems being a flat plate and vacuum tube solar collector. The water in the solar circuit is normally made frost proof by mixing it with glycol. For domestic hot water a storage tank is used with additional heat produced by an electrical or gasfired back up.

When using the heat in a combined system, the storage tank is used for both hot water central heating of the building and domestic hot water production. The tank is then connected to the hot water central heating of the building. As the gained solar energy is not enough to cover the total heating demand a back up heating device has to be added in the form of an electrical or gas fired heater. There are possibilities to combine solar thermal system with other types of energy like district heating, bio-fuels, heat pumps etc. Solar collector modules are also available as integrated roof building modules.

Figure C.1 Solar collectors in a residential building built in 2000 in Sweden (Source: Aquasol).

Figure C.2 Façade integrated collectors in larger residential building in Denmark (Source: Batec/ESTIF).

Solar photo voltaic systems

In a solar photo voltaic system energy from the sun is converted into electricity. A solar cell consists of a thin sheet of semiconductor material where electrons are unbound and produces an electrical current. A solar cell system consists of a number of solar cells connected in series forming a module. A typical electrical output power for one module is 100 W, which correspond to a surface between 0.6 and 1.5 m^2. The module produces direct current so it has to be converted to alternating current. About 10 to 15% of the solar energy that hits the solar cell is transformed to electrical power. The main part is transformed to heat and the degree of efficiency decrease when the solar cells become heated. By cooling the solar cells with for instance water there is a possibility to increase the degree of

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efficiency at the same time as heat is gained. Solar cell modules are also available as integrated façade building modules. There are a lot of applications where solar cells are used in locations where there is no connection to the electricity grid, for instance in mountain areas, lighthouses, sailing boats etc.

Figure C.3 Solar photovoltaic system at the Ullevi sport arena in Gothenburg Sweden. The system gives power for the total arena lighting system. (Source: Switchpower and GotEvent)

Bio-energy systems

Energy can be extracted from waste and biomass in many ways. Examples of biomass fuel are: fuel from trees (wood, bark, sawdust, and waste from paper pulp production), cultivated biomass fuels (energy forest trees, grass, rape, straw). Turf and some waste are also considered as biomass. An attractive alternative to be used is in the form of wood-chips or wood-pallets, which can be burned in high efficiency pellet burners. Only non-fossil biomass can be considered as renewable and CO_2-free. In waste incineration, for example, the total energy yield must be corrected to allow for the fossil fraction, and for any fossil energy used by the installation. Only the biomass fraction in energy production and in waste incineration plants is considered renewable and adding to the CO_2-reduction of the system.

The fuel is combusted in a boiler, which produces hot water for heating and domestic hot water. A boiler for biomass fuel needs more care than a boiler for combustion of oil. There is also a need of space to store the biomass fuel. For instance there is a need of 3.4 m^3 of biomass pellets to compensate for 1 m^3 of oil. Emissions from the burning of wood can still be a local environmental problem if not taken care of in the right way.

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Heat pumps

Geothermal heat pump systems

Geothermal heat pumps also called ground source heat pumps include heat pumps that use heat from a ground or shallow geothermal heat source. The heat from the heat pump can be used for space heating and domestic hot water. These heat pumps can also be used for cooling. The efficiency of a heat pump is indicated as a Coefficient of Performance (COP), the energy obtained in the heat pump related to the electrical power input or the gas used. For instance a heat pump with COP 4 means that of 1 kW electrical power input it is possible to achieve 4 kW of thermal energy under certain conditions of measurements. A more accurate measure of the efficiency of a heat pump is the Seasonal Performance Factor (SFP). This is calculated as a function of the climate of a whole year, the location and the size of the building.

There are different types of geothermal/ground source heat pumps:

Rock (geothermal heat): The heat is collected from a bore hole in the rock. Typical bore hole depth ranges from 100 to 200 metres. This type of heat pump is connected to a brine system with welded plastic pipes extracting heat from the rock. Some rock-coupled systems in commercial buildings use the rock for heat and cold storage.

Ground source heat pump: Heat is extracted from pipes laid horizontally or vertically in the soil (horizontal/vertical ground coils), and both direct expansion and brine systems can be used.

Ground water heat pump: The heat is collected by extracting the ground water from a bore hole in an underground aquifer system and reinjected back in another bore hole. The ground water has almost no impurities and therefore has to be protected against impurities from the surface (according to European legislation). This requires different design of the heat pump or an extra heat exchange. These systems are especially favoured in larger systems in both commercial and residential buildings.

Sea water/lake/river heat pump: The heat is collected from the sea or a lake. The circulation pipe is placed on the bottom of the sea or a lake.

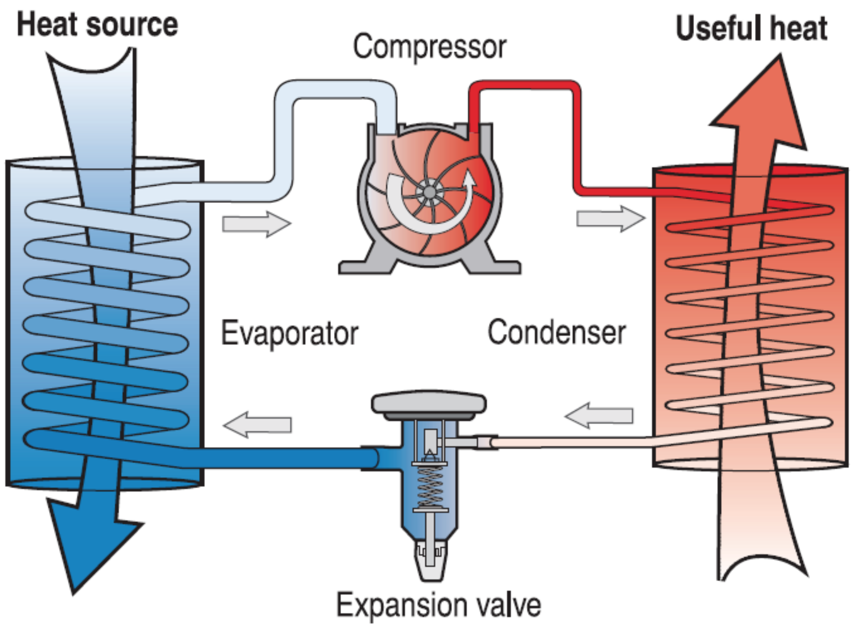

Figure C.4 Principle of the compression heat pump cycle. In the evaporator, heat is absorbed by the working fluid from the heat source at low pressure. The compressor then compresses the working fluid. In the condenser heat is removed at high pressure to useful heat.

<u>Air source heat pump systems</u>
Air-source heat pumps are widely used already in commercial buildings as a part of air-conditioning systems, which are designed for achieving the right climate in the building. These are standard solutions not considered in this type of feasibility study but only as a reference.

Air source heat pumps mainly focussed on the functionality of heating can be used in residential and commercial buildings in hydronic systems with a back up heating system. The back up system can be necessary in ‘standard’ buildings due to the low capacity of air-source heat pumps with low outside temperatures. In areas/countries with a strong electricity grid this back up system can be direct electrical heating. It is advised however to seek for low CO_2-emission solutions for back up, like high efficiency gas-boilers or other renewable heating devices. By this back up system the overall performance as SPF is on average 10-30% lower than water-source heat pumps. In low energy buildings and passive buildings this back up system can be designed as a hot water storage tank.
The two main types of air source heat pumps are:

Ambient air heat pump: The heat is collected from the ambient air and transmitted either to a hot water central heating heat-system and is also able to produce domestic hot water (air to water heat pump). Another type of ambient air heat pump is the air to air heat pump where the heat from the ambient air is transmitted to an indoor air unit. This type of standard air-conditioning systems, often offered as split cooling units and sold as heat pumps, have a low SPF value.

Exhaust air heat pump: The heat is recovered from the ventilation air, and providing space heating and/or domestic hot water heating.

Figure C.5 Heat pumps that recover heat from exhaust ventilation air during the winter period and are used as cooling machines during the summer period (Source: IVT heat pumps for larger buildings)

CHP systems on building level
CHP (combined heat and power production) is an installation, which produces heat and electricity. Natural fossil gas is today most common fuel used in small CHP installations. Electricity is produced with a gas engine, a Stirling engine, a micro gas-turbine or fuel cell. The conservation of energy and the CO_2-reduction is very much dependent on the power efficiency in the country and the corresponding emissions as well as the possibility to use the heat optimally without too much loss. Especially when producing domestic hot water care should be taken to reduce the high-energy losses.

The technology also works with bio-energy (gas, wood pellets and chips). In that case the technology is considered as producing renewable heat and electricity.

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In CHP installations for biomass also other fuels can be used if the burner technology is adapted to the fuel or the fuel is adapted to the burner. Especially in larger projects for housing blocks and small commercial buildings wood pallets can be viable.

C.2 Centralised energy supply systems based on renewable energy

District heating systems

The heat is produced in a district heating plant that could be heat plants, large combined heat and power plants (CHP) or plants for handling of waste heat from e.g. industry or sewage. District heating could also be produced by large heat pumps and thermal solar collectors. A part of a town or the whole town is supplied with hot water by insulated underground heat-distribution pipes. Fuels used in the heating plant could be oil, gas, biomass fuels, domestic waste, waste heat etc. In the building a unit is located consisting of a heat exchanger for heating water for space heating and a heat exchanger for production of domestic hot water.

As with CHP, the conservation of energy and the CO_2-reduction are very much dependent on the possibility to use the heat optimally, without too much losses. Control and decrease of distribution losses are, therewith, very important, especially for high temperature distribution for domestic hot water production. The CO_2-reduction is also very dependent on the fuel used at heat production and can be very different for different district heating plants.

Figure C.6 Combined heat and power plant for biomass combustion in Sweden (Source: Borås Energi & Miljö)

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Figure C.7 Example of district heating net with hot water distribution pipes .

District cooling systems

A district cooling system is based on the same principles as a district heating system, but it is cold water that is distributed in the area/district. District cooling is produced in various ways. Free or passive cooling uses cold water from lakes, seas, cold storage aquifer systems or other watercourses or uses snow gathered during the winter time. Absorption cooling uses the thermal energy from production of district heating. Heat pumps are able to produce heat and cooling at the same time and are the most common way to produce district cooling. The chilled water is distributed in the buildings through a heat exchanger.

“Green electricity”

Wind Power mills and hydro power plants can produce “green electricity” that can be delivered through the common electricity grid. Also biofuel based CHP plants can deliver “green electricity”. In the future also sea based wave power plants and large centralised solar photo voltaic systems may be utilised for this purpose. Buying “green electricity” is an efficient way to reduce the environmental impact of the electricity used by the building services systems (pumps, fans, etc).

Appendix D: Frequently Asked Questions

The use of AES is hindered by a combination of barriers, such as higher investment costs, lack of knowledge and additional required permits. The heart of the barriers is the estimation of risk on the part of the decision-makers, as presented by often unfamiliar AES. However, new developments always encounter resistance, and it is necessary to deal/cope with this. To be prepared, a list of objections which are usually put forward during the building process, including possible responses to these objections, are indicated below.

1. **Are AES prices competitive with regular alternatives?**
   - Investigations show that solutions/options are often much cheaper than investors/builders realise. The 'Energy Efficiency in Buildings: Business Realities and Opportunities' report by the World Business Council for Sustainable Development (WBCSD) describes that the additional costs of sustainable buildings were far less than perceived (5 % in reality, as against 17 % perceived). The impact of sustainable buildings was also greatly underestimated: buildings are responsible for 40 % of total emissions, while most people thought it to be 19 %.
   - Financial schemes are often possible: lease or hire schemes, outsourcing,
   - Financial assistance is often possible: for example, by national grant schemes or feedback tariffs.

2. **How can investors solve the split incentive?**
   - Investigations show that solutions/options are often much cheaper than investors/builders are aware of.
   - Profitable financial schemes are often possible.
   - In future, low energy consumption may be an integral part of the economic market value of a building. The energy labelling system is a first step in this process.

3. **Are AES as reliable as regular alternatives?**
   - All solutions/options are well past the demonstration stage. Most of them are in the market introduction phase, with good experience at national/international level. Most systems are based on straightforward technology.

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- It is crucial to find expertise and experienced installers/advisors at an early stage.

4. **How do AES influence the design of the building?**
   - It is challenging to integrate low-energy consumption in the design.
   - Nowadays, there are many technical possibilities for AES as well, such as models, installations/appliances for heating/cooling, façade photovoltaic systems, climate control, low-temperature heating devices etc.
   - It is more important to take flexibility into account, reserve space for installations etc.
   - Environmental design will probably be highly valued in the near future. Refer to the energy labelling system.
   - There are plenty of good examples of beautiful environmental architecture.

5. **How to perform feasibility studies with a small budget and limited time?**
   - Time and costs can be limited, if the work is performed as an integral part of the development of the building, with the studies being carried out at an early stage of the process (preferable), and experts involved during these early stages.
   - The work is also good preparation for the near future: it can be expected that energy performance standards will become more stringent (Kyoto-protocol, Post-Kyoto, adaptation of EPBD)

6. **How to act if feasibility studies are not (yet) required?**
   - If the investor is also the occupant of the building, it must be pointed out that, after investment cost, it is always the overall life cycle cost of the energy system that must be taken into account (including opportunities for AES). There are often cost-effective solutions of which the investor is not aware.
   - If the investor (real estate developer) is not the occupant of the building, it must be pointed out that carrying out feasibility studies for AES is also a way of being prepared for the near future: it can be expected that energy performance standards will become more stringent (Kyoto-protocol, Post-Kyoto, adaptation of EPBD), and feasibility studies may well become mandatory.

7. What is the cost of such a study ?

- There is no fixed cost, because the amount of work depends on the complexity of the study and, to a certain extent, on the size of the building.

8. Are there any financial incentives for these studies

- As is the case for most regulatory obligations, there is no financial support from energy utilities or the state.

9. Can energy utilities be associated with, or sponsor, the study ?

- As the objective of the study is to obtain an unbiased review of the different energy supply options, including the non-commercial renewable energy sources, it is recommended that energy utilities should not be associated with the preparation of the study.

10. When should the study be carried out ?

- In most regulatory regimes, feasibility studies of the use of alternative energy sources should be made available at the building permit application stage. In practice, this means that the review of options must be included in the overall programme for the new building, and that an energy specialist (installer, consultant) will need to be associated with the architect from the vey first design stage and onwards.

Appendix E: Examples of tools and methods that may be useful in the feasibility study

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No	Name of tool	Country	Stages of builiding process: Planning stage	Building program	Schematic design	Design development	Construction phase	Operational phase	Type of tool	Type of tool	Short description	Year	Organisation	Link to documentation	Target group
1	3CL	FR		x	x	x				Calculation algorithm	Tool for single family houses and apartment blocks, excel tool for demonstration		ADAME		
2	AEU	FR	x	x	x	x			LCA tool		LCA tool for development of materials that fullfils regulations with respect to the environment		ADAME		
3	ATHENA	CAN	x	x	x	x			LCA tool		LCA tool for architecs, engineers and researcher when designing buildings		Athena Institute	http://www.athenasmi.ca/about/lcaModel.html	Designers, Consultants, Engineering installors
4	BEES	USA	x	x	x	x			LCA and LCC tool		The BEES tool is a software program that implements a rational, systematic technique for selecting environmentally friendly and cost-effective building products.		USA federal government, NIST (National Institute of Standards and Technology)	http://www.bfrl.nist.gov/oae/software/bees.html	Designers, Consultants, Engineering installors
5	BILDTRAD	CAN		x	x	x			Building simulation	Software	Software tool to analyse building envelope energy efficiency of wall and window combinations in commercial and multi-unit residential buildings. Generate a report to be attached to the building permit application.		National Research Council of Canada and Natural Resources Canada	http://www.sbc.nrcan.gc.ca/software_and_tools/biltrad_e.asp	Building designers
6	BLAST	USA		x	x	x				Software	Powerful software tool for calculating heating and cooling loads for buildings.		University of Illinois	http://www.eere.energy.gov/buildings/tools_directory/software.cfm/ID=61/pagename_submenu=/pagename_menu=other_applicatioins/pa	
7	BREEAM	GB	x	x	x	x			Assessment method		Estimation of buildings effect on the environment				
8	BSim2002	DK		x	x	x			Building simulation	Software	Evaluation of the indoor climate and energy conditions as well as the designing of the heating, cooling and ventilation plants.		Danish Building and Urban Research		Researchers, Engineering consultants
9	Building Energy Analyzer (BEA)	USA		x	x	x			LCC tool		Provides economic analysis for commercial and industrial buildings of annual and monthly loads and costs associated with air-conditioning, heating, on-site power generation, thermal storage, and heat recovery systems for a given building and location.		Interagency Software	http://www.eere.energy.gov/buildings/tools_directory/software.cfm/ID=407/pagename_submenu=energy_simulation/pagename_menu=whole_building_analysis/pagename=subjects	HVAC and power generation consultants, system designers and operators. Facility managers, gas and electric utility marketers and HVAC/power generation equipment marketers.
10	Building renovation	LT						x		Website	Building renovation issues	2007		http://www.renovacija.lt/index.php?lang=2	
11	BUS++	FI		x	x	x			Building simulation	Software	Evaluation of the energy performance, ventilation, airflows, indoor air quality and noise level.		VTT Building Technology		
12	BV2, BV2 arch	SE	x	x	x	x	x	x	Building simulation	Software, BV2 arch is free to use	Calculation of the total annual use of heating, cooling and electricity. BV2 Arch special for early estimations by the architect.		CIT Energy Management AB	http://www.enerma.cit.chalmers.se/	Energy advisers, architects, building owners and managers, schools, product manufacturers
13	CalSol	FR	x	x	x	x				Software	Evaluation method for energy, economy and environment for thermal solar, PV and passive solar.		Francis Domain / INES Education	www.ines-solaire.free.fr	
14	CASBEE	JPN												www.ibec.or.jp/CASBEE	
15	CASSIS	FR		x	x	x				Software	Simulation of the systems thermal function and energy costs				
16	Checklist Residential building (extended,	NLD							Documentation for EPC calculation	Checklist	Guideline for building inspection	2005	SenterNovem	..\..\info\WP4\existing tools\NLD009 checklist-Woningbouw uitgebreid_tcm24-174287.doc	Building inspectors
17	Checklist Utility building (extended, short)	NLD							Documentation for EPC calculation	Checklist	Guideline for building inspection	2005	SenterNovem	..\..\info\WP4\existing tools\NLD008 checklist-Utiliteitsbouw uitgebreid_tcm24-174285.doc	Building inspectors
18	CMLCA	NLD	x	x	x	x			LCA tool	Software	Tool for analysis of LCA		Institute of Environmental Sciences, The Netherlands	http://www.leidenuniv.nl/interfac/cml/ssp/software/cmlca/	
19	CO2 calculator	LT	x	x				x		Calculator	CO2 calculator for different fuel types		"Ekostrategija"	http://www.ekostrategija.lt/index.php?lng=lt&content=pages&page_id=17&kat=3	
20	CombiSun	DK, AT, FR, DE, IT, SE, NLD		x	x	x				Desing tool	Design tool for architects and engineers to compare solar combisystems and properly size according to specific requirements for use.		Energy Agency (IEA) Task 26 "Solar Combisystems".	http://www.elle-kilde.dk/altener-combi/dwload.html	
21	Data input EP calculation, including attention points	NLD				x			Documentation for EPC calculation	Documentation	List of input needed for EPC calculation, and specific attention points	2006	SenterNovem	http://www.senternovem.nl/epn/tools_en_aanachtspunten/utiliteitsbouw/_20_verzamelen_gegevens_epu_berekening/index.asp	Consultants, Engineering installors, Building inspectors
22	Decision document	NLD	x	x	x	x			Instrument for ambition and communication	Documentation	Decision document	2007	SenterNovem	http://www.senternovem.nl/epn/tools_en_aandachtspunten/utiliteitsbouw/aanpak/beslisdocument.asp	Local authorities, Project developers

23	DEROB-LTH	SE		x	x	x			Building simulation	Software	Building simulation of power and energy need as well as the thermal climate in the building		Lund University, Sweden	http://www.ebd.lth.se/english	Researchers
24	DUBO list			x	x	x	x		Performance instrument	Checklist	Decision model for building (project) to determine sustainability requirements, also for check during design and construction		NIBE	http://www.nibe.org/	Local authorities, Designers, Real estate developers, Housing associations
25	Dutch practical guideline for the calculation of the EPC	NLD			x	x			Software and Documentation for EPC calculation	Software and Handbook	Guideline for Energy Performance calculations in new buildings	2005	NEN	http://www2.nen.nl/nen/servlet/dispatcher.Dispatcher?id=195708	Designers, Consultants, Engineering installors
26	ECOPro LCA	DE	x	x	x	x			LCA tool		Calculation of the impacts of energy and material usages and flows on the environment.		Institut für industrielle Bauproduktion (ifib), Universität Karlsruhe	http://annex31.wiwi.uni-karlsruhe.de/MainFrame_tools_germany.htm	Architects
27	ECOTECT	GB	x	x	x	x			LCA tool	Software	Complete environmental design tool which couples an intuitive 3D modelling interface with extensive solar, thermal, lighting, acoustic and cost analysis functions.		Centre for Research in the Built Environment, Cardiff University	http://www.squ1.com/products	Architects, engineers, environmental consultants, building designers, and some owner builders and enthusiasts
28	EFFem	SE	x	x				x	Environmental assessment tool	Free to use Internet-tool	Calculation of emissions from different energy sources and an estimation of influences of global warming, nitrification etc.	2002	SP Technical Research Institute of Sweden, CIT Energy Management, Department of building services Chalmers	www.effektiv.org/miljobel	Architects, engineers, environmental consultants, building designers, and some owner builders and enthusiasts
29	EN4M	USA		x	x	x			Building simulation	Software	Estimation of monthly/yearly building energy consumption in commercial buildings; calculates return on investment and payout on estimated cost of equipment and construction changes.		MC2 Engineering Software, Miami, Florida, USA	http://www.mc2engineeringsoftware.com/	HVAC engineers, energy engineers, building managers and owners
30	Energieperformance on Location (EPL)	NLD	x	x					Performance instrument	Software	Calculation method to achieve an Optimal energy infrastructure (OEI), quickscan excel) is downloadable		SenterNovem	http://www.senternovem.nl/gemeenten/aandeslag/epl/index.asp	Policy makers
31	Energy conventer	LT	x	x						Calculator	Calculate fuel needs in order to generate certain amount of energy	2005	Energy agency	http://www.avei.lt/?language=en	
32	Energy demand	LT	x	x	x					Calculator	Yearly demand of energy for your number of households	2005	Energy agency	http://www.avei.lt/?language=en	
33	Energy performance certificate	NLD	x	x	x	x			Performance instrument						
34	Energy Performance Coefficient, Residential buildings (EPW), Utility buildings (EPU)	NLD		x	x	x			Performance instrument	Legislation	Standard, Obligatory calculations for new buildings	2004	NEN	http://www2.nen.nl/nen/servlet/dispatcher.Dispatcher?id=195708	All key actors in the building process
35	Energy Performance standard handboek	NLD			x	x			Documentation for EPC calculation	Handbook	handbook to assessing correctness of EPC calculation and useful information for building inspection	2004	SenterNovem	http://www.senternovem.nl/epn/handhaving/toetsen_epc_berekeningen/_10_instrumenten_handhaving_epn/_80_handboek_handhaving_epn/index.asp	Building inspectors, Engineering installors
36	Energy saving measures in building	LT						x		Excel based software	Calculation tool for the heat savings when renovating the house	2007	Housing agency	http://www.bkagentura.lt/index.php?2073312235	
37	Energy variations utility buildings	NLD			x	x			Instrument for ambition and communication	Software	Calculation tool to determine energy performance of utility building and possible effects of energy saving measures		SenterNovem	http://www.senternovem.nl/epn/tools_en_aandachtspunten/utiliteitsbouw/hulpmiddelen/index.asp	Designers, Consultants, Engineering installors
38	Energy vision tools	NLD	x	x					Instrument for ambition and communication	Assessment	Site specific assessment to determine optimal energy infrastructure, focus on existing buildings		SenterNovem	http://www.senternovem.nl/gemeenten/aandeslag/energievisie/index.asp	Policy makers, Consultants
39	EnergyAide	USA					x	x	Residential Building simulation	Software	Comprehensive residential energy audit software package. The EnergyAide software can evaluate a broad range of energy saving opportunities in the home.		Energy New England, Foxborough, Massachusetts, USA		Residential energy conservation service providers, energy service companies, utility DSM programs, energy audit programs, weatherization service providers
40	Energy Performance Check	NLD		x	x	x			Auxiliary software for EPC calculation	Checklist	Checklist for EPC calculation	2006	SenterNovem	http://www.senternovem.nl/senternovem/tools/ep_check.asp	Building inspectors, Designers, Consultants, Engineering installors, (Private) clients
41	EnergyPlus	USA		x	x	x			Building simulation	Software	EnergyPlus includes innovative simulation capabilities including time steps of less than an hour, modular systems simulation modules that are integrated with a heat balance-based zone simulation, and input and output data structures tailored to facilitate third party interface development.		U S Department of Energy	http://www.energyplus.gov	
42	EnergyPro	LT	x	x	x			x		Calculator	Number of different analysis modules designed to analyse a wide range of issues in the building industry.	2003	VGTU	www.vgtu.lt	

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43	EPBD hub (under development)	NLD	x	x	x	x			Instrument for ambition and communication	Software	Calulation tool for AES in new and existing buildings	2006	SenterNovem, DWA, Cogen, TNO	http://www.epbdhub.nl/EPBDData/colofon.jsp	Designers, Project developers, Local authorities
44	EpvarW EPC and Costs	NLD			x	x			Auxiliary software for EPC calculation	Software	Calculation tool to determine energy performance of residential buildings and possible effects of energy saving measures, including their costs		SenterNovem	http://www.senternovem.nl/epn/tools_en_aandachtspunten/woningbouw/60_epc_en_kosten/epc_en_kosten.asp	Designers, Consultants, Engineering installors, (Private) clients
45	ESOP	FR		x	x	x				Software	Evaluation of thermal solar systems.				
46	ESP-r	GB		x	x	x			Building simulation	Software		1974, 2002	Department of Mechanical Engineering, University of Strathclyde, Glasgow, Scotland.	http://www.esru.strath.ac.uk/	Engineers, researchers, architects energy consultants.
47	GBTool, SBTool	CAN	x	x	x	x			Building simulation	Framework	SBTool is a generic framework for rating the sustainable performance of buildings and projects.	1996	Natural Resources Canada	http://greenbuilding.ca/iisbe/sbc2k8/sbc2k8-download_f.htm	Designers, Project developers, Local authorities
48	GEMIS	DE	x	x	x	x			Life-cycle analysis program	Software	GEMIS is a life-cycle analysis program and database for energy, material, and transport systems.	1987-1989	Öko-Institut and Gesamthochschule Kassel (GhK).	http://www.oeko.de/service/gemis/en/index.htm	Local authorities, Designers, Real estate developers, Housing associations
49	Green Building Advisor	USA	x	x	x	x			Performance instrument	Software	Identifies the specific design strategies that can improve the environmental performance, cost-effectiveness, and healthiness of of a building.	1999	CREST	http://www.ebuild.com	Architects and other designers, educational institutions, building contractors, facility managers, building owners.
50	Greencalc+	NLD		x	x	x			Performance instrument	Software, benchmark instrument, website	Calculation tool which gives a environmental index for utility buildings.		SenterNovem	http://www.greencalc.com/greencalc/viewprojects?stylesheet=en-overzicht.xsl&prefix=EN	Designers, Engineering consultants installors
51	Guideline for sustainable building for local authorities	NLD		x	x	x			Performance instrument	Software	Tool to facilitate choices for sustainable buildings	1995	Municipality of Tilburg W/E advisory	http://www.gprgebouw.nl/	Local authorities, Designers, Real estate developers, Housing associations
52	Heat pump calculator	LT	x	x	x	x				Calculator	Helps to select heat pump fo the building		"Alropa"	http://alropa.lt.aguona.serveriai.lt/calc/lt/	
53	Heat pump selection form	LT	x	x	x	x				Handbook, software	Helps to select heat pump fo the building	2007	"Vilpra"	http://www.vilpra.lt/lt/main/heating/siurb	
54	HOT2000	CAN	x	x	x	x			Building simulation	Software	Easy-to-use energy analysis and design software for low-rise residential buildings.	1998	Natural Resources Canada	http://www.sbc.nrcan.gc.ca/software_and_tools/hot2000_e.asp	Builders, design evaluators, engineers, architects, building and energy code writers. Policy writers
55	Instruction for inspection at building site	NLD							Documentation for EPC calculation	handbook	Instructions for building inspection on energy perfomance	2007	SenterNovem		
56	Instructions EPC-check	NLD							Documentation for EPC calculation	handbook	User instructions for EnergyPerformance Check software	2006	SenterNovem	..\..\info\WP4\existing tools\NLD011 Instructiewijzer EPCheck V202_tcm24-188318.pdf	Building inspectors
57	ISSO handbooks	NLD	x	x	x	x	x	x	Documentation	Handbook	Handbook for installation of heatpumps (ISSO81)	2007	ISSO	ISBN: 978-90-5044-135-3	
58	Lighting, 3D Thermal, 3D Airflow, 3D	DE		x	x	x			Building simulation	3D software	Simulation of thermal, lightning, ventilation and acoustic				
59	LISA	AUS	x	x	x	x			LCA tool	Decision support tool	Streamlined Life Cycle Analysis (LCA) decision support tool for construction.		University of Newcastle, Centre for Sustainable Technology, Port Macquarie, NSW, Australia	http://www.lisa.au.com	Architects, educators and researchers
60	List of measures in EPC on website SenterNovem	NLD	x	x	x				Documentation for EPC calculation	Checklist	List of measures in EPC	2005	SenterNovem	http://www.senternovem.nl/epn/maatregelen/index.asp	Designers, Consultants, Engineering installors
61	Market processes of heat supply, examples	NLD	x	x					Instrument for ambition and communication	Documentation	Some experiences of heat supply in practice	2006	SenterNovem		
62	MESSAGE modelling tool	LT	x	x				x		Mathematical model, handbook	Energy system modelling tool. Evaluation of different heat supply options, costs, investments, emissions	2002	LEI		
63	National package for sustainable new buildings (residential and utility)	NLD		x	x	x	x		Instrument for ambition and communication	Documentation	Book with all knowledge and experience on sustainable new building (utility and residential)		SBR	http://www.sbr.nl/	Local authorities, Designers, Contractors

64	National package for sustainable town planning	NLD	x						Instrument for ambition and communication	Documentation	Book with all knowledge and experience on sustainable urban planning and building	1999	SEV and SenterNovem	http://www.gelderland.nl/referentiekader_dso/DSOWEB/paginas/framelinks.htm	Urban planners, Consultants
65	Optimal Energy Infrastructure (OEI)	NLD	x	x					Instrument for ambition and communication	Documentation					Consultants
66	Optimizator of biofuel boiler capacity	LT	x	x	x			x		Calculator	Conversion of a district heating plant from fossil fuel to bio fuel	2005	Energy agency	http://www.avei.lt/?language=en	
67	Options energy supply	NLD	x						Instrument for ambition and communication	Documentation	List of Alternative Energy Systems	2005	SenterNovem	http://www.senternovem.nl/epn/tools_en_aandachtspunten/utiliteitsbouw/aanpak/opties_energievoorziening.asp	Local authorities
68	PHPP	DE	x	x	x	x			Building simulation	Calculator and handbook	Calculation of energy, including the design and of variuos systems and sizing of heat and cooling loads etc useful when designing Passive houses.	1998	Passive House Institute	http://www.passiv.de/07_eng/phpp/PHPP2007.htm	Architects and designers
69	Polysun	SUI	x	x	x	x			Solar thermal simulation	Software	Simulation of solar thermal systems including a system optimisation and fair system comparisons.		Institut für Solartechnik SPF, Hochschule für Technik Rapperswil HSR, Switzerland	http://www.solarenergy.ch/spf.php?lang=en&fam=15&tab=1	Designers
70	Reference buildings with high Energy Performance (residential and utility buildings)	NLD			x	x			Instrument for ambition and communication	Documentation	Examples of buildings with a high energy performance, good combination of options		SenterNovem		
71	RES conventer	LT	x	x				x		Calculator	Energy conventer between different renewable energy sources	2005	Energy agency	http://www.avei.lt/?language=en	
72	Structured decision making	NLD	x	x	x	x			Instrument for ambition and communication	Documentation	Five step decision document for energy savings	2006	SenterNovem	http://www.senternovem.nl/epn/tools_en_aandachtspunten/utiliteitsbouw/aanpak/gestructureerde_besluitvorming.asp	Local authorities, Project developers
73	TAS	UK	x	x	x	x			Building simulation	Software	Software package for the thermal analysis of buildings.		EDSL Ltd	http://ourworld.compuserve.com/homepages/edsl	Building services engineers and architects.
74	TRNSYS	USA	x	x	x	x			Building simulation	Software	An energy simulation program whose modular system approach makes it one of the most flexible tools available.		Solar Energy Laboratory, University of Wisconsin	http://sel.me.wisc.edu/trnsys/	Engineers, researchers, consulting firms, architects.
75	Wood wasten burning calculator	LT	x	x				x		Calculator	Calculator for different wood waste burning		"Ekostrategija"	http://www.ekostrategija.lt/index.php?lng=lt&content=pages&page_id=17&kat=2	