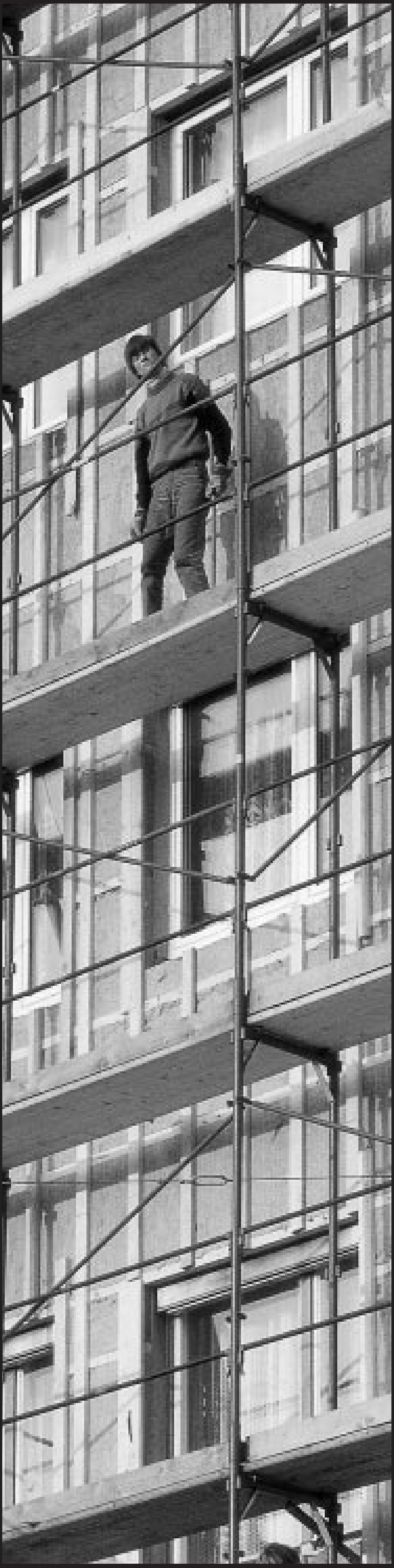
GUIDE



ENERGY EFFICIENCY IN PUBLIC AND MUNICIPAL BUILDINGS

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1. Energy Efficiency in Public and Municipal Buildings

Energy use facilitates all human activities, as well as social and economic progress. Energy is directly related to the most pressing social issues which affect sustainable development (poverty, jobs, population growth, health, access to social services, land degradation, climatic changes and environmental quality, etc.). Countries all over the world, consider the production and consumption of sufficient energy as one of their major challenges. The magnitude of the energy consumed per capita has become one of the indicators of modernization and progress of a country. Thus, up to now, energy issues and policies have been strongly concerned with increasing the supply of energy. The strategic and environmental consequences of energy consumption patterns have been neglected for a long time. The world continues to seek energy to satisfy its needs without paying enough attention to the social, environmental, economic and security impacts of its use. Today it is clear and widely accepted that such approaches to energy are unsustainable. Nowadays, when considering complex energy policy decisions the following two issues should be central to our decision making process.

Global oil and gas reserves may be exhausted in the course of a few generations. One quarter of the world population living in the industrialized nations today consume more than three quarters of the global natural resources. A well justified increase in the consumption by developing countries will put immense pressure on global natural resources. In addition, the use of energy , especially the combustion of fossil fuels, forms a major and growing threat to the environment and to the climate. The latest assessment from the UN Climate Panel indicates that even the present global level of fossil fuel consumption is not environmentally sustainable.

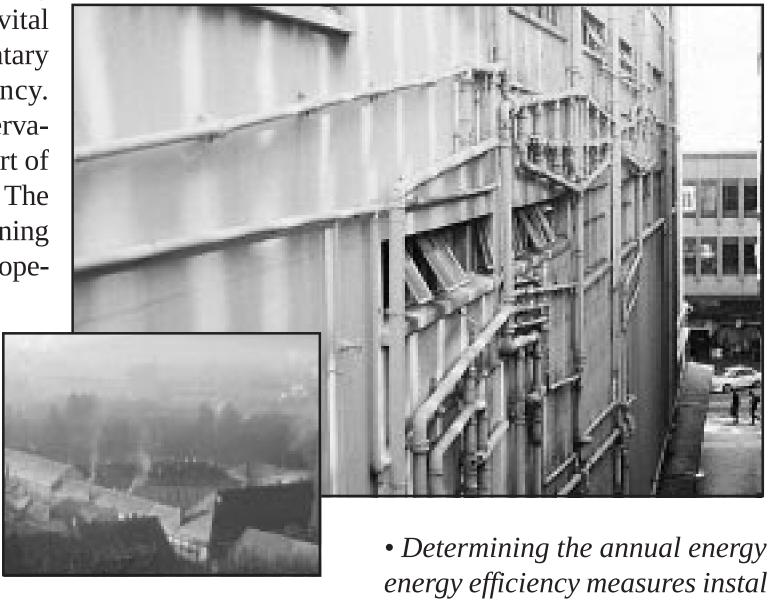
The consideration of these critical energy issues and challenges stresses the importance of integrating environmental and energy policy strategies. New energy technologies which are environmentally friendlier have to be adopted and integrated into the existing global energy system. It is essential that environmental and strategic resource concerns be included in the strategies of the reformed energy markets. Sustainable utilization of energy must also be given explicit priority through rational planning techniques such as integrated resource planning and energy efficient activities.

The adverse impacts of energy consumption and production can be mitigated either by reducing consumption or shifting energy supplies to options better able to support sustainable development objectives. Of the various starting points for efforts to reduce energy demand, it is technological performance that yields the largest and most accessible opportunities. Technological change has by far the greatest potential than changes in the patterns of consumption of goods and services, but this assessment must not preclude attempts to shift away from irrational and wasteful patterns of consumption. There is a growing recognition that some of the greatest and most cost effective opportunities involve improving end use efficiency by providing the same energy service with less energy inputs or to achieve more energy services with the same energy input. There are two types of energy efficiency measures:

1. *more efficient end use of energy in existing installations through improved operation and maintenance and/or replacement of some components*
2. *more efficient end use of energy in new installations, equipment. This can be achieved through systematic introduction of more efficient systems and technology introduced at the point of capital turnover and expansion.*

Specific energy consumption can be reduced by 20-50% in the case of energy efficiency improvements in existing energy using installations and 50-90% in the case of new installations. These reductions can be achieved by using the most efficient energy technology available today and are usually cheaper than increasing supply. In developing countries the potential for demand reduction is even higher since the technological advancement of processes in these countries are considered to Lacking those of the industrialized world. The potential for further efficiency improvements through continued research and development is high, as the performance of current technology is far from its fundamental physical limit.

The adjustment towards greater energy efficiency requires a thorough knowledge on the part of those who are involved. The practical projects undertaken have, in fact, often demonstrated that the durability of the installations and their maintenance are a reflection of the quality and reliability of the players involved. Feasibility studies of projects should include an analysis of the various players involved. Development programmes at local or regional level will have to depend on co-operation structures, such as regional or local energy agencies or even consumer associations. These networks, involving possible future users, have a vital role in the process of the voluntary promotion of energy efficiency. The transition to energy conservation measures is an integral part of regional energy programming,. The activity of regional energy planning includes the vital aspects of co-operation and communication. The actions to be carried out will be done jointly with the players in the region's energy field. It is therefore, essential to associate as large a number of partners as possible with this undertaking. It goes without saying that, as far as renewables and energy efficiency are concerned,that this aspect is extremely crucial.



Energy efficiency programmes can not only reduce customers' bills, but they can also improve the quality of energy services. For example, residential insulation and weatherization programs can improve comfort levels by eliminating cold spots in homes while still reducing overall energy consumption. For example, commercial lighting programmes can provide higher quality, consistent lighting levels in work areas and, again, reduce overall energy consumption.

Energy efficiency is an investment, and the return on the investment should be assessed. The objective is to make good decisions regarding investments in energy efficiency. Now, implementing successful energy efficiency programmes is becoming more critical and real-time feedback on success more important.

Energy efficiency programme evaluation is best discussed in terms of the provision of energy services to end-users, i.e., residences, commercial buildings or industry. A commercial establishment with air conditioning is actually purchasing an energy service, i.e., the maintenance of comfortable indoor conditions in their establishment. The energy used to drive the air conditioning unit affects the cost of cooling, but it is not the end product the customer is actually consuming. It is an intermediate product. Thus, evaluators need to be concerned with the end-use service provided. Obviously energy can be conserved simply by reducing the amount of cooling provided, i.e., setting the thermostat at a higher temperature, but the reduction in customer comfort, i.e., the welfare loss to the customer of having a lower quality of energy service needs to be taken into account.

The overall objective in the evaluation of energy efficiency programmes is to provide the information required by energy planners and policy makers to make good decisions regarding investments in energy efficiency programmes. The need to support decisions regarding energy efficiency investment programmes has important implications for the design of the evaluation and the level of confidence in estimates of programme effects. Accomplishing this overall objective may require other itemized objectives to be addressed by evaluations. These can include:

- *Determining the annual energy reductions that result from energy efficiency measures installed or actions taken as part of a programme.*
- *Assessing the overall changes in the quality and reliability of energy services as a result of measures installed and actions undertaken as part of energy efficiency programmes.*
- *Assessing the costs of the programmes used to attain these effects, the efficiency of delivery, and overall customer satisfaction with the programmes.*
- *Determining whether a single programme or portfolio of programmes is cost-effective relative to other options in meeting energy service and environmental objectives.*
- *Translating these programme induced changes in energy use into changes in environmental effects, e.g., changes in greenhouse gas emissions.*
- *Assessing other potential benefits resulting from programmes which might include increased reliability of energy supplies, reduced reliance on oil imports, improved welfare of low income families, and other objectives that may be set by individual governments.*

While any specific evaluation effort will have objectives specific to the circumstances in that country or for that programme, there are a set of basic evaluation objectives to consider.

1. Determine the change in energy use, and if relevant, changes in peak consumption resulting from the programme.

2. Assess programme costs and determine whether the programme is cost-effective relative to alternatives for meeting the objectives set for the programmes.

3. Assess programme implementation, marketing, and efficiency of delivery.Evaluation validates the expectations and assumptions made in the design of programmatic efforts to protect conservation resources.

While it is possible for the costs of evaluation to outweigh the value of the information produced, it is more likely that expenditures on evaluation will increase the cost effectiveness of a programme. For example, a verification plan that results in 8 percent of a programmes cost being spent on evaluation efforts, might improve the efficiency of programme implementation and delivery by far more than 8 percent. Programme evaluations can demonstrate that measures initially believed to be cost-effective are actually not cost-effective in certain applications or building types. In addition, if it is understood that there will be no quantitative evaluation and review, implementation and inspection protocols may be relaxed. If the staff implementing an energy efficiency programme understand that programme impacts are going to be verified through in-field studies, then they are more likely to be diligent in proposing only cost-effective measures for a site, and in making sure that they are properly installed. Ultimately, evaluations should provide the information necessary for making good decisions regarding resource allocation and investments in energy efficiency programmes. Evaluations should assist energy planners in assessing and managing risks associated with energy efficiency investments. This includes assessments of programme uncertainties and their implications for planning.

The building sector in Europe, is responsible for approximately 30% of the total energy consumption, approximately 60% of which is for space heating. This consumption results in CO2 emissions into the atmosphere, a factor which contributes significantly to the greenhouse effect and climatic change. The use of fuel for heating buildings amounts to 25% of the total CO2 emissions in the European Union. The energy consumed annually rises yearly, and in some countries this rise is significant. In Greece the energy consumed in the public building sector is estimated by the year 2000 to reach 170% of the energy consumed in 1990.

In view of the intense environmental problems, over the last decade efforts have been made by countries worldwide to decrease the energy consumed. The United Nations Framework Convention on Climatic Change adopted at the UNCED Earth Summit in Rio de Janeiro, in June 1992 and proposed a global strategy to restrict atmospheric emissions of gases causing the greenhouse effect. This was followed by the Rome Convention of 1995.

The industrialized nations have undertaken, either individually, or collectively, to bring down CO2 emissions to 1990 levels by the year 2000. The EU strategy for limiting greenhouse gas emissions is based on the community level strategy consisting research and development programmes (ALTENER), sectorial measures for energy efficiency (SAVE), regulatory, voluntary and fiscal measures, together with complementary national programmes. The European Parliament Resolution 8027/2-3-94 urged the Commission to develop procedures for the mandatory application of principles for bioclimatic architecture in public buildings. Additionally, a large number of measures inSAVE Directive 93/76, with in which all European countries should reduce CO2 emissions by the year 2000, concerns measures to decrease the energy consumed of private and public buildings. Within this framework, European countries have or are establishing measures, starting with measures directed to reducing the energy consumption of public buildings.

Energy consumed in buildings may be reduced by measures that:

- *reduce the building thermal losses (reduction of infiltration through building openings, thermal insulation of the building envelope, etc.)*
- *increase the efficiency and rationalize the use of heating systems*
- *utilize renewable energy sources, i.e. applying the principles of bioclimatic architecture and incorporating passive solar systems*
- *overall control of the building systems and energy behaviour, by applying an energy management scheme.*

To better access the actual energy consumption profile of a building and in order to obtain vital information on the type of measures and technologies that will improve the energy efficiency of the building an energy audit is necessary. The energy audit procedure is the main subject of this guide, complimented by several energy efficiency measures applicable to the public building sector.

Introduction

This guideline is designed to allow technically trained people such as janitors, plant caretakers and energy officers to take rough stock of the energy consumption of a particular building and to select and evaluate improvement measures. The simplification involved does, however, entail a certain inaccuracy. The results of an audit carried out on the basis of this guideline are thus to be used for the purpose of rough estimations only. A detailed analysis, calling in experts, will be absolutely essential above all before implementing any capital-intensive improvement measures.

I Using the guideline

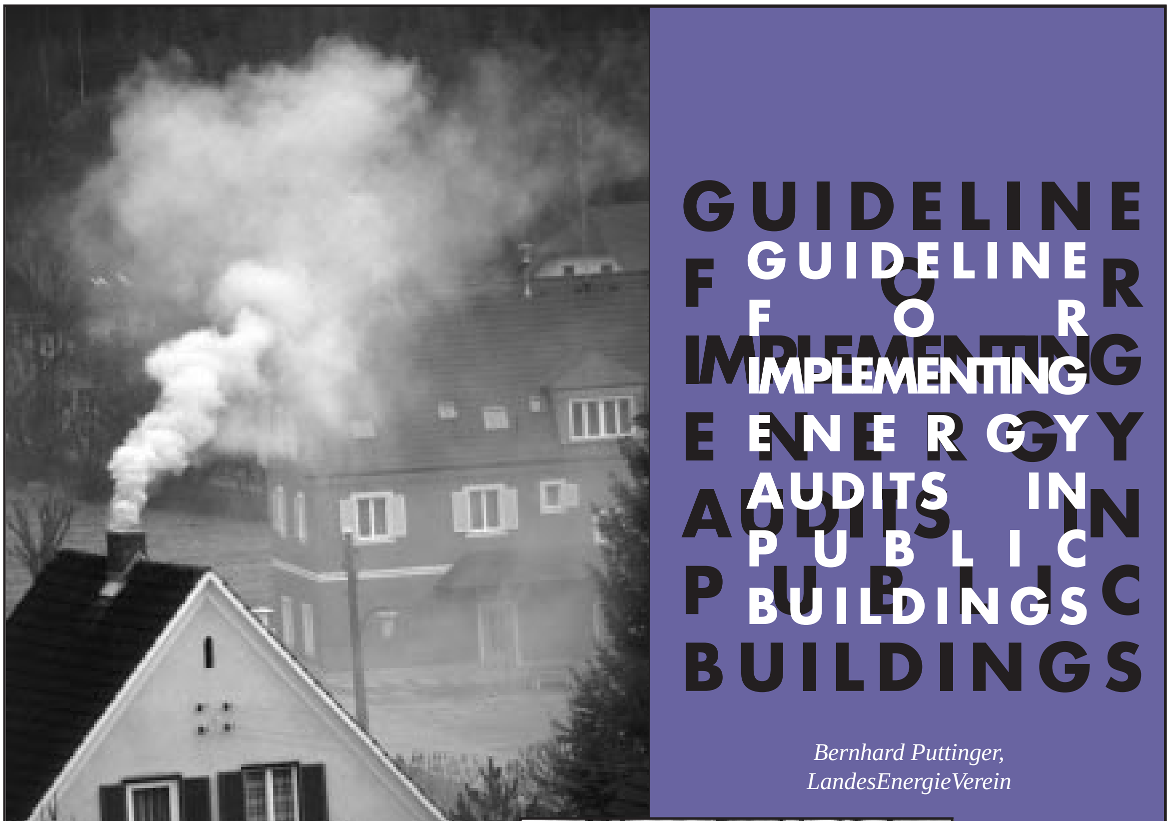
The energy audit comprises the following items (cf. title diagram): Data collection, data evaluation, selection of energy saving options and documentation in the form of an audit report. The aim is to record details concerning the technical energy facilities, the building, the organisational structure and possibilities of improvement. The energy audit does not include further planning and implementation of measures. A long-term energy saving programme ("energy management") can only be introduced on the basis of the audit results.

The "Energy Audit Guideline" essentially consists of forms covering all separate steps such as data collection, evaluation and selection of energy saving measures. The forms are explained in the appendix. These explanations provide important details as to how to interpret the questions in the forms and how to collect the necessary data. Thus it is important always to consult the explanations when working with the forms.

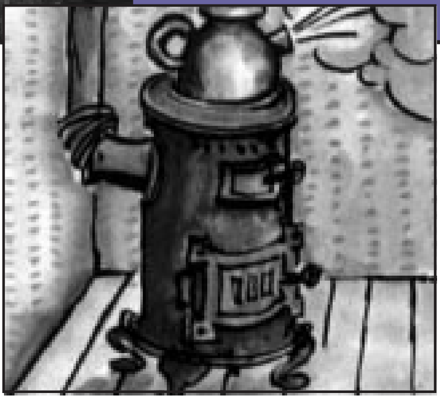
The forms follow the sequence of the auditing procedure and it is thus best to fill them in in the given order. Also, the forms are designed as master copies and can be included directly in the audit report so as to speed up auditing. The amount of work required for an audit can be estimated to be at least 10 h (pure work hours); the full duration of an audit from the beginning to the completion of the report can take much more time due to delays in collecting data.The only materials required for carrying out the audit are a calculator and writing implements.

The costs of an audit are limited to the work hours of the auditing personnel and the interviewers. Minor costs can be entailed in procuring the necessary climatic data.

To use the following forms, please make enlarged copies!


GUIDELINE
FOR
IMPLEMENTING
ENERGY
AUDITS IN
PUBLIC
BUILDINGS

Bernhard Puttinger,
LandesEnergieVerein



II Energy audit forms

The forms are divided as follows:
A: Data collection,
B:Data evaluation,
C: Improvement measures.

The necessary details on filling in the forms can be found in Appendix V.I "Explanation of forms" on page 16.

A Data collection

A.1 Basic data

Building ______________________________
Addres ______________________________
Phone number ______________________________
Purpose ______________________________
Year of construction ______________________________

Officer ______________________________
Date ______________________________

Remarks ______________________________

A.2 Climatic data; possible subsidise

Number of degree-days of last four years 19__ : ______ Kd 19_ : ______ Kd 19_ : ______ Kd 19_ : ______ Kd
Long-term (!) average of degree-days __________ Kd
Basis of calculation of degree-days [ ] 20/15 ([ ] 20/12) ([ ] 15/15) [ ] ________

Subsidies for energy saving measures
and renewable energy sources ______________________________
____
Remarks ______________________________

A.3 Energy bills

A.3.1 Fuel consumption of last four years

Mode of data collection: [ ] Energy bills + reserve level [ ] Energy bills only

Energy source 1: _____________ Purpose: [ ] Heating [ ] Hot water [ ]____________________
Calorific value H_u: _____ [kWh/ l | kg | m3]

		Year 19_	Year 19_	Year 19_	Year 19_	Avg.
Amount	[l | kg | m3]					
Amount	[kWh]					
Costs	[_____]					
Costs	[__/kWh]					

Energy source 2: _____________ Purpose: [ ] Heating [ ] Hot water [ ]____________________
Calorific value Hu: _____ [kWh/ l | kg | m3]

		Year 19_	Year 19_	Year 19_	Year 19_	Avg.
Amount	[l | kg | m3]					
Amount	[kWh]					
Costs	[_____]					
Costs	[__/kWh]					

A.3.2 Electricity consumption of last four years

Energy source electricity Purpose: [ ] Heating [ ] Hot water [ ] Lighting, ___________

		Year 19_	Year 19_	Year 19_	Year 19_	Avg.
Amount	[kWh]					
Costs	[_____]					
Costs	[__/kWh]					

A.3.3 Total energy consumption of last four years

		Year 19_	Year 19_	Year 19_	Year 19_	Avg.
Amount	[kWh]					
Costs	[_____]					

A.3.4 Fuel supply contracts

	Do long-term supply contracts exist	[ ] No [ ] Yes, which: ____________
|M02|	If so: Conditions of contracts	[ ] Good [ ] Average [ ] Bad
	If so: Withdrawal possible	[ ] No [ ] Yes, ____________
	Alternative supply contracts examined on regular basis	[ ] Yes [ ] No

The number in brackets refer to the number of the possible improvement given in in annex C, page 12.

A.3.5 Rate structure electricity

	Electricity price (working price) for different times of day and seasons (e.g.: day/night, summer/winter)	[____ / kWh]: ____________ ____________
	Basic charges last year	________ [____]
	Do fines exist for excessive consumption	[ ] No [ ] Yes
|M25|	Were such fines paid last year	[ ] No [ ] Yes, totalling ____________
	Remarks	____________

A.4 Building plans

Heated gross floor area Cellar:	_____ m2	Ground floor:	____ m2
Upper floors: _ *	_____ m2	Attic conversion:	____ m2
Total heated gross floor area	_________ m2		
Remarks	____________		

A.5 Building inspection

A.5.1 Building

|M33-38|

Building section	Structure (materials)	Thermal quality (good/average/bad)	Remarks, (gen. condition)
Outside walls			
Ceiling above unheated cellar			
Top intermediate floor / attic conversion			
Windows			
Outside doors			

|M41|	Radiator niches insulated	[ ] Yes [ ] No
	Mould formation	[ ] No [ ] Yes, where: ____________
|M34|	Damp walls	[ ] No [ ] Yes, where: ____________
|M04|	Windows and outside doors shut tightly	[ ] Yes [ ] No

A.5.2 Heating – heat generation

|M43|	Type of heating	[ ] Central heating [ ] Single storey [ ] Single stove
	Type of heat generator	[ ] Fuel boiler [ ] Heat pump [ ] Distant heating
|M44|	Number, type, year of construction and output of respective heat generator	____________ ____________
|M45|	Energy sources used	________
|M44|	Output is	[ ] Inadequate [ ] Adequate [ ] Too high
|M05|	If boiler: boiler insulated	[ ] Yes, __ cm, material:__________ [ ] No
|M05|	If boiler insulated: insulation	[ ] OK [ ] Faulty or damp
|M08|	If boiler: inside heating surfaces	[ ] Clean [ ] Little coating [ ] Severe coating
|M08|	If boiler: burner	[ ] Clean [ ] Little coating [ ] Severe coating
	If heat pump: heat source	[ ] Air [ ] Soil [ ] Water
	Installed thermometers	[ ] Boiler [ ] Feed [ ] Return [ ] ____________
	Other measuring equipment	[ ] Pressure gauge [ ] ____________
|M08|	Extensive maintenance, service	[ ] Annual [ ] Never [ ] ____________
|M10|	Additional electric radiators	[ ] No [ ] Yes, ____________
|M46|	Heat supply control	[ ] Automatic [ ] Manual [ ] None
|M06|	Rooms heated at night	[ ] No [ ] Partly [ ] Full heating
|M06|	Rooms heated in breaks (holidays, etc.)	[ ] No [ ] Partly [ ] Full heating
	Heating period usually lasts	from ________ to ____________

A.5.3 Heating – heat distribution

	Heat distribution	[ ] Direct [ ] Buffer storage
|M49|	If buffer storage: insulation	[ ] Yes, (OK)___cm, material: _________ [ ] No
	Distribution temperature feed	________°C
	Distribution circuit: number and building sections heated	____
|M48|	Separate distribution circuits for building sections with different usage / facing	[ ] Yes [ ] Partly [ ] No
|M49|	Distributing pipes through unheated rooms: insulated	[ ] Yes, (OK)___cm, material: _________ [ ] No
	Pipes tight	[ ] Yes [ ] No
	Distributed medium	[ ] Water [ ] Steam
	If steam system: is condensate recycled	[ ] Yes [ ] No
	If water system: regular deairing of heating equipment	[ ] Yes [ ] No
	Heat provided by	[ ] Radiators [ ] Underfloor heating [ ] Fan heaters
|M47|	Thermostat valves in heating equipment	[ ] Yes [ ] Partly [ ] No
|M09|	Heat provision impaired by curtains, coverings, etc.	[ ] Never [ ] Partly [ ] Often
|M11|	Radiators in non-heated rooms	[ ] No [ ] Yes, where: ______________________________
|M08|	Maintenance and internal cleaning of distribution system [ ] Annually	[ ] Every _ years [ ] Never [ ] ____________________

A.5.4 Hot water supply

|M51|	Water heating system	[ ] with heating [ ] separate from heating in summer [ ] always separate from heating
|M45|	If separate: type, number, year of construction and output of heat generator, energy sources used.	____
	Tank storage	[ ] Yes [ ] No
|M14|	If tank: storage temperature	__________ °C
|M50|	If tank: insulation	[ ] Yes, (OK)___cm, material: _________ [ ] No
	If tank: Tank contents fully heated	__________ per week ____ weeks / year
|M12|	Tank heated in prolonged breaks	[ ] No [ ] Yes
|M15|	Maintenance heat generation + tank	[ ] Annual [ ] Never [ ] ______________________
|M50|	Hot water distribution pipes insulated	[ ] Yes, (OK)___cm, material: _________ [ ] No
|M52|	If large distribution system: circulation system	[ ] Yes [ ] No
	Hot water used for	____
|M13|	Where and how can hot water be saved	____

A.5.5 Ventilation

|M17|	Building ventilation	[ ] Central ventilation system [ ] Manual (windows, individual fans)
	If central ventilation system:	
	Ventilation system with	[ ] Air heating [ ] Air cooling [ ] Air (de)humidification
|M18|	Ventilation system in operation during prolonged breaks (weekend, holidays)	[ ] No [ ] Yes, ______________________________
|M21|	Mechanical (de)humidification of air at night although unnecessary	[ ] No [ ] Yes
|M20|	Air temperature, fresh air humidity in summer	[ ] Too high [ ] Adequate [ ] Too low
|M20|	Air temperature, fresh air humidity in winter	[ ] Too low [ ] Adequate [ ] Too high
|M19|	Change of air in rooms	[ ] Inadequate [ ] Adequate [ ] Excessive
|M53|	Heat recovery system	[ ] Yes [ ] No
|M22|	Maintenance and service of system	[ ] Annually [ ] Never [ ] ______________________
	If manual:	
|M16|	Windows open during heating period	[ ] Never [ ] Briefly [ ] Lengthy periods [ ] Always tilted
|M42|	During heating period outside doors are	[ ] Usually closed [ ] Often open

A.5.6 *Electrical appliances and other relevant power consumers*

M24,55|

Appliances	No.	Average output [kW]	Mode of use (good | capable of improvement)	Energy efficiency (high | average | low)
Fans				
Pumps				
Electric radiators				
Refrigerating equipment				
Electric hotplates				
Gas cooker				
Copier				
Other:				
Other:				

|M54| Lighting chiefly by means of [ ] Low-energy bulbs [ ] Fluorescent lamps [ ] Halogen lamps [ ] Electric light bulbs
|M23| Lights on during day-time
or during breaks [ ] No [ ] Yes, ______________________________

A.5.7 *Details of use*

Breaks between use of building [ ] Night, from __ to __ [ ] Weekend, _____ [ ] Holidays, ____________
|M07| Room temperature of heated rooms ______ °C

Remarks ______________________________

A.6 *User / administrator opinions*

A.6.1 *User indications*

Room comfort [ ] Good [ ] Adequate [ ] Insufficient
|M07| Temperatures in rooms [ ] Too low [ ] Adequate [ ] Too high
|M46| Room overheating in direct sunlight [ ] No [ ] Yes, where______________________________
|M33-38| Feeling of cold: [ ] No [ ] Yes, where______________________________
|M04,19| Draughts [ ] No [ ] Yes, where______________________________
|M__| Radiators equally warm all over [ ] Yes [ ] No
|M__| Lighting [ ] Good [ ] Adequate [ ] Insufficient
|M16| Windows open during heating period [ ] Never [ ] Briefly [ ] Lengthy periods [ ] Always tilted
|M__| User ideas how and where to save
energy ______________________________
____

A.6.2 *Administrator / manager indications*

What is the motivation to save
energy [ ] Reduce costs [ ] Increase comfort [ ] ____________
Do you have energy saving
objectives [ ] Yes, ____________________ [ ] No
|M32| Do you have an energy officer [ ] Yes, ____________________ [ ] No
|M01| Is energy consumption recorded [ ] Monthly [ ] Annually [ ] No
|M31| Are plant caretakers trained [ ] Yes, ____________________ [ ] No
|M03| Are users informed about energy
saving possibilities [ ] Yes, ____________________ [ ] No
Have improvement measures been
carried out [ ] Yes, ____________________ [ ] No
Capital available for economic
improvement measures [ ] Yes, ____________________ [ ] No
Will audit results be followed up
(fine diagnoses, implementation of
measures) [ ] Yes, ____________________ [ ] No

|M__| Energy saving ideas ______________________________

Remarks ______________________________

B Data evaluation

B.1 Energy application, energy consumption and energy costs

B.1.1 Energy sources and use

Energy source	Heating	Hot water	Ventilation	Other:______________
______________	[ ]	[ ]	[ ]	[ ]
______________	[ ]	[ ]	[ ]	[ ]
Electricity	[ ]	[ ]	[ ]	[ ]

B.1.2 Average energy consumption and energy costs of last four years

Energy source	Consumption	Consumption	Costs
______________	______l | kg | m3 /year	_______ kWh/year	_______ ___/year
______________	______l | kg | m3 /year	_______ kWh/year	_______ ___/year
Electricity		_______ kWh/year	_______ ___/year
Total		_______ kWh/year	_______ ___/year

B.1.3 Development of specific energy costs (price per kWh)

Energy source	19__	19__	19__	19__
______________	________/kWh	________/kWh	________/kWh	________/kWh
______________	________/kWh	________/kWh	________/kWh	________/kWh
Electricity	________/kWh	________/kWh	________/kWh	________/kWh

B.1.4 Development weather-corrected | actual energy consumption, analysis

Weather correction possible [ ] Yes [ ] No !

Energy source	19__	19__	19__	19__
______________	_______ kWh	________ kWh	________ kWh	________ kWh
______________	_______ kWh	________ kWh	________ kWh	________ kWh
Electricity	_______ kWh	________ kWh	________ kWh	________ kWh
Total	_______ kWh	________ kWh	________ kWh	________ kWh

Fuel consumption trend [ ] dropped [ ] constant [ ] increased [ ] no trend discernible
Explanation ____
____

Electricity consumption trend [ ] dropped [ ] constant [ ] increased [ ] no trend discernible
Explanation ____
____

Total energy consumption trend [ ] dropped [ ] constant [ ] increased [ ] no trend discernible
Explanation ____
____

Remarks ____

B.2 Energy ratio of building

Heated gross floor area __________ m2
Which energy consumption is used for calculation:
[ ] Weather-corrected consumption of previous year
[ ] Non weather-corrected average consumption

	Energy ratio of this building	Energy ratio of comparable buildings	Deviation from comparable value
Heat	________ [kWh/m2year]	________ [kWh/m2year]	_______ %
Electricity	________ [kWh/m2year]	________ [kWh/m2year]	_______ %
Total	________ [kWh/m2year]	________ [kWh/m2year]	_______ %

The energy ratio of the total energy consumption compared to similar buildings [ ] Lower [ ] Roughly the same [ ] Higher

Cause of deviation ________________________________

____

Remarks ________________________________

B.3 Energy saving potential

Possible energy savings [ ] High [ ] Average [ ] Low

Experience shows economically meaningful energy saving potential is roughly _______ %

Remarks ________________________________

B.4 Detailed energy evaluation

Thermal quality of building	[ ] High	[ ] Average	[ ] Low
Annual level of use, heating	[ ] High	[ ] Average	[ ] Low
Output of heating system	[ ] Too low	[ ] Adequate	[ ] Too high
Annual level of use, hot water	[ ] High	[ ] Average	[ ] Low
Efficiency of ventilation system	[ ] High	[ ] Average	[ ] Low
Efficiency of lighting	[ ] High	[ ] Average	[ ] Low
Efficiency of other energy consumers: ____________________	[ ] High	[ ] Average	[ ] Low
Efficiency of other energy consumers: ____________________	[ ] High	[ ] Average	[ ] Low
Mode of use of building by users	[ ] Energy saving	[ ] Average	[ ] Not energy saving

Remarks ________________________________

C Improvement measures

C.1 Measures I: Requiring little capital, can be implemented immediately

No.		**Measure**	**Energy savings**			**Details**
			High	Avg.	Low	
		General				
01	[ ]	Regular (annual) recording of energy consumption		**X**		
02	[ ]	Conclude new supply contracts		**X***		
03	[ ]	Inform users about energy saving			**X**	
		Building				
04	[ ]	Windows and doors: Seal gaps		**X**		
		Heating				
05	[ ]	Insulate boiler		**X**		
06	[ ]	Shut down boiler in breaks, reduce room temperatures at night	**X**			
07	[ ]	Reduce room temperatures		**X**		
08	[ ]	Service heating and adjust feed temperature and burner		**X**		
09	[ ]	Do not obstruct radiators (curtains, radiator casings)		**X**		

No.		Measure	Energy savings			Details
			High	Avg.	Low	
10	[ ]	Remove electric radiators		X*		____
11	[ ]	Shut off unnecessary radiators			X	____
		Hot water				
12	[ ]	Optimize hot water system operating times	X			____
13	[ ]	Save hot water (economic showerheads, etc.)		X		____
14	[ ]	Reduce storage temperature to 50°C		X		____
15	[ ]	Regular maintenance of hot water system		X		____
		Ventilation				
16	[ ]	Brief periods of through-airing if not automatic		X		____
17	[ ]	No air-conditioning	X			____
18	[ ]	Shut down ventilation and air-conditioning during holidays	X			____
19	[ ]	Adjust air change rate to requirements (reduce)	X			____
20	[ ]	Set air-conditioning to max. permissible room temperature and humidity in summer, min.in winter		X		____
21	[ ]	Shut down air-conditioning (de)humidifying at night		X		____
22	[ ]	Regular maintenance of ventilation		X		____
		Lighting				
23	[ ]	Switch off lighting when not required		X		____
		Other energy consumers				
24	[ ]	Optimise mode and times of use		X		____
25	[ ]	Reduce peak electricity loads by means of suitable measures, e.g.: Harmonize times of use		X*		____
		Other measures:				
26	[ ]	____				____
27	[ ]	____				____
28	[ ]	____				____
29	[ ]	____				____
30	[ ]	____				____

* no energy savings but energy cost savings

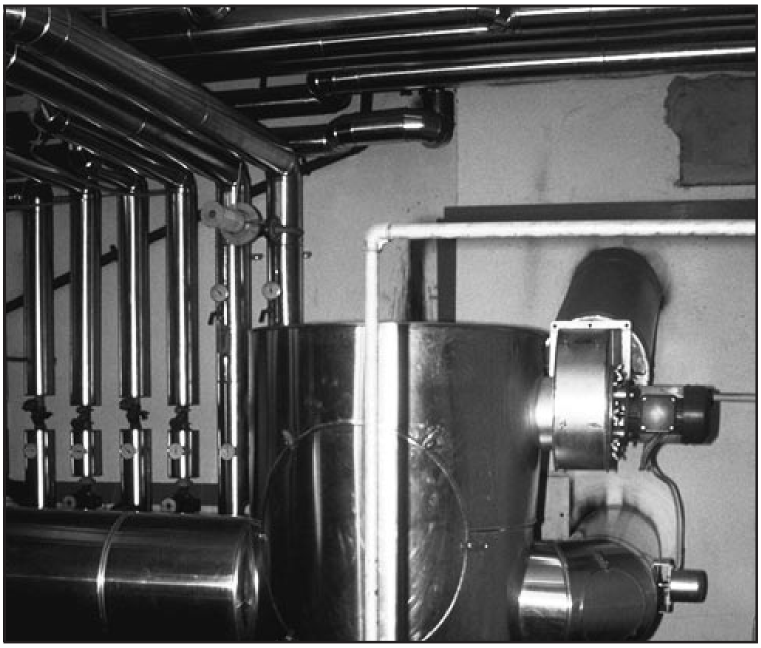
C.2 Measures II: Requiring capital and economic efficiency analysis

No.		Measure	Energy savings			Costs			Details
			High	Avg.	Low	High	Avg.	Low	
		General							
31	[ ]	Energy training of staff	X				X		____
32	[ ]	Appoint energy officer		X		X			____
		Building							
33	[ ]	Insulate outside walls	X			X			____
34	[ ]	Dry outside walls	X			X			____
35	[ ]	Insulate top intermediate floor, and/or roof	X				X		____
36	[ ]	Insulate cellar ceiling		X		X			____
37	[ ]	Replace windows	X			X			____
38	[ ]	Install additional glazing	X			X			____
39	[ ]	Install porch (inside)		X			X		____
40	[ ]	Close stairs at each storey (doors)		X			X		____
41	[ ]	Insulate radiator niches, lintels			X			X	____
42	[ ]	Automatic outside door closer			X			X	____

No.		Measure	Energy savings			Costs			Details
			High	Avg.	Low	High	Avg.	Low	
		Heating							
43	[ ]	Central heating or distant heating instead of single heating in building complexes	X			X			____________
44	[ ]	Replace boiler	X			X			____________
45	[ ]	Use renewable energies (e.g. solar, biomass heating)		X*		X			____________
46	[ ]	Install automatic control	X			X			____________
47	[ ]	Radiator thermostat valves		X			X		____________
48	[ ]	Separate heating circuits for building sections with different uses		X			X		____________
49	[ ]	Insulate distributor pipes, buffer storage		X			X		____________
		Hot water							
50	[ ]	Insulate pipes and storage tank	X				X		____________
51	[ ]	Decouple hot water and heating in summer	X			X			____________
52	[ ]	Hot water circulation system		X				X	____________
		Ventilation							
53	[ ]	Heat recovery system for ventilation systems		X			X		____________
		Lighting							
54	[ ]	Replace light bulbs with fluorescent or low-energy lamps		X			X		____________
		Other energy consumers							
55	[ ]	Replace old, inefficient appliances		X			X		____________
		Other measures:							
56	[ ]	____________							____________
57	[ ]	____________							____________
58	[ ]	____________							____________
59	[ ]	____________							____________
60	[ ]	____________							____________

* no energy savings but energy cost savings

III Follow-up work



Improvement measures can be implemented in 3 stages:

Immediate implementation of organisational measures indicated in C.1 entailing minor costs only. Monitoring of achievable energy savings and contingent economic efficiency of various clusters of measures (on the basis of measures listed in C.2) and selection of the best cluster of measures by experts (energy consultants, building engineers, heating system planners).Financing and implementation of the selected cluster of measures taking into account possible subsidies.

In addition, energy requirements should be identified and evaluated in accordance with B.1 at least once a year. It also makes sense for the administration to set a clear-cut energy saving objective, e.g. 35% reduction of energy requirements (weather-corrected) in 4 years or reduction of (weather-corrected) energy costs by 20% in 2 years.

IV Reporting

Proposal for content of energy audit report:

Cover sheet	*1 page*	*Energy audit report, building and location, officer and date of creation.*
Contents	*1 page*	*Introduction, 1. Summary of main results, 2. Data collection, 3. Results of stock-taking, 4. Selected energy saving measures, 5. Proposal for further procedure, 6. Appendix (Tables and form explanations, notes, other sources). ! Table of contents can also be integrated into the cover sheet !*
Introduction	*1 page*	*General remarks on the energy audit, auditing procedure, general remarks on the energy audit report.*
Summary of main results	*1 page*	*Important data and results, selected measures, notes on follow-up work, remarks*
Data collection	*5 pages*	*Forms A Data collection*
Results of stock-taking	*2 pages*	*Forms B Data evaluation*
Selected energy saving measures	*2 pages*	*Forms C Improvement measures*
Proposal for further procedure	*1 page*	*(Cf. No. III), expert calculation of economic efficiency, selection of a cluster of measures, implementation of the selected cluster of measures, parallel to this: regular recording of consumption data, objectives*
Appendix	*Several pages*	*Tables used, possibly form explanations, notes, other data recorded (energy bills, ...)*

The entire energy audit report thus comprises approximately 12 - 20 pages. The report should be presented to all persons involved (plant caretakers, energy officer, administration, financial department, manager, decision-makers). What is more, anyone interested should also be able to read the report.

V Appendix

V.I Form explanations

A Data collection

A	Data collection	Often, additional people need to be consulted for data collection: Janitor, plant caretaker and energy officer, e.g. for A.3 and A.5.
A.1	Building	Name of building, e.g. “Pörtschach primary school”
	Use	School, kindergarten, administration building, homes, fire brigade, hospitals, sports buildings, etc.
A.2	Number of degree-days of last four years	( ) The number of degree-days is a measure of how cold or warm a particular year has been. If the number is high, it was cold and energy consumption for heating purposes will be equally higher than usual. The number of degree-days is taken to compare the annual energy consumption of a building with that of another. ( ) This data is often not easy to obtain but is extremely important for the audit! The number of degree-days for the nearest town can be obtained from any national meteorological station and also often from heating system planning offices. There are certain calculations employed to compute this value, depending on the room temperature and outer temperature. Please obtain data on the 20/15 (=20°C room temperature and 15°C outer temperature - heating starts at this temperature) basis of calculation. Another important factor along with the number of degree-days is the long-term average of degree-days.
	Subsidies for energy saving measures and renewable energies	This information can be obtained from the national energy agency and from energy consultation centres. In addition to national subsidies, most Central European countries also offer local subsidies; contact local authorities for details.
A.3	Energy bills	The energy bills of the last four years are normally stored in the financial department of the administration. If they are not available, they can generally be obtained fairly easily from energy supply companies.
A.3.1	Fuel consumption	Ideally, the annual fuel consumption is ascertained as follows: The amount of energy purchased this year plus the existing reserve at the beginning of the year is reduced by the amount of unused energy at the end of the year. If this calculation is not possible because the storage level was not read at the end of the year in previous years (tank, storage room), or if the storage level cannot be estimated retrospectively, the amount of energy must be ascertained on the basis of the energy bills in this year. This procedure is, however, extremely rough and unfortunately often gives a false picture.
	Calorific value H_u	The “lower calorific value Hu” is the energy contained in a particular fuel. This value is only necessary for converting kg, l, or m3 of fuel into energy. Generally it is indicated in energy bills, if not it can be obtained from the fuel trader or can be found in Table 2 in the Appendix for Central European locations. The unit of measure can be taken as l, kg and m3, delete as applicable.
	Table	The national currency should be added to all costs. The average amount of energy used and costs should be calculated as a normal arithmetic mean – add up all energy consumptions and divide by the number of consumptions. The costs per kWh can be computed by dividing the costs by the amount.
A.3.3	Total energy consumption	The total energy consumption is the sum of electricity consumption and consumption of all other energies.
A.3.4	Conditions of supply contracts	Compare by consulting various fuel traders; please indicate remaining term of contract.
A.3.5	Rate structure electricity fines	Enter the national currency unit in the square brackets! Basic charges are charges not connected to consumption. If fines exist for excessive consumption, check whether such fines had to be paid last year. If this is often the case, agree on a higher level of consumption. If not, negotiate a lower level of consumption on a trial basis.
A.4	Heated gross floor area	The gross floor area is a reference quantity for energy consumption. It is the sum of all heated areas, i.e. areas equipped with heating. The outside dimensions should be used (incl. wall). The total heated gross floor area is the sum of all storeys. The depth is measured from one level of flooring to the next level of flooring. If no plans are available calculate the gross floor area with a tape measure on site. Please note that the outside dimensions must be used for this calculation!
A.5.1	Building	Enter individual materials and thicknesses in the column “Structure”. The thermal quality should be evaluated as follows (evaluation for Central European climate): ( ) Outside walls: “Good” if more than 6 cm high-grade insulation or 38 cm thermobrick wall without insulation, “Average”: approx. 30 cm cored brick masonry without insulation or concrete wall with up to 6 cm insulation; “Bad”: no insulation; ( ) Ceiling above unheated cellar: “Good”: more than 6 cm insulation, “Average”: Hollow filler block floor without insulation or reinforced concrete floor with little insulation; “Bad”: Reinforced concrete floor or similar without insulation. ( ) Top storey ceiling: “Good”: more than 12 cm insulation, “Average”: 5-12 cm insulation; “Bad”: less than 5 cm insulation. ( ) Windows: “Good”: Two or three-pane thermopane glazing with gas filling; “Average”: Two-pane thermopane glazing; “ Bad”: Single glazing. ( ) Outside doors: “Good”: Wooden doors; “Average”: Plastic doors, metal doors with core insulation, double glazing; “Bad”: Metal doors not insulated, glass doors with single glazing. Indicate the general condition of the building, damp, age, etc., under Remarks.
A.5.2	Number, type, output, ... year of construction of heat generators	The output of the boiler can be seen on the type plate. The output should be indicated in kW. Conversion factors for other performance units can be found in Table 1 in the Appendix.
	Output is	The output (thermal performance for heat pumps!) of the heating system is “Too high” if the full capacity is not required even on cold winter days, or if the boiler is only in operation at times (often the case in old buildings). The output is “Too low” if a comfortable room temperature is not achieved on normal winter days although the boiler is running at full capacity.
	Installed thermometers	Check proper functioning of thermometers also!
	Additional electric radiators	Please indicate the number, average output and estimated operating hours p.a. Electric radiators should be replaced as they cause high energy costs (high electricity costs).
	If steam system: Condensate recycled	Is condensate fed back into the boiler, used for other purposes or does it enter the waste water unused?

A.5.3	Separate distribution circuits for building sections with diff. ..	Separate distribution circuits for building sections with different uses or different facing allow for more efficient distribution of heat as unused heating circuits (e.g. for south-facing building sections) do not have to be operated.
A.5.4	If tank: ... fully heated	If the tank is heated up to half maximum twice a week, for example, enter full heat-up “Once per week”
A.5.5	Air temperature and fresh air humidity...	Generally speaking, 65% dehumidification of outside air in summer, and 30% humidification in winter is adequate for normal comfort.
	Air change in rooms	The minimum air change can be ascertained by testing. If draughts occur although the air is not foul, the air change rate is often excessively high. If the air is foul, the air change rate is too low.
	If manual: Windows are ...	Intermittent airing makes sense during the heating period if no air-conditioning system is installed. Open a large number of opposite facing windows briefly.
A.5.6	Electrical appliances and other relevant energy consumers	Indicate most important consumers only, i.e. those with high output and/or prolonged operating times. The mode of use means the way appliances are used: e.g. if appliances are left on when not in use, the mode of use is capable of improvement. The energy efficiency of an appliance should be judged good if energy consumption conforms to the latest standard of modern appliances (subjective assessment is adequate!). A far higher consumption should be rated “Bad”, as is the case above all with very old appliances.
A.5.7	Room temperature in heated rooms	If room temperature is reduced by 1 K (°C), 6% heating energy can be saved (applies for Central Europe).
A.6.1	Radiators equally warm all over	If radiators are not equally warm all over, they often need to be deaired.

B Data evaluation

B.1.1	Energy sources and use	Please indicate the main uses of energy sources (heating, hot water, ventilation, lighting, cooking, washing, cooling, ...).
B.1.2	Average energy consumption and energy costs	The data can be found in the “Data collection” form, items A.3.1 to A.3.4. The unit of consumption can be taken as l, kg and m3 (each per kWh). Please delete as applicable.
B.1.3	Development of specific energy costs	The data can be found in the “Data collection” form, items A.3.1 to A.3.4.
B.1.4	Development of weather-corrected | actual energy consumption, analysis	( ) As opposed to hot water requirements and most electricity applications, the heating energy requirements depend on seasonal climatic fluctuations. Hence, the heating energy requirements should be corrected with the aid of the number of degree-days computed in A.2, i.e. converted to a “model climatic year” for the particular location. The heating energy consumption (= sum of all energies apart from electricity) for a specific year is divided by the number of degree-days of that year and then multiplied by the long-term degree-days. ( ) If electric radiators are being used in addition to a fuel-fired heating system, do not weather-correct the data for reasons of simplicity. However, if heating is chiefly generated by electricity, the amount of electricity required for this purpose should be recorded (usually a separate sub-meter for heating only) and corrected with the aid of the number of degree-days. If no separate meter is installed no weather-correction, nor breakdown of heating energy requirements and other electricity requirements can be carried out! Please indicate under “Remarks”! ( ) If no number of degree-days is available the uncorrected data must be used. The severity or clemency of a particular year must be taken into account for subsequent analysis! ( ) Explanation of development of consumption: Frequent causes of consumption changes are increased comfort needed in the building, additional energy consumers, deviations in periods and modes of use. Also technical defects of energy equipment and changes in the quality and size (extensions) of buildings. If no weather correction was possible, the severity or clemency of the heating periods of a particular year must be taken into account.
B.2	Energy ratios of the building	( ) The heated gross floor area can be found in A.4.2. ( ) The energy ratio of the building can be computed quite easily by dividing the weather-corrected energy consumption of the previous year from B.1.4 (if not available: average total energy consumption from B.1.2) by the heated gross floor area. This calculation is carried out for heat consumption (= sum of individual energy sources use for heating and hot water), electricity consumption, and total energy consumption. Checksum: The sum of heat and electricity energy ratios must equal the total energy ratio. ( ) The energy ratio of comparable buildings can be seen in Table 3 in the Appendix. The energy ratio indicated there must, however, be converted to the climatic situation of the particular location. This is done by dividing the energy ratio by the reference number of degree-days 20/15 (= 3439 Kd, Dusseldorf, Germany) and then multiplied by the number of degree-days (long-term) of the location. If no number of degree-days is available (basis of calculation 20/15!), the uncorrected data must be used. In this case, the varying climatic conditions at the location and in Dusseldorf (Germany) must be taken into account for subsequent analysis! ( ) For this analysis, the differences between various installed energy consumers must be taken into consideration (ventilation system, school swimming pools, etc.). It must also,be taken into account that the reference energy ratio was computed for 1987 and that buildings have meanwhile been vastly enhanced in terms of energy efficiency. The average energy ratios in Central Europe will be far lower, whereas these values will probably be well suited for comparison in Eastern European conditions! ( ) The deviation from the reference number should be indicated in per cent and can be calculated as follows: Energy ratio of the building divided by the reference energy ratio, then multiplied by 100 equals the deviation in per cent. ( ) Cause of deviation: Frequent causes include more/less energy consumers, lower/higher room temperatures than 20°C, different mode and periods of use, but also, of course, more/less efficient equipment and buildings.
B.3	Energy saving potential	( ) A rough estimate of the energy saving potential is indicated in Table 4 in the Appendix. Always bear in mind that the energy ratio is based on the number of degree-days in Dusseldorf (3439 Kd). Hence, in order to rate the total energy ratio of the

building – as opposed to B.2 - it is necessary to convert the energy ratio to this number of degree-days. In order to do so, the total energy ratio is divided by the number of degree-days (long-term) of the location and then multiplied by the reference number of degree-days (= 3439 Kd, Dusseldorf, Germany). Then the Table gives a rough estimate of the achievable energy savings according to experience on the basis of the use of the building and the computed energy ratio.

( ) If no number of degree-days is available, the uncorrected data must be used. Differences between the climatic conditions of the location and Dusseldorf (Germany) must be taken into account. If the climate of the location is more clement than in Germany, it is necessary to add an estimated amount to the energy ratio of the building before consulting Table 4 for the energy saving potential. If the climate of the location is more severe, the energy ratio must be accordingly reduced to be able to compare it with the table.

( ) It should be pointed out once more that even if all economic improvement measures are implemented, energy savings can only be achieved if the mode of use of the building is not changed (e.g. increased comfort by increasing room temperatures). If it can be expected that comfort will increase, the energy saving potential will be accordingly lower!

B.4 Thermal quality of the building

The subjective evaluation of thermal quality can be ascertained on the basis of the individual assessments in A.5.1. It must be noted that the greatest influence is posed by the outside walls, then the top floor ceiling and then windows and cellar roof. Outside doors have practically no influence.

Annual level of use, heating

The annual level of use is a measure of how much (fuel) energy is converted into useful heat and passed on to the consumers (rooms); the higher, the better.

This value is influenced by (in order of significance) (cf. A.5.2, A.5.3): Age, dimensions of the boiler (excessive output = bad), insulation of boiler and piping, mode of control and maintenance. The annual level of use can be judged as being “High” if the boiler was built after 1978, if the output is adequate and if boiler and piping are well insulated (boiler: approx. 10 cm, piping: thickness of insulation equals inside diameter of pipe) and if an automatic control is installed. The annual level of use is regarded as being “Low” with old, oversized and rarely serviced systems without automatic control and little insulation. The annual level of use can only be measured in detail by experts.

Output of the heating system

Calculate as in A.5.2!

Annual level of use, hot water

Depends on the type of heating (coupled with or separate from heating in summer), the efficiency of the heat generator, the insulation of the tank and piping, and the storage temperature (cf. A.5.4). Hot water heating is “Bad” if coupled with the heating in summer and if the tank is only poorly insulated at an excessive storage temperature. A “Good” hot water heating system is separated from the heating system in summer (or all year round) with an efficient heat generator, adequate storage temperature (normally 50°C) and tank insulation (e.g. 10-15 cm mineral wool) and pipes (thickness of insulation equal to inside diameter of pipe).

Efficiency of the ventilation system

Only to be filled in if mechanical ventilation is used!

Influenced greatly by: Heat recovery, fresh air humidity and temperature setting, and maintenance (cf. A.5.5). Efficiency is only “High” if a heat recovery system is in use, if fresh air conditions are adequate (cf. explanation of A.5.5), and if regularly serviced. Efficiency must berated as being “Low” if no heat recovery system is installed and if maintenance is omitted or if fresh air is excessively conditioned.

Efficiency of lighting

“Normal” light bulbs are extremely inefficient. Thus, if the lighting system is mainly light bulb operated, the efficiency will be “Low”; if some amount of lighting is via low-energy bulbs, fluorescent lamps and halogen lamps it will be “Average”, and if he latter light sources prevail it will be “High” (cf. A.5.6).

Efficiency of other energy consumers

Evaluation as in A.5.6, for a comprehensive evaluation please observe the relevance of the individual energy consumers (in terms of energy consumption).

Mode of use of building

Influenced by (in order of significance): Height of room temperature, airing behaviour, way hot water, lighting and other energy consumers are used (cf. A.5.4 to A.6.1). Excessively high room temperatures and rooms with permanently tilted windows and careless use of light and other appliances must be rated “Bad”, adequate temperatures, correct airing behaviour and general energy-conscious behaviour should be rated “Good”.

C Improvement measures

C.1–C.2 Improvement measures

( ) C.1 and C.2 are catalogues of improvement measures that can be directly integrated into the audit report. C.1 contains measures that help save energy and that can be implemented with little or no costs. These are mainly so-called “organisational” measures” that can be implemented immediately without any further analysis. Catalogue C.2, in contrast, contains all other measures that can help reduce energy costs, but which essentially require capital (money) to obtain. These measures generally make sense (not always) in terms of business management (depending on the local situation, the building and the energy equipment). As opposed to Catalogue C.1 these measures must be reviewed by external experts (energy consultants, heating system planners) prior to implementation. What is more, these experts should also suggest a meaningful combination and carry out implementation planning.

( ) Forms C.1 and C.2 show a general indication of how high the contribution of each measure to energy saving can be. C.2 also indicates the costs involved in implementing the measures. It also allows a rough estimation of the economic efficiency of the measure. If the energy savings are rated higher than the costs, the measure will generally pay off very quickly. If the reverse is true, the measure will tend not to be economically efficient. If savings and costs are in balance, the measure will generally pay off, albeit over lengthier periods.

( ) The simplest way to fill in forms C.1 and C.2 is as follows. The forms for data collection (A) often contain small-print references to the improvement measures in C.1 and C.2 in the left column (e.g.: “|M45|” : “M” stands for measure, the number is the number used in forms C.1 and C.2). If the data collection forms are now re-examined, checking each question with a reference as to whether the checked condition is improved - in terms of energy efficiency – by the indicated measure this measure can be checked in the forms C.1 and C.2. The following applies as a general rule: Conditions capable of improvement are indicated furthest right in the list of possible answers in the data collection forms (A).

( ) Example: “A.5.1 |M04| Windows and outside doors shut tightly: [ ] Yes [X] No“ Measure 04 is: “Seal windows and doors”. As windows and doors do not shut tight according to the answer (“No”), M04 is an improvement measure and is checked in C.1.

( ) References without a number („|M__|“) indicate that although improvement measures make sense here, they are not listed in the pre-printed catalogues C.1 and C.2. These and other measures not listed can be added in the space provided for further measures at the bottom of C.1 and C.2. Note that the measure is properly assigned to C.1 or C.2 according to the kind of measure. Moreover, the energy savings (high, average, low) and in C.2 the costs (also high, average, low) should be estimated.

( ) The column “Remarks” is designed for detailed information concerning the selected measures. Describe here the scope of the measures (sections affected, how far must the measure go), the necessity and urgency of the measures and, above all, the relevance of the measures in terms of the expected energy savings for this building specifically (as opposed to the middle column containing general energy savings). Note for audit report: The most relevant measures should be summarized again separately in the audit report (in addition to the forms) so as to provide a clearer breakdown! Moreover, a note should be added to the “Remarks” column if several measures have been proposed and if implementing all these measures does not make sense; e.g.: M37: “Replace windows” and M38: “Install additional glazing”. As it is rather pointless to install additional glazing and then replace the same window, a note should be made in the “Remarks” column indicating this fact.

V.II Tables

Table 1: Conversion of performance units and SI prefixes

Conversion of performance units	SI prefix
1 kW = 860 kcal/h = 3600 kJ/h	k = * 1 000
1 kJ/h = 0.000278 kW = 0.2389 kcal/h	M = * 1 000 000
1 kcal/h* = 0.00116 kW = 4.186 kJ/h	G = * 1 000 000 000

*NB.: 1 kcal/h = 1 WE/h

Table 2: Calorific values of various energy sources in Central Europe (Austria)

Energy source	Unit	Density [kg/m3]	Calorific value H_u [kWh/kg]	Calorific value H_u [kWh/unit]
Heating oil extra light	l	830	12.0	10.0
Heating oil light	l	920	11.4	10.5
Natural gas	m3	0.70	13.5	9.5
Liquid gas	kg	2.02	12.8	12.8
Hard coal	kg	750	7.0-8.3	7.0-8.3
Coke	kg	500	7.5	7.5
Brown coal	kg	710	3.9-5.6	3.9-5.6
Firewood beech	rm	360-570	4.2	2410
Firewood spruce	rm	360-570	4.2	1520
Chips	srm	215	3.4	730-850

Table 3: Reference energy ratios of public buildings in Central Europe

(Düsseldorf, Germany, HGT$_{20/15}$ = 3439 Kd)

Building type	Energy ratio heat [kWh/m2a]	Energy ratio electricity [kWh/m2a]	Energy ratio total energy [kWh/m2a]
Administration	183	28	211
Schools	197	19	216
Kindergartens	237	19	256
Homes	172	26	198
Hospitals	195	-	-
Fire-brigade/contractor’s yard	216	21	237
Other buildings	191	42	233

Table 4: Rough estimate of economic energy saving potential

(Energy ratio based on Dusseldorf, Germany, degree-days$_{20/15}$ = 3439 Kd)

Building type	Energy ratio total energy [kWh/m2a]		
Administration	< 110	110 - 280	> 280
Schools	< 110	110 - 300	> 300
Kindergartens	< 135	135 - 340	> 340
Homes	< 105	105 - 260	> 260
Hospitals	-	-	-
Fire-brigade/contractor’s yard	< 125	125 - 310	>310
Other buildings	< 125	125 - 310	>310
Assessment of economic energy saving potential	Low: < 20%	Average: 20 - 40%	High: > 40%

1. Metering and control of energy consumption

1.1 Introduction

Energy consumption in the building sector has been increasing in the last decades and so have the associated costs. The cost of heating alone, in public and municipal buildings, represents a significant percentage of the total running costs. In this context, it becomes increasingly essential to properly meter and control energy systems in these buildings, in order:

- *to achieve and maintain acceptable living and working conditions (level of comfort)*
- *to eliminate energy wastage, and*
- *to ensure energy consumption accountability*

Depending on the size and the type of the building, a large number of metering and control options are available in the market, ranging from manually operated to fully automated systems.The following, is an overview of the most important options presented with an emphasis towards the simpler ones, as these afford significant savings with the minimum cost.

1.2 Energy metering

A reliable and well-designed energy metering system, although it does not save energy itself. It provides the basis for energy savings and proper energy management. The level of metering (the number of meters to be installed), depends on the type of building and the energy bill. The meters are regarded as a cost saving investment that should exhibit a reasonable pay-back period. Generally, three levels are distinguished, in order of increasing complexity:

Metering of the main energy flows: Refers to the metering of the electricity and fuel energy flowing into the building and it is usually provided by the utility supplying the building. It gives an indication of the total energy consumption trend but gives no no information on where the energy is being used. It should be considered as the minimum for all kinds of buildings.

Sub-metering of main energy points of use: Energy meters should be installed at main energy points of use or in departments that present a significant energy consumption and justify the cost of purchase and installation of a meter. A preliminary energy audit should help to identify these locations. Departmental sub-metering provides information on where the energy is used within a building. Most public and municipal buildings justify this level of metering.

Sub-metering of final energy users: In addition to departmental sub-metering, final energy users (like large motors, chillers, special equipment) can also be incorporated in the metering system. The system provides in-depth knowledge of the energy-use breakdown of a building and should be applied to large buildings with significant energy consumption.

1.2.1 Electricity meters

The majority of existing buildings, in the best case, are equipped with electromechanical one- or three-phase meters. These meters are of limited capability and the reading of their indication is prone to error.

New electronic meters have been developed in the past few years, covering a wide range of capabilities, from simple energy (kWh) measurement to the measurement and recording of a large number of electricity parameters (energy, power demand, power factor, voltage, current, time and season bands, harmonic distortion, etc.). Electronic meters are also capable of output signalling in order to activate control devices or can be integrated in to a network. Prices range from 300 to 2500 ECU per meter depending on the capabilities and the storage capacity of the instrument.

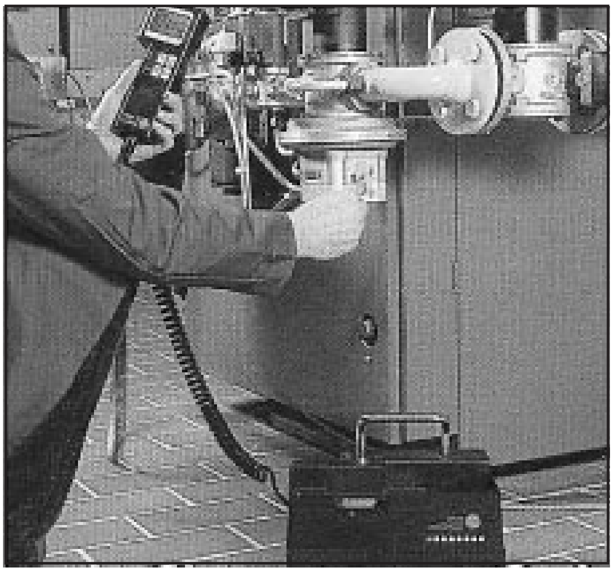
1.2.2 Heat meters

Hot water meters work by measuring the flow of water and the flow and return temperatures. On the basis of these values the energy consumed over the heating period is calculated automatically. The usual type of device is the rotary vane and the orifice plate meters. Prices for hot water meters start at about 300 ECU and increase depending on the diameter of the piping.

Steam meters are generally more expensive, starting from 3500 ECU for small diameters. Popular types are the orifice plate and the vortex meters. Modern meters are now available with output signalling which allows them to be incorporated in computerised management systems.

1.3 Energy controls

Proper control of heating systems presents significant opportunities for savings in all kinds of buildings. This is especially true for CEE countries where there is usually a lack of control at all levels.



In general, space heating control is accomplished at two levels:

• ***centrally***, *by regulating the flow of hot water in response to the outside temperature*

• ***individually***, *by responding to the actual needs of each space and occupancy pattern.*

In the following, simple and efficient ways to control space heating are addressed. They are based on international practice and also take into account the peculiarities of CEE countries.

District heating is a popular means of space heating in many European countries, especially CEE ones. The control options discussed in the following apply equally to this system (except for the ones that function centrally at the boiler plant level). DH systems are also controlled centrally but this control is accomplished by the utility and need not concern the end-users.

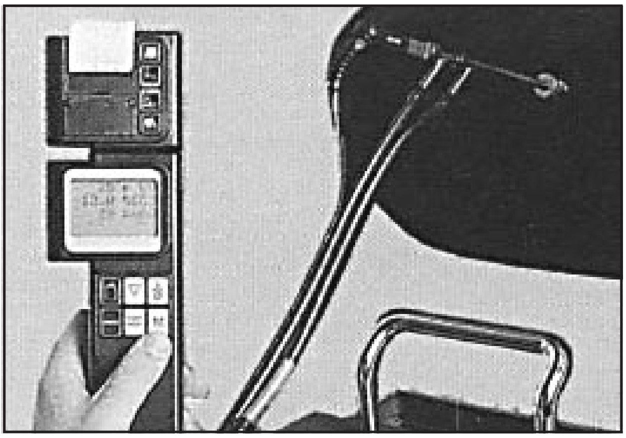
1.3.1 Manual control of space temperature

Manual control is accomplished by regulators on the radiators. This is the simplest mode of control, applicable to double pipe as well as to single pipe systems with a bypass. Manual regulation should be considered as the minimum for all kinds of heating installations. Obvious drawbacks are the dependence on the user's behaviour and the limited flexibility to changes.

1.3.2 Thermostatic valves

These add a degree of automation to the previous mode of control. Thermostatic valves are automatically regulate the flow of hot water entering the radiator and respond to the user's actual requirements. The valves are activated by thermostats with set-point temperatures input by the user. The latter is able to determine his/hers level of thermal comfort and also take advantage of internal or external heat gains.

Thermostatic valves are nowadays considered a very efficient choice for regulating space heating. They can be retrofitted rather easily to existing systems, especially to double-pipe or single-pipe systems with by-pass. Reported savings are in the range of 10% or more and PBP in approximately 1-2 years.



1.3.3 Weather compensation plus thermostatic valves

This mode of control provides great flexibility, high level of comfort and economic effectiveness. Control is accomplished at both the heating plant, by adjusting the temperature of the flow water to the outside temperature, and at the radiators, by thermostatic valves (described previously). It is a very common design of heating system in western European countries. Reported PBP for retrofitting is at 2-4 years.

1.3.4 Zoning

For buildings that exhibit significant differences in occupancy patterns, zoning control may be appropriate. According to this control mode the building is divided into zones with similar heating patterns which are served independently. This way, for instance, south parts of a building may benefit from solar gains there by reducing the need for heating as appropriate.

Zoning control is usually taken into consideration at design stage and not at retrofitting, due to the associated costs for changing the layout of the heating system.

1.3.5 Other considerations

Depending on the equipment installed, the building type and use, other modes of control may be necessary:

Boilers sequencing control, where multiple boilers are available. This ensures that the boilers matching the required load are used and that boilers are operating at loads close to their maximum capacity.

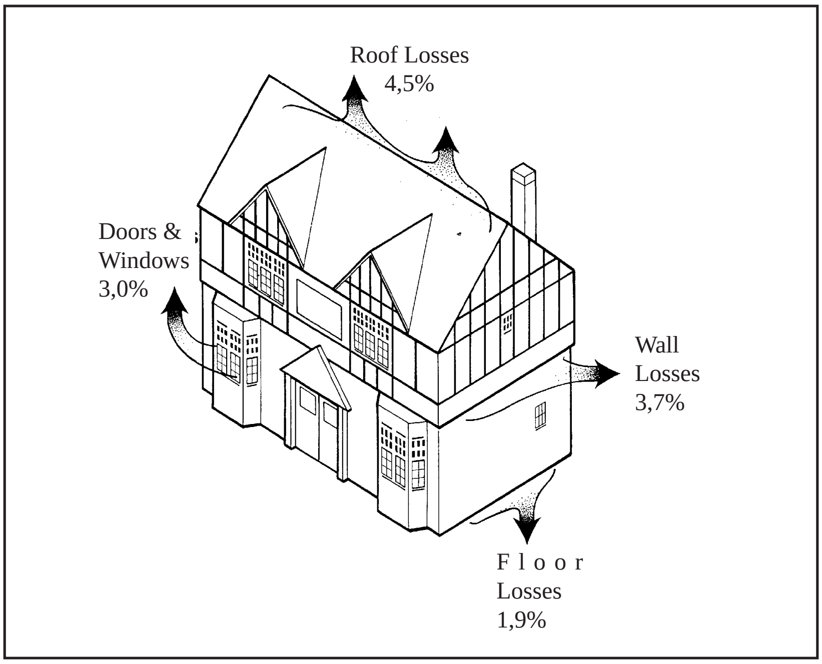
Time-switches, that set the heating plant on and off at pre-set times of the day. Seven-day switches are available for a different setting per day and allow for the weekends. **Optimisers** could be used alternativly , that start and shut down the heating plant after taking into consideration the external temperature and the inertia of the building.

Frost protection, which prevents the building from reaching frost temperatures (below 4°C) when not occupied. This is especially useful in the harsh climates of CEE countries.
The area of building energy controls is extremely extensive therefore each case should be confronted on its own merits and particularities. Sophisticated controls tailored to the needs of individual buildings have been devoloped in special cases. The employment of experienced consultants for the design of the interventions is strongly recommended since they will ensure that the most efficient choice is made at a sensible cost.

2. Interventions to the building envelope

2.1 Introduction

The building envelope, also known as the building fabric, comprises the roof, walls, floor, doors and windows of a building. Even a properly constructed and well maintained building will loose heat through all these components of the envelope, to a percentage that may reach 10-15% of its total fuel bill, as shown in the following figure:



Losses also occur due to air infiltration from doors and windows and due to the air exchange that is required in order to maintain the air quality needed.
Energy losses are significantly increased in the case of the existing building stock in CEE countries. Especially the buildings that were constructed around the 70s which are usually of prefabricated panel type and are characterised by low construction standards and significant energy savings potential.

Usual retrofitting practices and methods for the reduction of energy losses from the building envelope comprise the following interventions:

- *roof insulation*
- *wall insulation*
- *basement insulation*
- *draught stripping*
- *double glazing of windows*

It should be stressed that building retrofitting is rather expensive in most cases and is not often economically attractive, especially under the energy pricing situation prevailing in CEE countries. PBP of 10 years or more is the usual case. Economically attractive opportunities arise when energy interventions are combined with general renovation or refurbishment programmes.

2.2 Insulation materials

All material that resist the flow of heat through their mass are called insulation materials. The most important characteristic of them is their ability to hold air, since air itself is a very effective means of insulation. The thermal conductivity, ë, expressed in W/mK, (Watts per meter and degree Kelvin) is the measure of insulation effectiveness; materials with

low ë value are the best insulation materials.Other characteristics are also very important in selecting the proper insulation material, such as, flexibility at operating temperatures, low fire and explosion hazard, easy to store and handle, resistance to water and vapour penetration, chemical resistance, environmentally friendly.
There are a variety of insulation materials available on the market: mineral wool, glass fibre, polyurethane foam, expanded polystyrene etc. All these exhibit ë values in the range 0.03 to 0.05 W/mK, in comparison to concrete with ë values ten times higher.

2.3 Roof insulation

Roof insulation is amongst the most effective of interventions in terms of energy and cost savings, because:

- *the installation of roof insulation is relatively easy, without disturbing the use of the building by the occupants*

- *the energy losses through non-insulated roofs are significant due to radiation during night-time*

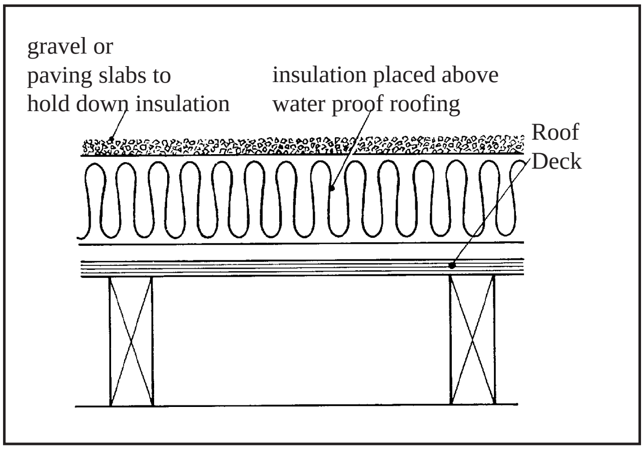
The main techniques used are the traditional roof and inverted roof insulation, the latter lately being applied more often. In both cases, care must be taken to prevent the accumulation of vapour which diminishes the effectiveness of insulation.

2.3.1 Traditional roof insulation

Acceptable insulation standards can be achieved by inserting an insulation layer between the roof deck and the waterproof covering. Vapour barrier is also used underneath the insulation to prevent vapour condensation. Insulation in this position keeps the roof structure warm. However, the water proof covering is exposed to weather conditions, temperature changes and mechanical stresses which result in ageing and eventual destruction of the material.

2.3.2 Inverted roof insulation

The technique of inverted roof insulation has been developed in order to cope with the inefficiencies of traditional insulation and is based on the installation of the insulation layer above the water proofing. This way, the water proofing is being protected from weather conditions and its life span is increased.
The insulation material used in the inverted roof technique should have outstanding resistance to water and vapour penetration. Modern material, however, complies with these requirements, making the technique very popular over the last years.



2.4 Wall insulation

The reduction of energy losses from the walls can be carried out in two different ways:

- *Internal insulation*

- *External insulation.*

For both types of insulation the advantages are a decrease in energy consumption as well as the increase in thermal comfort of the building users due to increased wall surface temperatures.

2.4.1 External insulation

External insulation has the advantage that the normal use of the building is not disturbed and, also, results in keeping the whole structure warm and dry. However the price is paid in terms of increased cost since extensive scaffolding is involved. The usual ways of applying existing insulation is by using:

- *insulation material fixed to external wall with adhesive and mechanical fixings and coverage by a reinforcing mesh with plaster layer*

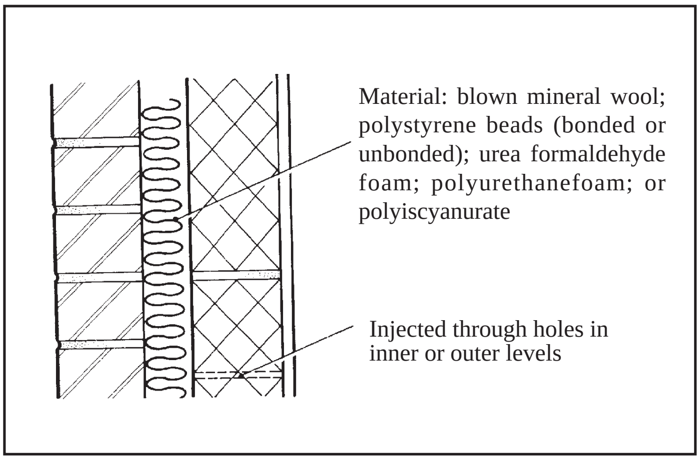
- *a combination of insulation and cement rendering*

External insulation requires a consideration of many construction details and should be carried out by experienced contractors. PBP for specific applications in CEE countries is reported to be 14 to 20 years.

2.4.2 Cavity insulation

The insulation in the form of foam-fill, blown mineral wool or polystyrene beads is applied between inner and outer masonry skins.
This type of insulation has a relatively low capital cost and short pay-back period (in the range of 4-8 years in EU).

2.4.3 Internal insulation



Internal insulation is applied to the inner side of the walls without modifying the facade of the building, which might be required for old, traditional-style buildings. Moreover, less material is needed, no scaffolding is required and individual application is possible (insulation of selected areas).
However, the following problems are encountered when using internal insulation:

- *the building will not operate during the works*
- *the building structure is exposed to weather conditions*
- *difficulties are encountered with piping, wiring, installed radiators, etc.*
- *the size of the rooms is decreased*
- *thermal bridges will not be avoided.*

Internal insulation should be considered when other options are not applicable.

2.5 Basement insulation

The usual way to cope with energy losses through the basement is by the insulation of the basement ceiling but care should be taken to avoid thermal bridges. Similar projects in CEE countries presented PBP of 6 to 8 years.

2.6 Draught stripping

Draughts due to defects in the structure itself or due to leaving windows and doors open, seriously affect the benefits which result from applying acceptable insulation standards and may lead to considerable energy losses.
As a first step, holes, cracks and any other structure deficiencies should be fixed and doors and windows properly sealed. Foam material, tape or cloth could be used. Doors and windows should be left open as little as possible in order to maintain the required air quality and minimise losses.
Projects in CEE countries involving major maintenance of the structure, especially around doors and windows, have resulted in PBP of 5 to 7 years.

2.7 Double glazing of windows

The windows are normally weak points in a building. The transmission losses through glass are 4-6 times higher than for walls and often thermal bridges exist between the frame of the wall. Installation of double glazing can reduce the transmission losses from windows by almost 50%.
In most CEE countries, nowadays windows are double, meaning two separate windows with wooden frames, each one opening independently. When properly maintained, this installation works quite efficiently from the energy point of view. Thus making double glazing of windows a non cost effective intervention. Indeed, reported PBP is more than 17 years.

2.8 Other considerations

Building envelope interventions for energy savings should not be assessed based on ROI criteria only. A number of other beneficial side-effects, which are not easily quantified, complement the cost savings achieved through energy saving interventions. Some of these are:
Thermal comfort improvement: The elimination of cold draughts either from infiltration or from the temperature difference between the walls and the room interior is significantly improves thermal comfort, living and working conditions.
Prolongation of the building service life: The improvement of insulation standards helps the building envelope to respond better to changes in temperature and avoid cracks and humidity penetration. This way the life span of the building is longer and maintenance costs are reduced.

Heating system optimisation: The reduction of energy losses may lead to the better operation of the heating system serving the building. Especially in the case where multiple boilers are in operation, one of them may not be needed at all, resulting in large energy savings from standing losses. It is a good idea to combine building envelope interventions with an energy audit of the thermal system in order to benefit from the synergetic effects.**Improvement of the acoustic environment:** In several cases good insulation standards have improved the acoustic environment of work spaces by isolating the building from outside abstractive noise.

Although sometimes it is tempting to insulate part of the buildings, where large savings are expected, this is not always a cost effective choice. The most expensive part of the insulating interventions are the scaffolding and the working costs and not the material itself. Moreover, in certain cases, partial insulation may make things worse, since it results in severe temperature differences between adjacent construction elements, thermal cracks and extended thermal bridges (see following picture, taken with a thermographic camera from inside a heated space. Warm walls and cold joins are indicated by different colours).

The efficiency of interventions in the building envelope depends heavily on the existing type and condition of the building, the general economic environment and the successful implementation of the measures. It is strongly recommended that expert advice is asked for, in order that the best options be selected.

3. Interventions in thermal system

3.1 Introduction

Water boilers are extensively used in buildings for space heating and production of domestic hot water, especially in areas where district heating is not available. Steam boilers are also used in large buildings, such as hospitals, to cover specific needs. By definition, a boiler is a closed vessel in which a fluid is heated by the combustion of fuel (solid, liquid or gaseous) or by the use of electricity. An ideal boiler should use all the energy released by the combustion process and transfer it to the fluid (e.g. water or steam). In practice, losses in the range of 10-30% are frequently found. Small boilers in buildings are usually operated without proper care and present increased losses which are directly translated into monetary losses. In the following, an overview of the main energy losses are presented, along with good energy practices for operating a boiler that can lead to savings of a considerable amount of money.

3.2 Overview of boiler losses

In summary, the energy losses from a boiler are the following:

- *Heat carried out into the atmosphere with the flue gases. This is the major heat loss of a boiler. Fault design, structure damages, fouled surfaces or wrong adjustments, i.e. too much combustion air in the boiler, are the main causes for increased losses of this type.*

- *Heat losses from the boiler casing (radiation losses). The casing losses are usually less than 1% but can be as high as 10% if the boiler is not adequately insulated or if the insulation is allowed to deteriorate.*

- *Losses due to incomplete combustion (i.e. unburned coal found in the ashes, soot or carbon monoxide in the flue gases). These losses are usually attributed to problems in the burner or the coal grate, to bad quality of fuel or to incorrect adjustment of the combustion parameters i.e. not enough combustion air in the boiler.*

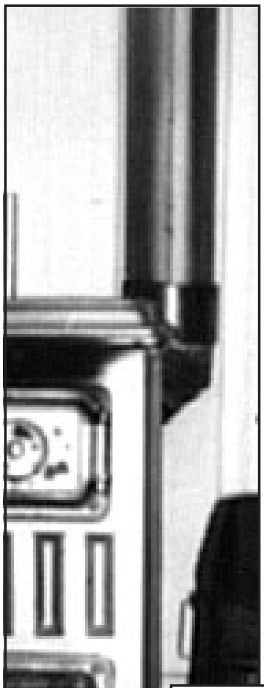
- *Losses due to the boiler blowdown (for steam boilers only). For a steam boiler it is necessary to reject some of the water to remove precipitated salts which can cause problems in the boilers and the steam mains. This process is known*

as boiler blowdown. Blowdown may represent a loss of more than 3%. The better the water quality used for steam production the less the blowdown losses.

• Other losses. An important factor that affects the efficiency over a certain period of time is the firing schedule of the boiler to meet demand variations. If a boiler is left to cool down often, excess energy is required to warm it up again before starting operation.

3.3 Monitoring boiler efficiency

In general, the following parameters should be monitored and controlled in order to achieve efficient combustion:



- *Flame appearance*
- *Smoke density*
- *Combustion gas composition*
- *Flue gas temperature*

3.3.1 Flame appearance

The appearance of the flame can provide a good initial indication of combustion conditions. It is difficult to generalise the characteristics of a „good“ flame since there will be variations depending on the burner design. A symmetrical, steady flame without long „streaks“ or sparks is a good indication. The flame should be directed to the centre of the boiler and not come in to contact with the combustion chamber walls since this may cause incomplete combustion.

3.3.2 Smoke density

Smoking can occur with oil and coal fuels, and is a certain indication of incomplete combustion; it should always be avoided since, besides the energy loss due to unburned fuel, presents serious environmental implications.

Smoke is measured with a special instrument (Baccarach test) which is part of the gas analyser kit.With gaseous fuels, smoking is not a problem, even with poor combustion. As a guide to acceptable operating conditiothesmoke number observed at low excess air rates should not exceed the following:

Fuel Used	Maximum Smoke Number
Coal	4
Light diesel oil	1-2
Heavy fuel oil (Mazout)	3-4
Natural gas	0

3.3.3 Combustion gas composition

The composition of the flue gases depends on the combustion conditions and the degree of excess air present, and is considered among the main factors influencing boiler efficiency. The oxygen and the carbon dioxide content are measured with gas analysers and should be kept within the ranges indicated in the following table.

Fuel	Excess Air (%)		O2 in Flue Gasses (%)	
	Min	Max	Min	Max
Natural Gas:	10	15	2.0	2.7
Fuel Oil:				
Light	12.5	20	2.3	3.5
Heavy	20	25	3.3	4.2
Coal:	30	50	4.9	7.0

CO content should be also measured and kept to a minimum. The presence of CO shows also a degree of incomplete combustion. In this sense, the presence of CO is putting a down limit to the reduction of excess air. The objective in regulating the boiler is to use the least air quantity that permits complete fuel combustion (almost zero CO content).

3.3.4 Flue gas temperature

Flue gas temperature must be held to a minimum to maximise boiler efficiency. It is estimated that 1% savings are achieved for every 25oC of temperature reduction. However, the temperature of the flue gases should not be reduced below a certain level as this might result in SOx condensation and subsequent corrosion problems. A safe temperature for fuel oil is 180oC. For natural gas the safe temperature is much lower.

The two basic causes of increased flue gas temperatures are:

- *insufficient heat transfer surface*
- *fouling of heat transfer surfaces.*

Considerable improvements in efficiency can be obtained if the water vapour in the flue gases is condensed by further cooling. Boilers which make use of the energy of the water vapour are known as condensing boilers. Problems of corrosion, however, make such boilers not suitable for coal or oil. Moreover, a condensing boiler is about twice as expensive as an equivalent conventional heating boiler.

3.4 Flue gas analysis

Monitoring of boiler efficiency means mainly the monitoring of combustion conditions. A simple visual inspection by an experienced technician may reveal some problems but safe assessment of the boiler's condition and accurate adjustment of the combustion parameters can only be done using a gas analyser.

The instrument analyses a sample of flue gasses to identify the basic combustion parameters and, consequently, the efficiency of combustion. There are two different categories of portable gas analysers:

- *the chemical gas analysers (Orsat apparatus), which cost about 400-500 ECU*
- *the electrochemical gas analysers which cost 2000-4000 ECUs or more, depending on the degree of automation and additional capabilities.*

The chemical gas analysers are suitable for small and medium size boilers, while the more expensive electrochemical analysers are mainly used for testing large scale industrial boilers or when environmental parameters e.g. NOx emissions have to be measured.

According to conservative estimations, the cost of a chemical gas analyser is paid back in less than two years. This figure refers to boilers which are already in a relatively good condition and consume fuel worth about 15000 ECU annually. In cases where the boilers are in a bad shape or the annual fuel cost is higher than 15000 ECU the pay-back period is reduced to a few months.

3.5 Other considerations

Apart from the issues discussed previously, other factors also play an important role in improving boiler efficiency. Among these are the following:

Feed water temperature: Boiler efficiency can be increased by preheating feed water in an economiser (heat exchanger using flue gases as the heat source). In general, an increase in feed water temperature of 6*C will result in 1% less fuel being burned at the boiler.

Combustion air temperature: Boiler efficiency can be increased by recovering waste heat from the flue gas and preheating the combustion air. An increase in combustion air temperature of 25*C will result in about 2% increase in efficiency.

Firing rate: The highest boiler efficiencies typically occur over the range of firing rates from 70 to 90% of rated capacity. Therefore, it is not good practice to select a large boiler at design time in order to cope with future needs because it will operate inefficiently till these needs arise.

Load variation: Fluctuating loads can have an adverse effect on boiler efficiency, especially when there are frequent periods of low load. When boilers are regularly shut down at times of no load, there can be substantial heat losses due to cold air being drawn through the boiler and due to radiation losses. There are many ways to improve this situation:

- *rationalisation of the load demand, if possible*
- *rationalisation of the boiler firing schedule*
- *improvement of the firing control system*
- *installation of a flue gas shut-off damper to eliminate the circulation of cold air in case of boiler shut down*

.

- *installation of two or more smaller boilers instead of a large one (after a careful load and cost analysis).*

In general terms, however, the selection of boilers or the interventions for efficiency improvements should be the job of qualified professionals. The additional costs involved in hiring outside contractors have proved worthwhile in most cases.

4. Solar systems application in public building

4.1 SOLAR PHOTOVOLTAIC APPLICATIONS IN PUBLIC BUILDINGS

4.1.1 State of the Art

Photovoltaics can be integrated to virtually every conceivable structure, from bus shelters to high rise office buildings or even turned into landscaping elements. Building PV power supply systems are usually in the range of several kW of nominal power and they are usually connected to an available electricity grid. Building-integrated PV systems have an economic advantage over conventional PV generator systems as the solar modules serve multiple purposes. They are part of the building envelope, ideally replacing conventional facade or roof material. Depending on the type of integration, the PV modules may also provide shading or noise protection. Therefore, once put in the building context, photovoltaics should not be viewed only from the energy production point of view. Because of the physical characteristics of the PV module itself, these components can be regarded as multifunctional building elements that provide both power and shelter.

Photovoltaic systems connected to the public grid require an inverter for the transformation of the PV-generated DC electricity to the grid AC electricity at the level of the grid voltage.

In short, photovoltaics is worth considering in the case that,

- *the building has access to solar radiation*
- *the building is or will be energy efficient by design*
- *innovative design options are preferred*

From an architectural, technical and financial point of view, PV in buildings today,

- *may replace conventional building materials*
- *can provide an improved aesthetic appearance in an innovative way*
- *does not require extra land area and can be utilized in densely populated areas*
- *does not require additional infrastructure installations*
- *can provide electricity during peak times and thus reduce the utility's peak demand requirements*

4.1.2 Problems and Barriers

National and even regional regulations for grid connection differ widely with respect to the policy of interconnection requirements and reimbursement agreements for PV-generated electricity fed into the grid. Another barrier is the fact that, presently photovoltaics is not yet economically competitive in bulk power generation.

1.3 System Economics

The cost of a PV system can be grouped into,

- *capital cost, including investment, interest rate, depreciation, replacement*

- *consumables*

- *operating cost*

- *other (insurance, taxes etc.)*

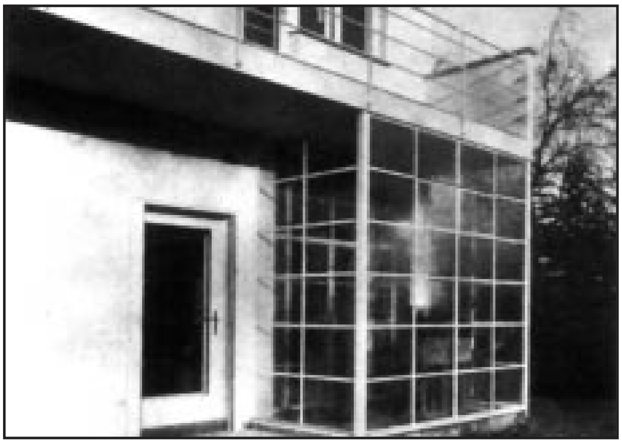
The economics of PV systems is determined by the cost and the revenues for the electricity produced. Additionally, in modern commercial buildings, facades often cost as much as a PV facade; this means short-term pay-back for the PV system.

In 1997 prices, the cost for grid-connected PV systems is in the order of 8 KECU/kWp installed. This capital investment for PV may be reduced to an average value of 40% due to the avoiding of costs for conventional building elements, such as glazing and roof elements etc. Thus, for building integration, the actual cost for PV is around 4800 KECU/kWp.

The annual energy fed to the grid by a PV system depends on the daily solar availability. In Europe, the annual electricity produced per kWp PV varies in the range 900 kWh to 1400 kWh. Assuming a good solar resource site of 1200 kWh/kWp and an average electricity PV kWh price in the order of 0.4 ECU/kWh, the revenue from the electricity sales to the utility on an annual basis per kWp PV is calculated 480 ECU. In this way, the pay back period is 10 years for building-integrated PV systems. It must be mentioned that each case may comprise certain particularities which, effectively, increase or decrease significantly the previous PBP average.

4.2 APPLICATION OF PASSIVE SOLAR SYSTEMS IN PUBLIC BUILDINGS

4.2.1 State of the Art



Bioclimatic architecture, a practice which originates from antiquity, is directed towards designing buildings that are thermally and visually comfortable to live in year-round, with the minimum energy consumption possible, taking into account the local climate, and utilizing local materials and renewable energy sources (sun, wind, geothermal energy, water, etc.). Passive solar systems, building components which operate by collecting, trapping, and storing solar energy, maximize the utilization of solar energy for space heating. Passive solar systems may be applied in new buildings, incorporated into the building bioclimatic design, or in existing buildings as retrofitting measures. The direct gain system (a window facing south, accompanied by the space mass for heat storage) is the most commonly applied solar system. Other passive systems which may be applied to various building types depending on their function and form, and can also be applied as retrofit energy saving techniques, are:

- *Solar glazed walls, incorporated to southern facades of buildings*

- *mass walls which may have vents for warm air circulation to the spaces (Trombe-Michel walls)*

- *thermosyphoning air panels (insulated glazed walls acting as solar collectors which heat the building air)*

- *Sunspaces or solar atria attached to buildings*

All passive solar applications need to be combined by measures for reducing the building heat losses (reduction of ventilation and infiltration heat losses by air tight frames, thermal insulation of the opaque building structure, night insulation of windows and of passive systems, etc.). Additionally to passive solar systems, active solar and photovoltaic systems may contribute to covering part of the building energy load.

In Greece, an average heating load of public buildings in the coldest climatic zone is around 150 kWh/m2, while the total electric consumption is approximately 22 kWh/m2. The potential of applying energy conservation measures in public buildings, varies according to the building use and size, construction and condition, and greatly according to the local climate. It has been estimated that in Greece, the heat load reduction by applying combined measures in public buildings may reach up to 30%, or even 70% (in the case of school buildings), a percentage which in the coldest climatic zone of the country amounts to an absolute reduction in the area of 40 and 80 kWh/m2 respectively. In addition to the energy saved for space heating, passive solar and energy conservation techniques applied to buildings raise the comfort levels inside both in winter and summer.

2.2 System Economics

The economic viability of passive systems and all other relative systems applied, depends on the system used, the degree of intervention, the energy consumed, etc. In the case of new buildings, the cost of applying bioclimatic design principles and passive solar systems, is very low, and often nil. Generally, a 10-15% increase in construction cost is considered reasonable. In the case of building retrofitting, the cost of installing a passive solar system is generally higher, and depends on the area of the system, materials used, and labor which may vary significantly from case to case. What should, however, be considered is that interventions, when viewed at national scale, have a lower cost and a significantly higher benefit to national economy, and therefore, may be subsidized by the state. As an example passive solar retrofit options which are viable when viewed on a national economy scale, are given for the public school buildings in Greece:

In Greece there are more than 15,000 schools with facilities for more than 1,600,000 pupils. The mean total final energy consumption for heating and lighting of schools is estimated around 270,000 MWh per year, that is equivalent to 16,300 tones of fuel oil and 78,000 MWh electricity. The cost of this energy is calculated at 2.6 billion drachmas (fule costs of 1995). The resulting annual CO2 and SO2 emissions are 150,000 and 1,000 tones per year respectively. The average energy consumption for heating is 92 kWh/m2 heated floor area, which may be reduced by 30-70 %.

The overall energy, economic and environmental assessment of the refurbishment proposals at a state level shows that applying a thermosyphoning air panel or a sunspace to south facades of existing school buildings, combined with other energy conservation measures is viable only if subsidized by the state. The study of energy refurbishment of Greek schools has demonstrated that several passive and low energy solutions, even when expensive for the end-user, are viable when viewed on a national economie scale and taking into account the associated environmental benefits.

4.3 APPLICATION OF ACTIVE SOLAR SYSTEMS IN PUBLIC BUILDINGS

4.3.1 Solar thermal systems

The use of Active Solar Systems in the domestic sector is very well established in most European Countries. Solar System users, with the help of several incentives for each E.U. country, have installed such systems to eliminate their energy use and to help reduce the pollution from fossil fuels and the global warming risk.

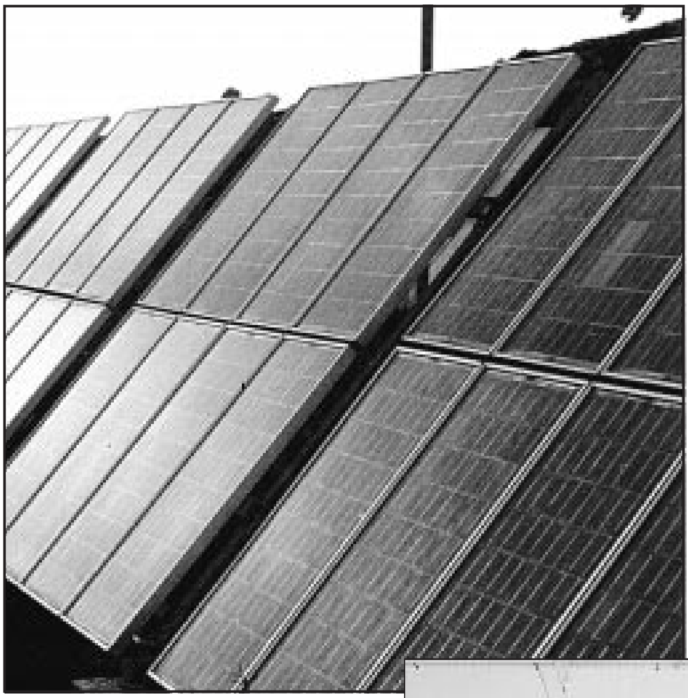
The energy bills for the production of domestic hot water, for space heating or space cooling on Public buildings can be reduced or even eliminated with the help of a thermal solar system. There are several installations of large solar systems on Public buildings producing domestic hot water, and a few others contributing thermal energy for space heating and cooling in Europe. Most of them were financed by several National or European projects. The quantity of domestic water daily (or generally the heating/cooling load), the year round demand profile and the required temperature level are the key factors that will guide the selection and the sizing of the solar system.

Public buildings can have a demonstration effect on its users and on the public who use the building.

4.3.2 Cost - Payback time period

The individual users of Active Solar Systems expect to have their cost saving investment back as soon as possible, which means, for most European countries, 5-8 years, depending on the individual weather and economic environment.

This pay-back period may not be extremely favourable for individual users, but could be assisted by Public entities, that are not supposed to decide with strict economic criteria.



The cost of the solar components (collectors, tanks) along with several other expenses that must be prepaid, are all payable before any useful heat output production occurs from the solar system. The energy savings during the life of the solar installation must pay-back these expenses. It is obvious that a solar installation can-not be handled the same way as an ordinary heat producing plant.

The heat production must be maximized continuously over several years, otherwise the economic gain from the solar system will never overcome the expense.

4.3.3 State of the art

The need for air-conditioning occurs on the same days (and even the same hours) that the maximum solar radiation occurs in most Public buildings. The use of solar thermal systems for air-conditioning, along with absorption chillers and heat pumps has been demonstrated in some building, and is a very attractive option for electrical energy consumption.

The Third Party Financing scheme used in large solar installations in some European countries has proven to reduce technological risks and maximize the economic benefits by dividing the payments into a series of thermal energy bills for the actual solar heat consumed.

3.4 Barriers

Public buildings all over the world are famous for the waste of energy their users make, for a number of reasons. Several projects are aiming to reduce energy waste in Public buildings. Before the decision for the installation of a solar system in a Public building, all measures to eliminate energy waste should already be successfully finished. It is not a good idea, and it is not helping the good reputation of solar systems, to invest a great deal of money and labour to collect, transfer, store and use the solar energy while, in the end the heat is wasted

The operation of the solar system should be monitored regularly and all maintenance measures must be taken for its thermal output not to deteriorate with time. A common problemwith un-attended solar systems occurs when a malfunction is not fixed on time, because no-one cares, or can not understand the problem, because the backup system will provide the necessary heat to the users, using ordinary energy sources.

5. Lighting optimisation

5.1 Lamps replacement and regulation

Good lighting in a building is to provide proper lighting in the right place at the right time. This enables the occupants to see easily and in comfort allowing them to perform their duties efficiently without strain and fatique. In addition, good lighting enhances the appearance of a space to provide a pleasant internal environment and can contribute to the creation of different atmospheres appropriate to different activities. Lighting should also be energy efficient. Lighting is one of the most significant energy consuming feature areas in public buildings, even though it receives scarce attention due to its weak energy concentration (8-10 W/m2). This power density, multiplied by annual operational hours, represents an important consumption of approximately 8 to 26 kWh/m2. In the service sector lighting accounts for the lion's share of electricity consumption (40%) as is indicated in the Table 1.

Table 1. Percentage of energy consumption in the public building sector

Electric Consumption	%
indoor lighting	36
cooling	26
heating	11
other uses	6
kitchen	6
ventilation	4
outdoor lighting	4
sanitary hot water	3

The objective in a lighting project is to cover the needs with regard to specifications (lighting level, uniformity and dazzle), comfort (luminance and reproduction distribution of the colour) and pleasure (light direction, colour and structure). Technical conditions must be provided (reliability, safety and permanence). In addition, operational conditions (facility of use, flexibility and adaptability) and economic conditions (budget and development).

In this guide emphasis is placed on energy efficiency in lighting, and thus the following aspects of lighting will be considered: lighting level (DIN 5035), light sources, lamps (IN 60958) and regulation.

5.1 Lighting level

The DIN 5035 standard establishes luminance according to the use to which the premises to be illuminated are dedicated. Evidently, the first saving point will be to eliminate the surplus lighting levels. The efficiency of lighting can not only be measured as W/m2, since it depends on the lighting level. This is defined as the consumption ratio (Rc in W/m2 100 lux). Nowadays, values of 2.8 and above can be reached in offices. The efficiency of the system is the product of the efficiency corresponding to the source of light (bulb), by that of the lamp.

luminance (lumen/m2 = lux)

7-12	general outdoor, rural roads
15-25	gardens, industrial zones
30-50	streets, highways
50	entrances, parking
150	panoramic outdoor, store, reception room, corridors, staircases, washrooms, general tasks
200	dining room, public premises
300	meeting rooms, offices, hotel rooms, laundry, tasks requiring some precision
500	work stations, large stores, laboratories
750	reading, manufacture, drawing, classroom, kitchen, task involving detail
1000-3000	shop windows

5.2 Light Sources

In Table 2, an indication is given on differences in luminous efficiency (lumens/W) between the different types of lamps It should also be emphasised that the duration, colour temperature (more or less warm light), chromatic reproduction index (reliability in the reproduction of colours), need for auxiliary equipment, range of power and costs influence the decision on utilizing a specific lamp. Moreover, for better efficiency, the use of natural lighting should be optimised (design of the buildings with larger windows facing south, skylights or transoms), Attention should also be devoted to keeping the windows clean and on regulating the operation or luminous flow when natural light is sufficient.

5.3 Electronic Ballasts (electronic reactances)

Fluorescent tubes are low pressure mercury discharge lamps that require auxiliary equipment: a feeder provides the high initial voltage to begin the discharge and a ballast or reactance (inductance) adapts the voltage to low values, which, once required intensity is reached, stabilises the discharge.
Ballasts represent 20 to 30% of the tube's energy consumption, energy which is transformed into heat. Fluorescent tubes of 38 mm to 26 mm of diameter, together with the use of triphosphorous fluorescent powders in its inner side provide high luminous efficiency and excellent chromatic reproduction.
The first step is to reduce losses in the ballast (reactances of decreased losses) through inductances which are from 9% to 13% more efficient.
Electronic ballasts carry out the operation of voltage limitation through an electronic circuit (transformation to high frequency, 28 to 40 kHz) reaching savings of up to 20-23%. Models exist for each power of the tube, for two tubes and special assemblies for four tubes..

Source of light	W	Duration (hours)	efficiency (lm/W)	Tcolour(°K)	CRI
standard	25-2000	1000	10-14	2700	100
halogen	25-2000	1000-2000	12-25	3100	100
fluorescent tube (LP Hg)	18-58	7500-12000	50-90	2600-7000	50-98
fluorescent compact	5-55	6000-8000	55-80	2800-5800	85
mercury vapour (Hg HP)	50-2000	12000	40-60	3500-4500	49-55
mixture	160-500	6000	19-28	3600	60-90
metallic halides	70-2500	2000-10000	75-90	3000-5500	65-95
sodium vapour (Na LP)	35-180	6000-8000	70-170	- -	- -
sodium vapour (Na HP)	35-1000	8000-12000	42-124	2300-2500	20-80
induction	23-85	10000-60000	48-65	3000	80

The operating voltage levels of the electronic ballasts are between 198 to 264 V, can be connected directly to continuous current (use as emergency lighting) and allow the luminous flow to be regulated by a dimmer, limiting current. A power factor of 0.96 can be achieved which makes capacitors unnecessary. Start-up is instant and without fluctuations, the strobe effect is eliminated from the light and defective or discharged tubes are disconnected automatically. Optionally, they can incorporate a filter, which preheats the tube at start-up, lengthening the life of the tubes to 12,000 hours.

ballast	nominal W tube	lm	Wb	Wt	lm/W
normal	18	1450	8	26	55.7
	36	3450	10	46	75.0
	58	5250	14	72	72.9
low losses	18	1450	5	23	63.0
	36	3450	6	42	82.1
	58	5250	8	66	79.5
electronic	18	1350	3	15	90
	36	3240	4	36	90
	58	5000	5.5	55.5	90

Filters must be incorporated to avoid interferences coming from the electricity grid. It is recommended that they comply with Standard IN 60929. In spite of its considerably lower cost (five-ten times) compared to that of a normal ballast, their gradual substitution is recommended (the change tends to include also the fluorescent tubes), for operations greater than 40 hours/week.

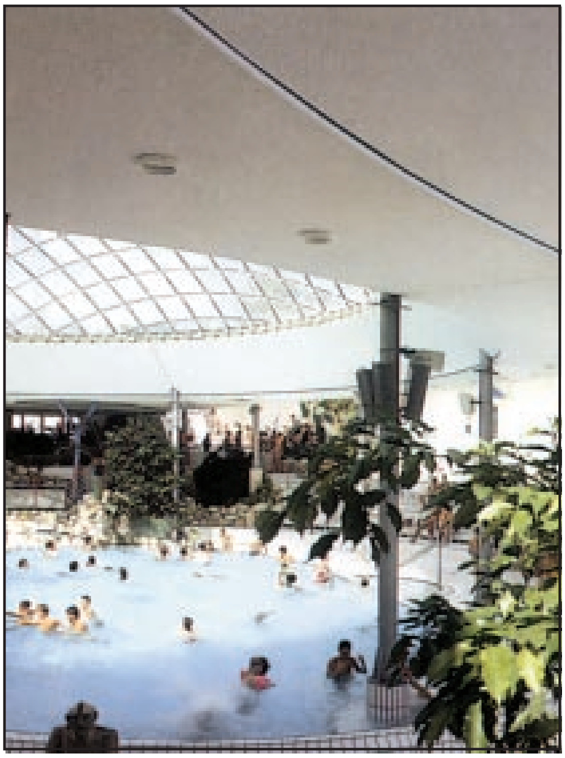
In many cases, the combination of tri-phosphorous tube, electronic ballast and lamp with an efficiency superior to 60% (bright aluminium, low dazzle index) permits the number of tubes to be reduced from 4 to 3 or even from 3 to 2. Moreover, the new 16 mm diameter fluorescent (6, 8 and 13 W), 7 mm diameter (6-8-11-13 W) and U shaped tubes (40-65 W) offer new possibilities.

5.3 Compact fluorescent (with integrated and non-integrated control gear)

Compact fluorescents are formed by several small diameter fluorescent tubes (10-15 mm) connected by a union bridge. In the base are the electrodes and the elements that control the mercury pressure. The blister (optional) is cylindrical or spherical.

Non-integrated (5-55 W) lamps are presented without ballast or feeder, with caps G to spikes. Integrated types incorporate ballast and feeder in cap Edison E14 or E27 (range of 5 to 25 W). Both types can be associated with magnetic or electronic ballasts. Models with conventional reactance, whilst being more economic, are less advisable.

Non-integrated models are recommendable in zones accessible to the public, since they deter theft and permit the use of luminaires designed for these specific lamps.
The substitution of standard incandescent lighting to compact lighting with conventional or electronic reactance permits four - five times more luminous efficiency (50-80 lm/W), a life of 6,000-8,000 hours, lower heat radiation than incandescent lamps, less dazzle, a wide colour-range (2,800-4,000-5,800°K) and improved CRI levels because of the triphosphorous fluorescent powders used. Start-up takes 0.5-2 seconds (according to ambient temperature) and initial luminous flow (40%) takes 2 minutes to reach maximum.



Up to 500,000 ignitions are possible with a cadence of 60 seconds lit and 150 seconds turned off, but their useful life is reduced if the lighting period is less than two minutes. Luminous flow diminishes to 15-30% towards the end of their useful life. They can operate at up to 5 degrees below zero and accept feed tensions of between 207 and 244 V. Some models can be connected to continuous current of 176-356 V for use as emergency lighting.
Their power factor is low (0.5) due to non-sinusoidal consumption (content in harmonic), therefore it can not be compensated with capacitors. Lamps up to 25 W are subject (until the end of 1997) of EMC electronic compatibility requirements (IEC 1,000-3-2 and IN 61,000-3-2).
In spite of being from 6 to 12 times more expensive than a standard incandescent lamp, their substitution is recommended when they operate for more than three hours per day, as long as there is not an excessive number of daily ignitions.

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5.4 Luminaires

The design of a lighting system will opt for general lighting, supplementary systems, with aesthetic criteria heavily considered in addition to energy. There are a large range of luminaires to choose from: industrial connectors, screens, industrial bells, downlights, projectors and wall candelabrum. Conversely as far as the photometric distribution increases, efficiency is reduced. Wherever possible, local rather than general lighting will be preferred. It is important to avoid direct and indirect dazzle, excessive contrasts and to maintain a good degree of cleanliness at the light source and the lamp.

5.5 Regulation and control

Permits significant savings in functions during occupation time, influence of natural lighting, etc.:

- *switches: to turn on/off many light points from a single switch is not a good practice. If it is possible, to use a localised switch for each zone is recommended (ignition of the pairs, ignition of the odd, etc.)*

- *time controllers: upon activating the switch, the connection time is fixed and limited. They are of projecting mechanism, modular or of box fund..*

- *hourly interrupters: a mechanical clock, electrical or electronical, opens or closes one or more contacts. These can be fixed or pluggable, with daily or weekly programming and analogic or digital displays. They are employed in facilities that operate on a repeated cycle base*

- *card interrupters: upon inserting a magnetic card, a microcontact is triggered and upon withdrawing, the light is turned off. Employed in hotels, sports tracks, etc.*

- *light limiting : photocells able to turn on or off lighting in function of lighting level*

- *crepuscular switches: photocell of regulated sensibility (5 to 1,000 lux). They can be pure crepuscular (only sensitive to light) or combined with clocks or to modulate with the outside photocell*

- *movement detectors : infrared or kinetic sensors detect the presence of persons, thus, turning lighting on or off. The cells, with detection angles of 60 to 180 degrees, installed in walls or roofs*

- *light regulation : cut wave conventional dimmers are available for incandescence, halogen of double wrapper (to net tension) or low voltage halogens (through transforming of safety). As opposed to the tension reducers, these dimmers are available for the regulation of from 25-100% of flow in electronic fluorescent lamps or in 18 W fluorescent tubes with electronic ballast and from 10-100% in the case of 36 and 58 W tubes, as long as the total controlled power is not over 900 W or in excess of 100 ballasts. Otherwise one must use amplifiers which interconnect groups of ballasts.*

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GUIDE

Energy efficiency in public and municipal buildings

This guide is part of an ECOS OUVERTURE project carried out by the Regional Energy Office of Eastern Macedonia and Thrace, the region of Thessalia (Greece) and the Styrian Energy Agency (Austria) together with the regions of Haskovo in Bulgaria and Oltenia in Romania. The aim of the project is to increase energy efficiency in public buildings in these regions.

This guide shows a way to increase comfort and energy efficiency.
The easy step by step procedure given in this guide, leads to an analysis of the current situation in the building and helps you to find the most promising measures to increase energy efficiency.

- *It describes measures which are cheap and easy to implement*
- *and it gives a very good data base, if you need to consult an energy expert with regard to the implementation of special,capital intensive, measures*
- *or if you have to prepare a building database - maybe for an EU-Project*

About the ECOS OUVERTURE Programme

This programme promotes mutually beneficial co-operation between the regions, cities and other locally based organisations in the European Union and their counterparts in Central and Eastern Europe, the Newly Independent States of the former Soviet Union (NIS) and the Mediterranean. It is financed by the **Directorate Generals for Regional Policy and External Affairs**, but is managed and run by the regions and cities of Europe and their representative organisations themselves. Financial support comes from the European Regional Developement Fund, the Phare Program and the regions and cities that manage the Programme. Since 1991 these programmes have successfully supported more than 250 co-operation projects involving over 1000 local and regional authorities across the European Union and Central and Eastern Europe. In general, projects can cover spheres of co–operation for which the local or regional authorities have responsibility. The four major spheres are: Local and Regional Democracy, Local Economic Developement, Urban and Regional Services and Policies, Environment and Energy.

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