Municipality program

Building Energy Efficiency Project

BEEP 1.0

ALLIANCE TO SAVE ENERGY - MUNICIPAL PROGRAM

Building energy efficiency project

BEEP 1.0

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Introduction

Whether you would like to learn how to calculate the heat losses in your buildings and the energy consumption for internal lighting, whether you would like to evaluate the technical and economical effects of various kinds of energy efficiency measures, or whether you would like to obtain the Energy Efficiency Project automatically together with the Business plan which would help achieve the project according to all projected calculations, then learn how to use the BEEP program.

The BEEP Program aims at offering a solution to the problem of energy efficiency for buildings of all natures and sizes. The model is mathematically and technically detailed and accurate. Its limits depend exclusively on the user's level of expertise and the purposes for which the program is used. It focuses on energy consumption used for heating spaces and internal lighting, as we shall detail later in this manual.

The basic purpose of this program is the development of energy efficiency projects and business plans for buildings directly under municipal authority (kindergartens, schools, healthcare centers). Achieving such activities requires a sound knowledge of technical and economical aspects of the problems. We will describe them later in the manual. To realize energy efficiency projects, a combination of own investment means and additional (external) financial means often proves necessary. Donations or credit arrangements with domestic or foreign donor/credit institutions can provide such assistance. The program offers a working environment that allows a high flexibility in producing reports:

- ***Multilanguage system***: this feature enables the user switching the whole program environment language at any time. This actually means that we can choose displaying the titles of all graphical elements of the program and all the generated reports in any of the (predefined) languages. Practically, the program limits the feature to a so-called two-language regime of work. Language number 1 is an international language (English in this version) and Language number 2 is the local language (the language of the country for the Project - Bosnian in this version). Despite all its advantages, this feature also has one disadvantage - it requires the user entering all textual information in both languages, which is a condition to generate reports in both languages.
- ***Multicurrency system***: this feature allows entering financial data and accessing project reports (prices, costs, savings) in any world currency. The program defined some of the world's main currencies (Dollar, Euro) and local regional currencies (dinar, convertible Mark…). The user can add countries and currencies when needed - it is then necessary to adjust the currency value according to its actual exchange rate. The selected currency of reference is set to be the dollar, and the value of all other currencies is defined towards the dollar.

About the manual

The BEEP program and this manual are meant for municipal teams dealing with energy efficiency. The manual refers to the basic understanding of technical, economical, and ecological models used in the BEEP program. It aims to help the user working with this program. In some cases, the manual goes beyond the level of informative material. Through practical examples, it leads the user deeper into the problematic of energy efficiency and into the economical principles that need be followed while working on a project. This includes global climate problems, caused by an enormous concentration of greenhouse effect gases into the atmosphere.

The manual itself comprises 10 chapters:

- The first three chapters describe technological, economical and ecological models, used during the development of the program.
- The fourth chapter is dedicated to the software installation.
- The other chapters explain one by one how to work with the BEEP program.

The manual includes a plethora of examples (primarily related to economic models), which will help the user understand some terms and expressions. A large number of pictures were also included (especially those describing the screen/window appearance when working with the program), which will help the user start working with the program.

Conventions:

Important remarks are stated within a grey rectangle.

Examples are given within a white rectangle.

Even though the author of the program made every effort to avoid problems arising from missing or incorrect data input (while working you will notice numbers of warnings about missing or incorrect data input), one cannot exclude the possibility of an error occurring while running the program. In such case, we ask you to contact the author who will then correct the problem.

The author

The Basic Graphical Elements of the program

This part of the user's manual will give an overview of the graphical elements used in the program. Users are familiar to all of them, or at least with most of these elements, which are part of standard Windows application

The Form (window) is the basic graphical element of all Windows applications. From the user's aspect, the form represents a rectangular window, made out of the title line and the body of the form. Picture U1 shows an empty form (a form that does not contain any other graphical element). The title frame includes:

- ***A control button*** (1): Such button has a double function. Graphically, it simply looks like the program logo or icon. As for its functions, pressing the button will open a command list allowing the basic manipulation of the form.
- ***Title form*** (2): It textually describes the purpose of the form.
- ***Full set of buttons for manipulation of the form*** (3): (minimize - minimizes the size of the form, maximize - maximizes the size of the form, close - button used to close the form).

Picture U.1 Form (window)

The command button (Pict.U.2) is a graphical element that allows performing certain program actions. We activate the commands by pressing the mouse (clicking) on the active command button. The command button can be active (the name of the button is then written in black color) or inactive (the name of the button is written in light grey color). We cannot activate a function as long as the corresponding button remains inactive. The program sets the state of the command button (active/inactive) by itself. It shows the user which of the actions are allowed in the current phase of the program.

Picture U.2 Active and inactive command button

The input field (Pict.U.3) is the graphical element that enables inputting and/or editing textual and/or numerical data. This program uses the following (not standard) convention. Data or values shown on a light yellow, green or red background cannot be modified. Data or values shown on a white background can be modified.

Picture U.3 Input field

List box (Pict.U.4) is a graphical element, which enables the user selecting one value from a list of values. This graphical element consists of the display field, and of the arrow to open the list. First, the user opens the list by pressing the arrow and selects one of the values available from the list. Once a value was selected, the list closes and the chosen value appears in the field.

Picture U.4 List box

The up/down button (Pict.U.5) is a graphical control, which is usually used together with the input field. Pressing the upper arrow of this button enlarges the contents of the related input field upwards. The other way round, pressing the lower arrow will reduce the contents of the related input field downwards.

Picture U.5 Up/Down button

Table (Pict.U.6) is a complex graphical element, which consists of the title, several input fields, and lines that allow moving the contents of the table horizontally and vertically. The convention on colors is identical to the one used for input fields. The user can, as needed, modify the width of the columns by dragging the mouse between the titles and the neighboring columns.

Picture U.6 Table

Yes/No Button (Pict.U.7) is a graphical element, which enables the user to give simple so-called 'binary' answers (yes/no, correct/incorrect, has/does not have). The status of this button changes simply by pressing the button. The empty square field of the button represents a negative answer, and a filled field is a positive answer.

Picture U.7 Yes/No button

Radio Button Group (Pict.U.8) consists of a collection of graphical elements that allows choosing one of the values of the group. The selected value is marked with a spot in the circle of the radio button. The other values cannot be selected and there are no marks in the circles of the radio buttons. A value is selected by clicking the adjacent circle. Once a value has been selected, all other values are automatically getting the statute of non-selected values.

Picture U.8 Radio button group

Chapter

1

The technical model

In this chapter, you will learn more about the basics on building technical models used in this program. For the development of this model, the Author has relied on current rules and recommendations in the field.

As already stated in the introduction, the BEEP program is primarily intended to produce projects and business plans in advanced energy efficiency of buildings. Knowledge of basic technical and economical terms is a prerequisite to such achievements. The heating system model, the thermal model of the building and the elements of the building - as well as their interaction - form the central part of this chapter.

No matter its purpose and size, most of the energy inside a building is spent on air-conditioning (heating and cooling of rooms), heating water, preparing food and lighting space.

The cooling of rooms is essentially done by using individual cooling machines, which are located inside the buildings (so-called split system), and energy spending for this purpose are difficult to estimate. Even though energy spending for the preparation of hot water and food can be quite large, any activity aimed at increasing energy efficiency is directly conditional upon the replacement of the consuming machine itself, but also upon its conditions of use (use of the most economic energy rate).

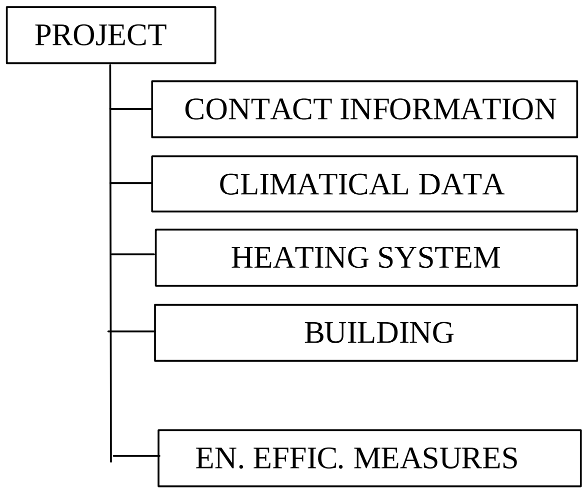
We shall therefore not address these two forms of energy spending in this document. In the case of buildings with specific use, energy consumption as such must sometimes be seen from a different prospective.

However, energy consumption in these specific cases is not subject to the size of the building, or the quality of the thermal insulation of the building, but rather by the performance (degree of usage) of the energy-consuming device. We shall therefore also ignore such cases in the model.

Considering the above - and within the BEEP program -, activities which aim at improving energy efficiency in buildings will focus on energy spending for heating and internal lighting of the building.

The Project - the basic elements of the program

All relevant information about the building analyzed with the BEEP program is grouped in a unique document called the Project. This means that the Project represents the common denominator for all the information about the heating system, the building, and energy efficiency measures etc., related to a certain building. All this information is presented as a hierarchical structure as shown on picture 1.1. Even though the contact information about the individuals who conducted this project does not belong to the technical information, they are a part of the report created by the BEEP program, and therefore included in the model.



Picture 1.1 Hierarchical structure of Project data

Climatic data

Losses in heating energy in a building significantly depend on the climate factor:

- temperature of the air and of the ground throughout the heating season,
- duration of the heating season,
- windy conditions.

Besides the heat losses, the permeability (diffusion) of the building envelope to water steam is another important factor in choosing the material for constructing a new - or renovating an already existing - building, as this can lead to the condensation of water steam in the building envelope. Sometimes, for example, the additional thermal insulation of some walls may substantially reduce the heat losses. However, it may at the same time lead to the condensation of water steam in the building envelope.

Finally, besides the thermal estimates and the estimates of water steam diffusion, it is necessary to check the heat stability of the construction (ability of the building to keep a relative presence of temperature in its inner area, while both the external temperature and the heat of the building vary).

Data relevant to the building project and its heating system are defined for each populated area. Relevant climatic information for the evaluation of thermal power and energy losses include:

- **Projected temperature of external air.** This value (the difference between the temperature of the internal space and air) is used to evaluate the *heating power losses* through the building. This is not the lowest temperature ever registered in the area, but the one which is calculated on the lowest temperatures for the last few (usually 10) years.
- **Projected temperature of the ground**. This value is used for the calculation of *heating power losses* through those elements that are in direct contact with the ground (the floor of a building, the internal walls). Although while projecting we make a difference between the projected surface temperature of the ground (that comes in contact with the internal walls) and the projected temperature of the ground under the building (that comes in contact with the floor of the building), the BEEP dos not differentiate these data and one single value is used for both purposes.
- **Average temperature of the external air during the heating season**. This value is used for the evaluation of the *heating energy losses* throughout the building parts that are in contact with external air.
- **Average temperature of the ground during the heating season**. This value is used for the evaluation of the *heating energy losses* throughout the building parts that are in contact with the ground. As for the projected temperature of the ground, we consider a single average value for those parts that are in contact with buried walls, and the temperature of the ground in contact with the building foundations.
- **Number of days of the heating season**. We use this information in combination with the preceding average temperatures in the evaluation of the *heating energy losses* in buildings. While projecting a building and a heating system, we use the so-called number of degree-days rather than the average temperature of air and the duration of the heating season. This value is an estimate relying on the assumption of an internal temperature of usually 19 or 20° C. The temperature is then analyzed hour by hour during the heating season. We obtain the value of the degree-day by adding the difference between the temperatures of the internal space and the hour-by-hour temperatures of the air during the heating season. The BEEP program uses a more complex model that does not allow the use of the degree-day. This means that the BEEP program, besides the losses through building parts that are in contact with the air, also considers energy losses through parts of the

building envelope that are in contact with the ground. The BEEP program also takes into account the periods of time in which the building is not being used (weekends, holidays, vacations), and those when the temperature of the building - and the related energy spending - is much lower than usual (minimal spending needed for sustaining the heating system in normal state).

In order to check the possibility for water steam to condense in the building envelope (so-called calculation of water steam diffusion) we need to gather information about the following climatic measures:

- The measured number of humid days. We use this information to evaluate the infiltration of humidity into building throughout the winter season (the wet season).
- The measured number of dry days. We use this data to evaluate the drying out of the building during the summer period (the drying season).
- The measured external temperature throughout the wet season. We use this value (as the difference between the desired temperature of the internal space and that of the external air) to evaluate moisture infiltration through the building during the wet season.
- The measured temperature of the ground throughout the drying period. We use this value to evaluate the drying out of the building during the drying season.
- The measured relative moisture of external air throughout the wet season. Throughout the wet season, the relative moisture of external air is greater than the relative moisture of the air in the internal space. Due to this difference, moisture infiltrates the walls of the building.
- The measured relative moisture of external air throughout the dry season. Throughout the dry season, the relative moisture of external air is lower than the relative moisture of the building. This difference leads to the drying out of the building.

According to all national standards for projecting buildings and heating systems, categories have been set for all kinds of buildings, and each of them has criteria that need to be met in order for the project to be accepted. It is of course always possible to insist on such standards when constructing a new building. The problem of energy efficiency for existing buildings should be considered exclusively in the light of its economical justification.

As an illustration, we shall briefly describe the current standards applicable on the territory of Serbia and Montenegro. These standards are, to the Author's best knowledge, still applicable in former Yugoslavian republics and are very similar to those used in other countries in the region.

Standards were prepared for every major location in Serbia and Montenegro, which include information about the project, the average temperatures of the air and of the ground, as well as the duration of the heating season. In addition, for each populated area, a categorization has been done on the winds conditions of the area (normal, windy or very windy area).

For the evaluation of the diffusion of water steam, the territory of Serbia and Montenegro has been divided into three climatic zones. These are shown on the map of climatic zones.

The standards define nine types of building elements. They were further split into sub types so that the BEEP program identifies 12 groups of building elements:

- External wall (not ventilated): external wall without air circulation
- External wall (ventilated): external wall with air circulation
- External wall: external wall built into the ground
- Internal wall
- Horizontal element on the ground: the basement of the building
- Horizontal element over the basement
- Horizontal element over an open space
- Horizontal element under unheated attic
- Mezzanine element: the plate which separated two heated floors
- Plane roof
- Sloping roof over a heated room
- Sloping roof over a unheated room

The following parameters were defined for each of these kinds of buildings: the highest allowed heating installation, comments on the possible need to evaluate the diffusion of water stream, heat stability of the building. It is essential for the user to properly identify the category the building belongs to.

Heating system

Systems intended to the heating of rooms are those that are the most energy spending within a building. Therefore, the largest room is included in this system for the evaluation of energy efficiency measures.

The heating system is generally made out of the following elements (Pict. 1.2):

- Primary source of energy (coal, fuel, natural gas, electricity, etc.)
- Converter - a device for the conversion of primary energy into heat energy (boiler, oven),
- Regulatory system (regulation of the heating system)

- Buildings heated from the converter through an external system for the transportation of heating energy (usually external heat pipes).

As shown on the picture, the BEEP program allows defining one heating system inside one project, but the number of buildings heated by that system is not limited. That means that the user could very easily create a variant in which, for example, one central boiler would heat several buildings in its neighborhood. Those buildings are usually interconnected by heat pipes partly passing through the ambient (air or ground).

The BEEP program model takes into account all losses of heating energy, starting with the level of use of the converter, the efficiency of the regulation system, the heat losses in **heat pipes** (external to the building) and **heating pipes** (inside the building), through to the losses within the building itself.

Picture 1.2 Principled overlay for system of space heating

This actually means that the whole heating system efficiency is - besides the energetic parameter, converter and the regulation system - also defined by the thermal characteristics of the building and by the energy transport system. Of course, the outlines shown on picture 1.2 illustrate the usual conditions of space heating. In certain specific practical cases, one can find all of the elements shown on the diagram (example 1), but sometimes the project might not include one of the elements (example 2).

Example 1: Some school is comprised of 3 buildings (the school itself, the sports hall and a dining room with kitchen). A common kettle (coal driven) heats the whole block of buildings. The regulation of the heating system is manual. The transport of heating energy from the kettle to the buildings passes through external heat pipes buried into the ground. In this case, we have all the elements shown on diagram 2.1. The energetic source is coal, the converter is a kettle on solid fuel, and the regulation is manual. There are heat and heating (external and internal) pipes.

Example 2: The municipal building is heated with by thermo-regulated ovens that are located in the rooms. In this example, there are neither heat pipes nor heating pipes. The energy source is electricity, the converter is a thermo-regulated oven, and the regulation is automatic (maintains the adjusted temperature).

The program uses the abbreviation (m.u.) for the measurement unit of the energy source. Depending on the nature of the energy, the measurement unit can be mass related (kilogram, ton), volumetric units (cubic meter, liter) or one of the energy units (kilowatt-hour, gigajoul). The user should choose the usual unit (the one applicable for the acquisition of such energy on the market).

Parameters for the source of energy:

The BEEP program model describes a source of energy with the following parameters:

- *Definition of the measurement unit*: the user can choose the measure to be used for the description of a source of energy (mass, volume or energy) and which measurement unit will be used to describe the quantity of the source of energy,
- *The heating power or the energetic value of the source of energy:* (k/Wh/j.m) is a parameter which shows the amount of energy that can be obtained by the complete combustion of a measurement unit for a certain source of energy (this parameter does not include the efficiency of the converter),
- *Energy price*: The user can decide in advance on the payment method for the energy he/she will use. The model includes three options. Energy can be paid according to the used quantity by square or cubic meter of the heating space. The last two options allow the include those cases where the actual energy consumption and the monthly energy bill are not directly proportional (that is the case in remote control heating in some countries in southeast Europe).
- *Emission of green house gases*: The user can define the quantity of green house gases that result from the combustion of one measurement unit. Chapter 3 addresses this topic more in details.
- *Emission of other damaging substances:*: besides the green house gases, energy combustion produces other damaging substances that induce local negative effects. Chapter 3 also addresses this topic more in details.

Converter parameters

The BEEP program describes converters (stoves, boilers) with the following parameters:

- *Life length* is the parameter that defines the life duration of the converter. This is essential to the evaluation of the investments needed for the installing a new converter (described in Chapter 2).
- *The annual maintenance costs* are included as a parameter in the evaluation of the yearly costs of the heating system. These costs include the common repair costs (spare parts and maintenance).

- *Potential energy sources*: the user needs to define for each converter all the potential energy sources, and the degree of the side effects (efficiency) of the converter.
- *The price for installation of a new converter*: whenever the measures for energy efficiency include the replacement of the converter, it is then necessary to obtain information about the required investment for such replacement. Alike for the costs related to the supply of energy, the user has three options for stating the costs for a converter: according to the consumed an installed power (installed kilowatt kW); according to the surface of the heated space; or according to the volume of the heated space. It is also possible to express the costs for the replacement of converters by using a so-called fixed and variable part (where the investments are I_{kon} expressed in monetary units, coefficient *a* represents the fixed costs in monetary units, coefficient *b* the variable costs in monetary units by installed kilowatt, and *P* the installed power of the converter):

$$I_{kon} = a + bP$$

The parameters of the regulation system

The regulation system is described by its degree of efficiency. The program adopts the usual classification. The heating system can be considered with or without the classification into zones. The regulation itself can be automatic, manual with static control, or be the usual manual regulation. By combining these divisions we define six kinds of regulations and each kind has a matching related degree of user's effect.

Example 3: We need 100.000 kWh heating energy to heat some building during the heating season. Determine the quantity of energy (coal) needed for one heating season knowing that the energetic value of coal is 3.000 kWh/t and that the efficiency of the converter amounts to 60%.

$$\frac{100.000\,kWh}{3.000\,kWh/t} \cdot \frac{1}{60/100} = 55{,}56\,t$$

The buildings

The shell of a building consists of a collection of all the elements that differentiate the structure from the ambient (air and the ground on which the building is built). In general, those are the external walls (facade) with built-in doors and windows, the roof of the structure and the basement of the building, which is in contact with the ground.

While projecting - and during later interventions (reconstruction) -, the thermal characteristics of the building must be taken into account. One must take into account the optimal relation between the surface of the walls and the glassy surfaces, especially in the projecting phase of the building. The glassy surfaces offer a much weaker heat resistance in relation to the walls, so from the energy aspect they represent the weakest elements of every facade. Moreover, the carpentry works - essentially through their junction points - are places through which cold air pours into the room during the heating season, leading to additional spending of energy.

Heat losses in a building can be divided into

- transmission (conduction losses)
- infiltration (losses as a result of the penetration of through openings)

Transmission losses: Heat transfer through an element of a structure (floor, ceiling, wall, sloping roof, glassy part of a window or door) is made of a combination of transfers of heat. From the inner air (the air in a room) to the outer side of the element of a structure, the heat is transferred through the mass of an element and the transfer of heat from the outer side into the ambient (air and earth). For the elements of the structure with a thickness much smaller than the dimensions of the surface (which is usually the case), the transfer of heat is practically done in one direction - which is normally towards the surface of the element. In stable conditions:

$$Q = k_{ek}(t_u - t_a)S$$

where:

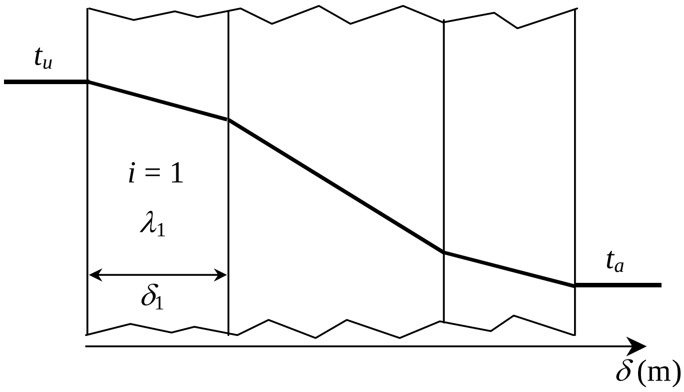
Q (W)	- heat conduction,
k_{ek} (W/m^2°C)	- heat transmission ratio (heat transmission),
t_u, t_a (°C)	- respective temperatures of the inner room and the ambient,
S (m^2)	- surface of the elements.

For elements with more layers - which is about always the case with walls, floors, ceilings and sloping roofs - the total (equivalent) heat conduction is given by the equivalent of the conduction of each layer. The user should therefore input the structure of an element as precisely - count all the layers - and as accurately as possible (from the project if possible) and input the thickness of each layer.

Therefore, as a measure of energy efficiency, it is foreseen to install an insulation layer on the horizontal and vertical parts of a building. This way, the equivalent of conducting heat through a building is reduced, which in turn reduces the heat transfer and the amount of energy needed for heating spaces. During these activities, the thermo isolation layer must obviously be checked to determine whether it results in the condensation of water steam in part of the building envelope.

In terms of evaluation of the equivalent thermal conduction of a building, the order in which layers are defined and their composition are irrelevant. However, that order is essential for the correct calculation of the diffusion of water steam. That is why the user should respect the conventions and place the layers of an element starting with the first layer on the inner side (in the case of separating walls and works between floors, both separating sides are in direct contact with the inner space – the diffusion of water steam is not calculated for such elements)

The transfer of heat through and element with multiple layers is illustrated in Picture 1.3. The temperatures of the inner and outer surface of the element are represented respectively by t_u and t_a



Pic.1.3 Field of temperature for elements with multiple layers

Infiltration losses: These losses result from an influx of cold air, through openings on the building structure into the rooms. In order to meet health rules, it is necessary to ensure some influx of cool air. An excessive influx of cool air needlessly increases energy spending for heating and it should be lowered. Apart from the projected intentional openings - ventilation - located in specific parts of a building (example: the doors), external air infiltrates through carpentry jointing (windows and external doors) of a building. This is particularly important in the case of buildings with old carpentry, where such losses can exceed 10% of the total heating energy needed.

- The calculation of infiltration losses is done for each room according to its own specifications; losses are calculated based using following measures
- wind conditions;
- position and location (the exposure) of the building (single or multiple buildings, exposed or unexposed area);
- location (part of the world) and structure (type and quality of carpentry jointing), windows and external doors in a room;

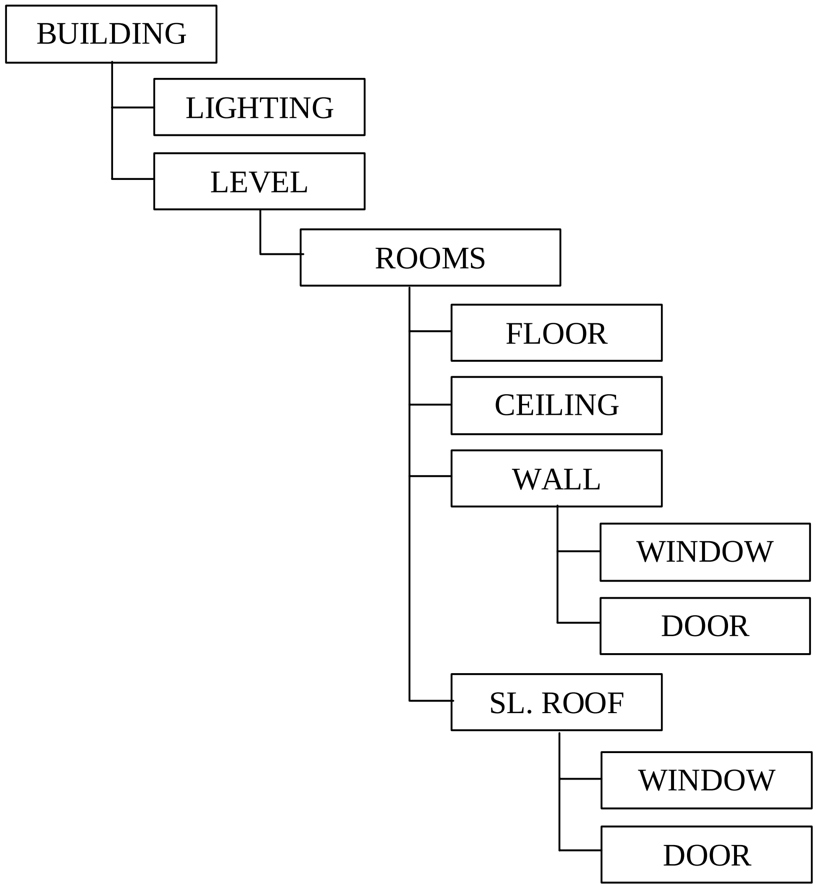
- Length of openings through which cold air can flow into the room (size of windows and external doors), and the length of openings through which the air flows out of the room (inner door).

The BEEP program the definition of multiple buildings that use a common heating system. They can be linked with the heating system through external hot water pipes.

Heat energy losses along heat pipes are calculated on the ground of basic information about their composition and thickness (the material the pipes themselves are made off and their surrounding thermal isolation). Due to the similar definition of building structure groups, and even if the physical elements are different, the heat pipes are shown as a group of structures in the program. The complete information on an external hot water pipe, which links a converter to a building, include following information:

- *Data on material and their thickness* (for example a pipe)
- *Length of the pipe* in meters
- *Internal diameter of the pipe* in millimeters
- *Ambient the pipe goes through* (options: air *or* ground)
- *Temperature of the active fluid* (hot water or water steam) used to calculate the difference between the temperature of the fluid and the ambient, which will in turn be used to calculate the heat loss itself.

Information about a building is hierarchically organized as shown on Pict. 1.4. Each of the elements will be described in details later on.



Picture 1.4 Model of buildings in the BEEP program

Lighting

As far as the lighting of rooms is concerned, we need to first clarify two terms often misinterpreted or used in the wrong context. The whole concept of lighting is comprised of **the light** and **the luminous source.** The light represents a component that physically connects some element of an object (ceiling, wall) to the luminous source. Inside the light, we place a luminous source. A luminous source is a device that produces light (popular name - bulb). The basic characteristics of a luminous source, which are relevant for this model, are the type of socket of the source, life length (usually stated in working hours), electrical power in Watts and the light flux in lumens. Replacing the lighting system can include:

- replacement of the light and of the luminous source,
- replacement of the luminous source only.

In the first case the investments are much higher, but in that case the new luminous sources do not need to have the same type of socket as the existing one (a typical example of replacement of the lighting system change is the replacement of existing bulbs with fluorescent tubes. In such case it is necessary to change the lights as well).

In cases of replacement of the luminous sources only (bulbs), one needs to make sure that the sockets of the new bulbs are of the same type as the existing ones (a typical example of this would be the replacement of a bulb with a compatible fluorescent bulbs (CFL). Such change is simply done by “unscrewing” the existing and “screwing” in the new bulbs).

In both cases it is necessary to make sure that the combination of the source and the additional light fluxes - of both the existing and the new sources - are nearly the same, so the quality of lighting would not be affected. In economical terms, such replacement is justified only when new luminous sources with less electrical power (less electrical energy spending for the same light flux).

In order to evaluate the spending of electrical energy for the lighting a building in advance, the following model has been created:

- The year is divided into two period, and the user defines the duration of each period in days:
  - Period 1 is the period of intensive use of internal lighting (winter period).
  - Period 2 is the period of less intensive use of internal lighting (summer period).
- In order to consider the difference in price for electrical energy during the day, each period includes two intervals. The user defines the energy price for each interval. These prices should match the day rates for electrical energy. In the case of difference of prices for electrical energy during the winter and the summer period (either as a result of seasonal tariffs, or as a result of intensive usage of electrical energy during a season with a tariffing system by zones -

more about the tariffing system will follow in Chapter 5), the user should then input 4 prices - the energy price for each of both periods for both intervals.

- The inner lighting bulbs of a building are classified into **bulb groups.** One group is comprised of bulbs with identical characteristics (power, flux, life length) and with identical use in both intervals and both periods (usage for an average number of days by intervals and periods).
- Users whose bill for electrical energy include the component "electrical power", will point out that - for each period - a price has been set for a kilowatt. For each group of bulbs, the input should include information and group related factors according to the maximum power of the whole building (the same-time factor will be explained in detail in Chapter 5).
- While calculating the costs of internal lighting and besides the consumption of electrical energy (and possibly the power demand), the costs for maintenance of the existing lighting system are also included. Depending on the life length of a bulb - which is shown in working hours and intensity of its use throughout the year -, its real life length is determined and so are the number of times the bulb needs to be replaced during a year. The maintenance costs for the new lighting system are reflected in the investment costs.

Example 4: A group of bulbs is comprised of 10 bulbs with a power of 100W and a life length of 1000 working hours. Period 1 lasts for 150 days. Period 2 has the same duration of 150 days (the building is not used for 60 days). During Period 1, this group of bulbs is used on average 5 hours and 2 hours during the first and second day interval, respectively. During Period 2, the group is used on average 3 hours during the first day interval and 0 hours during the second day interval. The energy price during the first day interval is 3.83 monetary units per kilowatt/hour (MU/kWh) and 0.96 MU/kWh during the second day interval. Energy prices are identical for both Periods. Calculate the annual energy costs for the group of bulbs and their life length in years.

Total power for the group of bulbs: $10 \cdot 100W = 1000W = 1kW$

Energy consumption:

Period 1, Day interval 1	$150 days \cdot 5h / day \cdot 1kW = 750kWh$
Period 1, Day interval 2:	$150 days \cdot 2h / day \cdot 1kW = 300kWh$
Period 2, Day interval 1:	$150 days \cdot 3h / day \cdot 1kW = 450kWh$
Period 2, Day interval 2:	$150 days \cdot 0h / day \cdot 1kW = 0kWh$
Yearly energy consumption:	$750 + 300 + 450 + 0 = 1500kWh$

Costs :

Period 1, Day interval 1:	$750kWh \cdot 3{,}83MU / kWh = 2872{,}5MU$
Period 1, Day interval 2:	$300kWh \cdot 0{,}96MU / kWh = 288{,}0MU$
Period 2, Day interval 1:	$450kWh \cdot 3{,}83MU / kWh = 1723{,}5MU$
Period 2, Day interval 2:	$0kWh \cdot 0{,}96MU / kWh = 0{,}0MU$
Yearly energy consumption:	$2872{,}5 + 288{,}0 + 1723{,}5 + 0{,}0 = 4884{,}0MU$

Life length: $1000 / (150 \cdot (5 + 2) + 150(3 + 0)) = 1000 / 1500 = 0{,}67 years$

In order to define the price for electrical energy for internal lighting, the user should use the so-called model of incremental costs. This means that - in case the user pays a price for electrical energy based on the quantity of consumed energy (zonal model) - the price for the highest block (zone) must be input, reached for a single period. Such approach is correct, as it will reflect an economical reduction precisely in the highest block - in case of a reduction in the consumption of electrical energy for internal lighting -.

Level / floor

Useful space in a building can be arranged on one or more levels (floors). This new element, the so-called *container element*, has been introduced in order to show information not only on the total energy spending, but also on the spending for each of the levels during the process of developing energy efficiency measures a building. This element cannot be described mathematical as such, but is used to combine elements of the lower hierarchical level (rooms of the same floor). The only measure the user needs to input is the height according to the level definition. This value is later used as an initial one, while imputing the data concerning the height of rooms.

Rooms

Each level/floor of a building is comprised of one or more rooms. As far as energy consumption for heating rooms is concerned, and besides the height of a room (the height of the highest spot in the room), valuable information includes:

- The desired/projected temperature during the heating season in case a room is heated;
- The number of heating devices (radiators) in case a room is heated.

This means that one can group all the rooms that have the same heating and cooling characteristics into a common space. For example, if a business building is comprised of offices that all have heating devices (desired temperature during the heating season 20° C) and cooling devices (desired temperature of 25° C during the cooling season), all these offices can then be grouped into a common office space. The other rooms can be grouped the similar way.

The possibilities to request different desired/projected temperatures in some rooms of a building - the possibility for one of the rooms to be unheated (for example common basement rooms of buildings, the space below the sloping roof) - increases the reality of a model, while at the same somewhat complicating the calculation. To calculate the flow of energy through the individual elements of a building, it is necessary to know the temperatures for both sides of the element. The temperature in the rooms that are not heated is not known in advance. It is related to the temperatures of the surrounding rooms in which the temperatures are known and the temperature of the ambient (air, ground).

A model was developed within the BEEP program, which - through the resolution of the system of linear equations - calculates the temperatures of unheated rooms, and offers calculations further approaching reality.

Every room is separated from other rooms and from the surrounding ambient by its segments: the floors, ceilings, walls and sloping roofs. A description of the elements of a room will follow.

In order to facilitate the work, and prior to inputting data on floors, ceilings, walls, segments of sloping roofs, the user defines all horizontal and vertical compartments which form the building in the framework of the project. This will allow to check the thermal conduction and to calculate the diffusion of water steam and the heat stability of the elements prior to using those to create the parts of the building.

***Example 5*:** A building structure (external wall) is made of layers as shown on the table. The layers are sorted from the inside to the outside. The first column lists the components, the second one lists the thickness of the layer (in centimeters in the table, it should be translated into meters for the calculation), and the third one lists the heat conduction of the component (λ). If the coefficient of heat transfer for inner (α_u) and outer (α_s) air amount to 8W/m^{2}K and 23W/m^{2}K, calculate the equivalent heat conduction of the construction and calculate the heat power losses. The dimensions of the structure (wall) are 10mx3m, the projected temperature of external air is –15°C and the temperature of the internal space is 20°C.

Component	d (cm)	λ (W/mK)
Plaster morter 1600	2,5	0,810
Bricks	38,0	0,760
Cement-plaster mortar 1900	2,5	0,990

The equivalent heat resistance of the group of components is calculated as already explained:

$$k = \frac{1}{\frac{1}{\alpha_u} + \sum_{i=1}^{n} \frac{d_i}{\lambda_i} + \frac{1}{\alpha_s}}$$

Based on the information from the table we get:

$$k = \frac{1}{\frac{1}{8} + \left(\frac{0,025}{0,810} + \frac{0,380}{0,760} + \frac{0,025}{0,990} \right) + \frac{1}{23}} = 1,38 \frac{W}{m^2 K}$$

For the surface of the structure 10x3 = 30m^2 and the difference in temperature between internal and external spaces 20-(-15) = 35ºC, power losses amount to:

$$P = k \cdot S \cdot \Delta T = 1,38 \cdot 30 \cdot 35 = 1449W = 1,449kW$$

Floors

The floor segment forms a horizontal border between the considered space and the ambient or the space underneath. The floor segment is defined by its surface, the description of the structure (used to define the equivalent heat conduction) and the description of what lies under the floor area. The model anticipates that the floor segment will include:

- space on the underneath floor,
- so called unknown space (use this option when the space underneath the floor is heated but does not belong to the analyzed parts of the building),
- ambient (air or ground).

Ceilings

The ceiling segment forms a horizontal border between the considered space and the ambient or the space above. The ceiling segment is defined by its surface, the description of the structure (used to define the equivalent heat conduction) and the description of what lies above the floor area. The model anticipates that the ceiling segment will include:

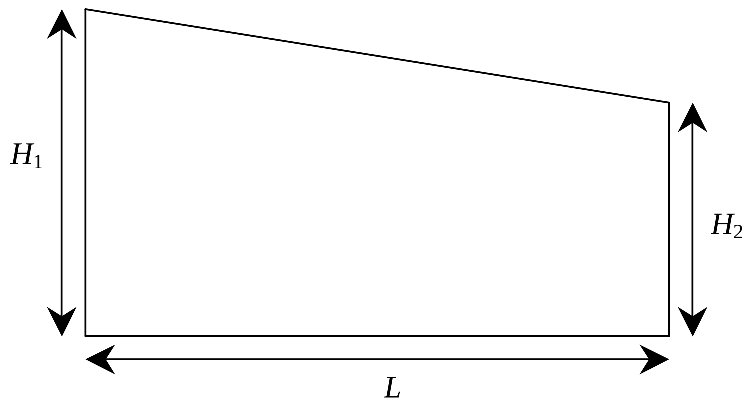
- space on the upper floor,
- so called unknown space (use this option when the space underneath the ceiling is heated but does not belong to the analyzed parts of the building),
- ambient (air or ground).

Walls

The wall segment forms a vertical border between the considered space and the ambient or the adjacent space. The wall segment is defined by its length (*L*), its starting and ending height (H_1, H_2) (used for the calculation of the surface of the segment), the description of the structure (used to define the equivalent heat conduction) and the description of what is adjacent to the wall surface (Pict. 1.5.). The model anticipates that the following elements will be adjacent to the wall segment:

- rooms on the same level, adjacent to the considered space,
- so called unknown space (use this option when the space underneath the ceiling is heated but does not belong to the analyzed parts of the building),
- ambient (air or ground). In case of an external wall, it is necessary to define its orientation. Information about the orientation of a wall is used to calculate the infiltration losses of a room.

Contrarily to the floor and ceiling segments - for which the surface is directly given in m^2 - the surface of a wall is defined by three parameters: *L*, H_1, H_2. The surface of the wall is calculated based on these data (the surface of windows and doors of the wall segment is deducted from the gross surface of the wall). In some cases, this option allows to fictively divide one segment into 2 sub segments and make the heat losses model more precise - for example when part of a wall is buried into the ground and another part is in contact with the air. This also allows the modeling of wall segments in contact with a sloping roof.



Picture 1.5 Graphical presentation of the wall segment

Sloping roof

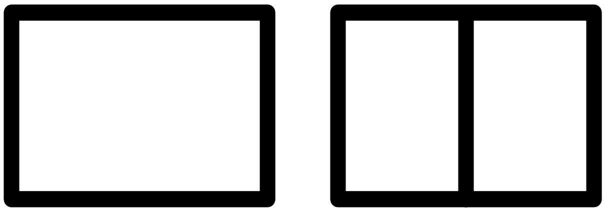
The sloping roof segment forms a border between the considered space and the air. Just like the wall segment, the sloping roof segment is defined by its length (*L*), its starting and ending height (H_1, H_2) (used for the calculation of the surface of the segment), the description of the structure (used to define the equivalent heat conduction) and the orientation of the sloping roof segment.

The model anticipates that carpentry works (windows and doors) can fit onto on wall and sloping roof segments.

Carpentry works (windows and doors)

Within the BEEP program model, windows and doors are elements of the building that can be built in individual segments like wall and sloping roof. Windows and doors are defined by:

- their dimensions (width and height),
- the kind of window or door (frame material, the way it was fitted with glass), for the evaluation of the heat conduction of the window/door,
- the number of carpentry jointing (defined by the number of width (Nwid) and the number of height (Nhei) which participate in forming the carpentry jointing as showed on picture 1.6),
- volume of carpentry jointing (defined by the values of width (Nsir) and height (Nvis) which are part of carpentry jointing, as shown on Pict. 1.6.)
- insulating quality of carpentry jointing
- existence of roller shutter boxes above doors/windows and the quality of insulation of that surface.



One-sash window

$N_{sir} = 2$
$N_{vis} = 2$

Two-sash window

$N_{sir} = 2$
$N_{vis} = 3$

Picture 1.6 Various widths (Nsir) and heights (Nvis)

One can conclude that the BEEP program model allows the analysis of two components of heat losses for windows and doors:

- transmission losses through the surface of windows/doors itself, and the transmission losses through the roller shutter boxes
- infiltration losses through carpentry jointing and infiltration losses through the roller shutter boxes jointing.

Energy Efficiency Measures

Once the project has been defined (the heating system and a building with internal lighting) we can simulate a whole set of energy efficiency measures. According to the model used in the BEEP program, the energy efficiency measures are grouped into so-called **groups** or **packages** of measures. A number of packages can be created for each project, and each package can contain a number of individual energy efficiency measures. A package defines basic economic input:

- the economic life length of a project,
- the real interest rate,
- projected inflation.

Likewise, the user can choose whether the package should include savings on reducing green house gas emission, and can define prices for an equivalent carbon dioxide ton.

You will find detailed information on the economic side of the model in Chapter 2. Ecological considerations (including the emission of green house gases) fall under Chapter 3.

Finally, investment costs not directly linked to the acquisition and installation of energy efficient products can be defined for each package:

- costs for projecting and planning,
- production costs,
- costs for the production of documentation,

- project management costs,
- costs for control and delivery after completion of the project,
- training costs, taxes, etc.

Once these common data have been defined at level of energy efficiency package, individual measures will be considered. The BEEP program allows simulating the following measures for energy efficiency:

- change of energy source,
- change of regulatory system,
- additional thermal insulation of external heat pipes,
- additional insulating layer to a horizontal element (floor, sloping roof),
- additional insulating layer to a vertical element (wall),
- additional insulating layer to a sloping roof,
- replacement of carpentry (windows, doors),
- repairs to insulation of carpentry jointing,
- repairs to insulation of roller shutter boxes,
- change of internal lighting.

The user inputs the relevant technical and economical information for each of these measures (required investment, life length, etc.) and gets answer on the worthiness of the measure. An "**assistant**" is available during the process of defining these measures. It will provide advice on choosing elements - converter, energy source, insulating material or bulbs - which best meet the criteria defined by the user (maximum coefficient net current value (NPVQ), maximum coefficient net return on capital), or the shortest period of return on invested capital (MBP)).

Before the intermediary project achievement phase, it is essential to perform a so-called **sensitivity analysis**. The basic economical parameters vary during this analysis, and their impact on savings and profitability of the project can be assessed.

Finally, for each package of energy efficiency measures, it is possible to generate reports that can greatly facilitate carry out the project:

- energy efficiency project,
- business plan
- thermal evaluation of a building (before and after carrying out energy efficiency measures).

Chapter

2

The Economic model

Energy efficiency is defined as a set of measures by which energy spending (heating spaces, lighting, and hot-water preparation) can be reduced to satisfy some needs without reducing the comfort and quality of life. The basic motivation for using these measures is the possibility of cutting costs. Therefore the economical part of the model is extremely important for understanding this program completely.

While carrying out a project - and besides the technical effects - one should also carefully consider its economical effects,. It is essential to assess correctly the investments required for project achievement, the benefit of using the new technologies, the return on invested capital (duration, conditions), etc. The economical evaluation is particularly relevant in cases where part of the means for the project comes from donors or loans. In such cases, the economical calculations need to persuade the donor/credit institution that their investment will be profitable and that the invested means will be returned through savings.

All along this chapter, we shall introduce definitions of basic economical terms that are used in the program. The user does not need to be accustomed to the mathematical interpretation of these values to succeed in his work. However, the Author considered useful to educate and familiarize the user with such concepts.

Technical and economical life length of the Project

The life length of a project is a very important parameter in evaluating the economical effect of energy efficiency measures. The technical lasting of measures/projects depends on the physical life length of equipment or material. The economical lasting of the projected means the period of time during which the project will generate profit according to the defined plan. In some cases, the economical life length of a project can be significantly shorter than the actual life length of a project.

In our analysis, we consider the economical life length of a project.

The most often quoted example of the difference between the technical and economical life lengths of a project (even though not in direct connection with energy efficiency) is the computer industry. Although the life length of a computer can exceed 10 years, it needs to be replaced with a new one every two-three years, due to extremely fast development in this area. It is essential to define the life length of a project, particularly in cases where the project is made up of measures that have different life lengths (the life length of a measure). In such case, it is necessary to calculate the repetition of each of the measures (the so-called cycle of measures) during the life length of a project (more about it follows).

Actualization of money in time

The effects of energy efficiency measures are considered at a longer time horizon. In addition, initial investments are linked - as a rule - to certain loan arrangements. To reach a correct valorization of these effects, it is therefore essential to possess information on indicators of the interest rates policy.

The actualization of money in time can be done in two ways. Sometimes we wish to know how much the money we have now is going to be worth in the future, for example at the end of a life length of a project (reducing the end of an interval). We often need to know how much a certain amount of money will be worth in the future (on realization of yearly savings for example), when referred to the present moment (reducing to the beginning interval). The calculation of the future financial influx - which would for example relate a project to the present moment (a year of investment) - is called actualization.

In order to actualize money, we need to know the value of the interest rate. Two interesting measures for such analysis consist of:

- **The nominal interest rate** (n_r) means the percentage for the calculation of the dynamic value of money in time. In cases where the project is not risky, the nominal interest rate is equal to the interest rate of commercial banks.
- **The actual interest rate** (r) is calculated based on the nominal interest rate, corrected with the amount of the projected inflation. **Inflation** (b) means the average annual increase in consumption prices. The actual interest rate is thus the nominal interest rate corrected with the amount of projected inflation, and is calculated as follows:

$$r = \frac{n_r - b}{1 + b}$$

Even if interest rates are practically expressed as a percentage, they will be expressed in relative units because of the simplicity of formulas. The proportionate value can easily be calculated by multiplying the relative unit by 100.

The banking sector privileges the use of nominal interest rate. In terms of economy efficiency of a project, it is however advisable to use the real interest rate.

Therefore the price increase, considered through the projected inflation level (at least in theory) will be projected on the energy price also (a savings component) and onto the material and service prices (investment components).

Money adjustment is done according to actual interest rate

In general, the adjustment of current monetary value V_o to the end of an interval of n years, according to actual interest rate r, is calculated as follows:

$$V_n = V_o \left(1 + \frac{r}{100}\right)^n$$

Example 1: What will be the value of V_o = 100 current monetary units in n = 5 years, with an actual interest rate of r = 5% ?

$$V_5 = 100\left(1 + \frac{5}{100}\right)^5 = 100 \cdot 1{,}05^5 = 100 \cdot 1{,}276 = 127{,}6$$

Reversely, we can calculate the current value of our money V_n in the year n with an actual interest rate r:

$$V_o = \frac{V_n}{\left(1 + \frac{r}{100}\right)^n}$$

Example 2: What is the current value V_n = 150 of the monetary units that we shall have in the fifth year n = 5, with an actual interest rate r = 5% ?

$$V_o = \frac{150}{\left(1 + \frac{5}{100}\right)^5} = \frac{150}{1{,}05^5} = \frac{150}{1{,}276} = 117{,}5$$

The interest rate for an arbitrary period of time

Economical analysis usually expresses interest rates at yearly level. It proves however sometimes necessary to consider shorter (month, quarter) or longer (life length of a measure) time intervals. Adjusting the interest rate to the desired time interval can be achieved quite easily.

Once we know the interest rate r_1 given for a period T_1, we can then adjust it to any time interval T_2 using the following:

$$r_2 = (1 + r_1)^{T_2/T_1} - 1$$

Example 3: What is the monthly interest rate (T_2=1/12 years), knowing that it amounts to r_1 = 12% on yearly basis (T_1=1 year) ?

$$r_2 = \left(1 + \frac{12}{100}\right)^{((1/12)/1)} - 1 = 1{,}12^{1/12} - 1 = 0{,}009489 = 0{,}9489\%$$

Example 4: What is the interest rate for the whole life length (T_2=5 years) of some energy efficiency measures in a project, knowing that it amounts to r_1 = 12% on a yearly basis (T_1=1 year) ?

$$r_2 = \left(1 + \frac{12}{100}\right)^{(5/1)} - 1 = 1{,}12^{5} - 1 = 0{,}76234 = 76{,}234\%$$

Investment costs

Investment costs are those necessary to start the project and to ensure its functioning throughout its life length. They are comprised of projects costs, acquisition of tender dossier, education, etc. and of costs in capital for the acquisition and installation of material.

The global initial investment (I_o) can be divided into the investment needed only once - at the beginning of the project (I_{oF}) -, and cyclic sporadic investments that are essential to keep the project alive.

$$I_o = I_{oF} + I_{oC}$$

We shall illustrate with an example of energy efficiency project:

Example 5: An energy efficiency project with an economic life length of 10 years includes the measure of replacing the internal lighting. Replacing the lighting includes the replacement of the lamps (armature) and the replacement of the lighting source (bulbs). The life length of the new lamps is substantially longer than the life length of the project (we consider it endless), and the bulbs have a life length of 3 years. In this case, it means that the total investment (I_o) can be divided into a component (I_{oF}) related to costs for acquisition and installation of the new lamps, and a component (I_{oC}) related to costs for acquisition and installation of the new bulbs. During the whole life length of the project - 10 years -, the costs (I_{oF}) will occur only once at the beginning of the project, whereas the costs (I_{oC}) will be repeated 10/3 = 3,33 times.

The necessary investments can be secured from own resources, from donors or through commercial loans. The most consistent projects combine all three source of financing. As one can conclude from this definition, there are two kinds of investment costs:

- **Initial investment costs**: those are the costs for starting the project (in particular those necessary to initiate all related energy efficiency measures). The calculation of such costs is essential during the process of gathering means to carry out the project.
- **Adjusted investment costs**: those are the costs necessary for starting measures of maintenance/replacement during the whole life length of the project. These costs allow evaluating the economical parameters of the project relevance (this will be further explained later on).

In ideal cases - when all of the individual life measure cycles inside the project are equal and identical to the life length of a project - the initial investment costs are equal to the adjusted investment costs. In different cases, they are different.

Let us express the initial investment costs of some energy efficiency measure by

$$I_o = I_{oF} + I_{oC}$$

If a measure has a life cycle of (m) years and if the actual yearly interest rate is (r), the interest rate on the life cycle of the measure (rc), can be calculated as follows:

$$rc = (1 + r)^m - 1$$

If the life length of a project is (n) years, we need to calculate an additional investment cycle $k = n/m - 1$ for the measure, besides the initial investment in the year zero. Because these investment cycles will happen in the future, we calculate the adjusted investment (I_{ac}) by adjusting them to the present moment and adding them up. In fact, the adjusted investment can be calculated by summing up the component (I_{oF}) which occurs only the beginning of the project, the investment into the initial cycle (I_{oC}), and the adjusted investments into all the other cycles during the life length of the project.

$$I_{ac} = I_{oF} + I_{oC} + I_{oC}\left(\frac{(1+rc)^k - 1}{rc(1+rc)^k}\right) = I_{oF} + I_{oC}\left(1 + \frac{(1+rc)^k - 1}{rc(1+rc)^k}\right)$$

Example 6: An energy efficiency project has a life length of n = 10 years. One of the measures considered in the project is the replacement of the internal lighting. Replacement of internal lighting is comprised of the replacement of the lights that costs I_{oF} = 100 monetary units and the replacement of the lighting sources that costs I_{oC} = 50 monetary units. The life length of the lights is significantly longer than the life length of the project, whereas the life length of the bulbs is m = 3 years. Calculate the initial and adjusted investments needed to carry out this energy efficiency measure. The yearly actual interest rate amounts to r = 5%.

- initial investment: $I_o = I_{oF} + I_{oC} = 100 + 50 = 150$
- adjusted investments: $rc = (1+r)^m - 1 = (1+5/100)^3 - 1 = 0{,}1576 = 15{,}76\%$

$$k = n/m - 1 = 10/3 - 1 = 2{,}33$$

$$I_{ac} = I_{oF} + I_{oC}\left(1 + \frac{(1+rc)^k - 1}{rc(1+rc)^k}\right)$$

$$I_{ac} = 100 + 50\left(1 + \frac{(1+0{,}1576)^{2{,}33} - 1}{0{,}1576(1+0{,}1576)^{2{,}33}}\right)$$

$$I_{ac} = 258{,}55$$

Annual costs and savings

Annual costs mean all those costs necessary for the acquisition of the energetic source and for the regular maintenance of equipment in the energetic field of some building. To calculate the economical effects of some project, one should consider the annual costs before project implementation (current state) and the annual costs after project implementation (new state).

For a year t, the annual costs (C^t) can be defined as the sum of the costs for the acquisition of the energetic source (C^t_{ei}) and the costs for maintenance and spare parts (M^t):

$$C^t = \sum_{i=1}^{n} C^t_{ei} + M^t$$

The difference between the initial state and the new state represent the <u>annual savings</u> (B_t). By default, these savings result from lower fuel and electro energetic costs, but could also be obtained by reducing the running costs. In some cases, the acquisition of more expensive spare parts can lead to an increase in maintenance costs.

Cumulative (adjusted) savings (CB)

During its life length, a project will generate annual savings. To correctly evaluate the effects of a project and make a comparison of several variants, we need to calculate the whole savings realized during the life length of a project adjusted to the initial moment (zero year). Cumulative savings can be defined based on the annual savings (B_t) for each year *t* during the life length of a project, *n* years and a known yearly interest rate, *r*.

$$CB = \sum_{t=1}^{n} \frac{B_t}{(1+r)^t}$$

In cases where the yearly savings during the life length of a project are equal, for example when $B = B_1 = B_2 = \ldots B_n$, we can use the simplified formula:

$$CB = B\frac{(1+r)^n - 1}{r(1+r)^n}$$

Example 7: The implementation of an energy efficiency project will result in yearly savings of B = 100 monetary units. Calculate the cumulative savings that will be achieved during the life length of the project n = 10 years. The actual yearly interest rate amounts to r = 5%.

$$CB = 100\frac{(1+0{,}05)^{10} - 1}{0{,}05(1+0{,}05)^{10}} = 722{,}17$$

Net Present Value (NPV) and Net Present Value Coefficient (NPVQ)

The average profitability of some project is based on the analysis of the parameter that represents the difference between the adjusted (cumulative) savings and the adjusted investments. This parameter is called the net present value and is calculated as follows:

$$NPV = CB - I_{ac}$$

The project is profitable when the net present value is greater than zero (the adjusted savings during the life length are greater than the investments). In other cases, it would make no sense to invest in a project.

The analysis of the net present value coefficient - which is defined as a ratio between the net present value and adjusted investments - will lead to conclusions that are even more important to evaluate the profitability of the project:

$$NPVQ = \frac{NPV}{I_{ac}} = \frac{CB - I_{ac}}{I_{ac}} = \frac{CB}{I_{ac}} - 1$$

The project is profitable when this coefficient is greater than zero. Furthermore, the coefficient (in case it is greater than zero) shows the number of monetary units earned by investing one money unit into the project.

Example 8: Investments needed for the implementation of some energy efficiency project amount to I_{ac} = 700 monetary units. We expect yearly savings of B = 200 monetary units during the life length of the project n = 5 years). Calculate the net present value and the net present value coefficient, knowing that the yearly interest rate amounts to r = 4%.

cumulative savings: $CB = 200\frac{(1+0{,}04)^5 - 1}{0{,}04(1+0{,}04)^5} = 890{,}36$

net present value: $NPV = CB - I_0 = 890{,}36 - 700 = 190{,}36$

n.p.v. coefficient.: $NPVQ = \frac{NPV}{I_0} = \frac{190{,}36}{700} = 0{,}27$

The positive values of coefficients *NPV* i *NPVQ* show the profitability of the project. The value of 0,27 for *NPVQ* indicates that each invested monetary unit brings yearly earnings of 0,27 monetary units.

In countries that do not face big problems to obtain means of investment, the projects are usually ranked following the coefficient *NPVQ*, according to which projects with the highest net present value coefficient are seen as the most profitable.

Pay back period (PBP)

The pay back period - or time for return on invested capital - is the time interval after which we consider that the level of realized savings has reached the level of the initial investments, and that the remaining life length of the project brings only profit.

The simplified way (so-called static approach) to evaluate the pay back period -without consideration to time related change in currency values (without considering interest rates):

$$PBP = \frac{I_{ac}}{B}$$

Pay off period (POP)

The most appropriate way to calculate the period of return on invested funds implies that we take into account the dynamic changes of monetary values in a timeline, i.e. consider the interest rate. The pay off period is actually calculated by equalizing the realized savings and the adjusted investments as follows:

$$CB(POP) - I_{ac} = B\frac{(1+r)^{POP} - 1}{r(1+r)^{POP}} - I_{ac} = 0$$

We then get the formula for the pay off period (*POP*):

$$POP = -\frac{\ln\left(1 - r \cdot \frac{I_{ac}}{B}\right)}{\ln(1+r)} = -\frac{\ln(1 - r \cdot PBP)}{\ln(1+r)}$$

Example 9: We need to invest I_{ac} = 700 monetary units for the implementation of some energy efficiency project. We expect yearly savings of B = 200 monetary units during the life length of the project n = 5 years). Calculate the pay back period and the pay off period for this project, knowing that the yearly interest rate amounts to r = 4%.

pay back period : $PBP = \frac{I_{ac}}{B} = \frac{700}{200} = 3{,}5\ years$

pay off period: $POP = -\frac{\ln\left(1 - r \cdot \frac{I_{ac}}{B}\right)}{\ln(1+r)} = -\frac{\ln\left(1 - 0{,}04\frac{700}{200}\right)}{\ln(1+0{,}04)} = 3{,}84\ years$

As we can see from this analysis, the calculation made with the interest rate (dynamic approach) gives a longer pay back period than the static approach. This means that whenever the interest rates are positive, the pay off period (*POP*) is always longer than the pay back period (*PBP*). They would be equal only when the interest rate is zero.

The internal norms of capital return rates measure the quality of a project.. It is an interest rate according to which a project would have a zero net present value during its life length, that means according to which the actual (cumulative) savings during the life length matches the adjusted investments. To obtain such parameter, we consider the following:

$$NPV(IRR) = B\frac{(1+IRR)^n - 1}{IRR \cdot (1+IRR)^n} - I_{ac} = 0$$

Unfortunately, we cannot get an analytical expression to calculate this parameter. We can use the iterative approach, which is too complicated to explain in this manual.

This factor shows the profitability of a project. It shows for example that each commercial loan with an actual interest rate (without inflator effect) lower than the internal norms of return rates is acceptable, as it allows whoever initiated the project to achieve profit. Both the net present value coefficient and the internal norms of capital return rates will allow the ranking of projects in terms of chances for success.

The net present value coefficient and the internal norms of capital return rates are used to rank potentially successful projects.

Chapter

3

Ecological model

Besides technical and economical aspects, the present energetic - be it at planetary, national or municipality level - implies considering ecological aspects. The amount of harmful substances emitted into the atmosphere during the past century - and in the beginning of this one - has exceeded the natural absorption possibilities and threatens to generate disorders of large proportions.

In order to achieve a realistic model of energetic problems, the BEEP program includes a specific ecological model. The combustion of energy for heating purposes and the consumption of electrical energy for internal lighting result in the emission of harmful gases. Every reduction in energy spending, as well as the choice of ecologically less negative energy source, will have positive effects on the local and global ecological conditions.

The BEEP program divides gas emissions into two groups:

- greenhouse gases (GZB) with a global negative effect - warming up the planet;
- other harmful emissions with primarily local negative effects.

Greenhouse Gases

Life on planet Earth is possible just because of the existence of the greenhouse natural effect. The natural appearance of gases producing greenhouse effect, primarily water steam, carbon dioxide and methane, allows the solar energy to pass through to the earth. It gets onto it as light, while remaining in the atmosphere as infrared heat. (Pic.3.1)

Such phenomenon keeps the planet heated enough, which insures normal life on our planet. The absence of the greenhouse gases would reduce the temperature of our planet with approx. 33ºC. Anyway, during the last century, this positive greenhouse effect has turned into a serious threat. Industrial development and population growth have led to a constant increase of the emission of the greenhouse gases - combustion of fossil fuel, clearing the forests and agricultural land clearing. In the past 100 years, the emission of greenhouse gases has proved much in excess of the natural absorption possibilities. Besides these gases - which already existed in the atmosphere with a concentration that was enlarged by human activities -, new synthetic gases were emitted (chlorofluorohydrocarbons and halogens) and it has been found that these too have an effect of greenhouse gases.

Picture 3.1 Greenhouse effect

Such a significant increase in the quantity of emitted harmful gases now threatens a delicate balance as it directly influences the insulating effect of the atmosphere. Picture 3.2 illustrates the concentration of carbon dioxide in the atmosphere during the last 160 years.

Picture 3.2 Concentration of carbon dioxide in the atmosphere

Forecasts conclude that this effect could lead to an increase of temperature on earth, up to of 2-4°C. Such case could lead to serious modifications - distribution of precipitations, warming up of icebergs, and rising of sea levels.

In order to prevent - or at least mitigate - these negative effects, several conferences were held since 1992 that underlined the potential threats. The Kyoto Protocol, adopted in 1997, introduces the obligation for individual members of the international community to reduce their emission of greenhouse gases.

The most developed countries have endorsed the obligation to reduce their emission of greenhouse effects by 5-7% in the coming period. Considering the difficulty of reaching such objectives (along with the preservation or the further development of the industrial production), and taking into account the global dimension of the effect (practically, the part of the world in which these gases are produced does not really matter), mechanisms have been put in place which allow the so-called market development of greenhouse gases. This actually means that those countries with no international obligation to reduce their emission, but realizing projects which lead to a reduction of greenhouse gases, can sell this reduction to a country that has such obligation but cannot meet it due to technological or economical (too expensive investments) reasons.

This offers undeveloped - and developing - countries a great opportunity to sell their rights on greenhouse gases and, so doing, to cover the investments they need to develop new technologies in the energetic sector.

That is why the BEEP program classifies this category of gases as a special group. The user can decide whether to include the greenhouse gas reduction as a component of the yearly savings - as an energy efficiency measure - (this will be detailed later on).

International conventions classify greenhouse gases into six groups.

- carbon dioxide
- methane

- nitrogen suboxid
- chlorofluorohydrocarbons
- halogens
- sulfur- hexafluoride

Carbon dioxide, methane and nitrogen suboxid fall in the category of the so-called natural gases that appeared in the nature well before the development of the civilization, whereas the other three groups gather the so-called artificial or synthetic gases, produced by the human being for some technical or technological purposes.

To date, the group of greenhouse gases is comprised of 24 registered gases. Based on their 'insulating' characteristics and on the time needed for their natural absorption, we add a matching coefficient that shows their negative effect related to the measuring unit of the greenhouse basic gas- carbon dioxide. This means that the global emission of greenhouse gases for a certain process - industry, traffic or energy - can be expressed in so-called equivalent tons of carbon dioxide. This equivalent amount is obtained by adding up the amounts of the individual gases, which have been multiplied in advance by their mass coefficient.

The price for an equivalent ton of carbon dioxide on the world markets depends on the demand and supply, but one generally considers that it varies between 3 and 5 dollars per ton.

Example 1: Heating a school requires the consumption of 200 tons of carbon dioxide during the heating season. Energy efficiency measures reduce this consumption down to 150 tons**.** The economical life length of the project is 10 years. The price of an equivalent ton of carbon dioxide is 3$/t. The combustion of one ton of carbon dioxide emits 1.3 tons of carbon dioxide. Calculate the yearly reduction of emission of greenhouse gases, the yearly financial savings due to the reduction of emissions and the total savings due to the reduction of emissions during the whole life length of the project. The actual yearly interest rate $r = 4\%$.

yearly reduction of emissions : $R_{GZB} = (200 - 150)1{,}3 = 65 tons$

yearly savings: $B = 65t \cdot 3\$/t = 195\$$

total savings: $CB = 195 \frac{(1+0{,}04)^{10} - 1}{0{,}04(1+0{,}04)^{10}} = 1581{,}62\$$

Other harmful emissions

Besides greenhouse gases - which have a global negative effect - the combustion of energy produces a whole range of other gases that have a local negative effect. The BEEP program defines four ranges of combustible products:

- carbon monoxide
- sulfur dioxide
- nitrogen oxide
- clear carbon

An excessive presence of these substances in the air can jeopardize people's health. That is why the ecological model of the BEEP program also includes these gases, even if international standards do not allow to properly expressing their financial value.

ECONOMIC MODEL

Chapter

4

BEEP 1.0 Program installation

A correct installation of the BEEP program will allow you comfortable work in your language, including all signs. Read this chapter carefully and follow all instructions.

The BEEP Program was developed in Microsoft Visual Basic. All data input by the user are stored in a Microsoft Access database. Besides this, the program allows to create different kinds of reports (from those simple ones which describe individual groups of data: country, cities, energy sources …, to complex ones: energy efficiency project, work plan, etc.). All these reports are generated directly in Microsoft Word format.

Make sure that the version of the installation CD is identical to the version of Microsoft Office installed on your computer. If you, for example, install the Office 2000 version on a computer with Office XP, you will get an error message during the creation of a report and the program will halt due to incompatible MS Word version.

Hardware requirements

The proper functioning of the BEEP software requires approximately 30 MB free space on hard disk. A higher amount of operational memory and a processor with higher performances will increase user's satisfaction. Considering the large number of computing operations executed by the program and the high amount of data exchanged with the database, we recommend - although this is not a necessity - installing the program on Pentium 3 computers with at least 128 MB active memory.

Software requirements

The execution of the BEEP program is independent from the operating system. This means that the program works on all commercial operating systems (Windows 95, 98, ME, NT, 2000 and XP). However, not all operating systems display eastern european character sets properly. The program itself was developed and tested on operating systems 2000 and Windows XP. According to the author of the program, the Windows NT operating system should deliver good results in terms of working with eastern European character sets. Other platforms do not offer any guarantee as for the manipulation of these characters. In order to ensure a better work with the BEEP program, we therefore recommend users to use one of the three afore mentioned operating systems.

This version of the program creates reports output in MS Word XP format. In order to make full usage of the program, the user should thus have MS Office XP installed. If not, the program will halt during any attempt to create reports.

Installation procedure

The installation of the BEEP program is comprised of a few steps. As the installation procedure depends on the installed operating system, we recommend you to read carefully the installation instructions and to respect these for the proper functioning of the program.

Prior to the installation itself, it is necessary to follow these steps, which will prepare the computer for use of the program. First, those of you who need to use their local language should adapt their local settings. This can be done the following way:

- Click the **Start** button at the bottom left of the screen, then select **Settings**. From the list, choose **Control Panel**.
- Once the Control Panel window has opened, choose the icon **Regional Settings** or **Regional Options** (the name of the icon depends on your operating system).
- After opening of this window, you should choose one of the options (countries) that offer support to latin eastern european character sets.

*** If you are a Windows 2000 or Windows XP user, select **Bosnian (Latin)** from the list, and under *Language settings for your system* select **Central Europe**. Set this choice as your default by clicking **Set Default**. During this procedure, you might be required to insert the installation CD of the operating system, in order to copy some necessary files to the hard disk.

*** If you are using an operating system that does not fully support specific eastern european character sets (Windows 95 or Windows 98 operating systems), then select **Slovenia** or **Croatia** from the listed countries.

Once these changes have been made, your operating system will ask you to restart the computer in order to update your settings.

Prior to program installation as such, Windows 95 and Windows 98 users should run dcom98.exe from the installation CD in order to copy several essential components to the operating system.

Users of Windows NT, Windows 2000 and Windows XP operating systems do not need to run this program and can skip this step.

We now come to the installation procedure of the program itself. From the installation CD, run the program **setup.exe**. Once this program has started, a window will open on the screen, showing *Copying Files, Please Stand by*.

After completion of this procedure, a window will pop up for the installation of the BEEP program. Start the installation by clicking the **OK** button. If you do not wish to proceed to the installation, click the **Exit Setup** button.

In the next window, you can choose the location where to install the BEEP program. The installation program suggests installing the BEEP program at location C:\Program Files\BEEP\. If you accept this location, clicking the upper left button (figuring a computer) will start the installation. If you choose to change the suggested location, click the **Change Directory** button, then choose a suitable location and then click the button to start the installation. If you wish to cancel the installation, click the **Exit Setup** button.

Finally, you will have to select a name for the program group that will be created in the Start/Programs command on your computer. The suggested name is BEEP - Building Energy Efficiency Program. If you agree with this name, click **Continue**. You can also modify this name in the field **Program Group** and then click **Continue**.

After completion of all these adjustments, the installation process will start - you can follow its progress on the progress bar. Once the installation has terminated, a window pops up indicating that the installation was completed successfully (*Setup was completed successfully*). Click the **OK** button, the installation procedure has terminated.

Prior to reinstalling - for any reason - the BEEP program on a computer it was already installed on, you then need to remove the existing version. To remove the program, click Settings, and then Control Panel and finally the icon Add/Remove Programs. Clicking on this icon will display a list of all programs installed on your computer. Select the application - Building Energy Efficiency Program and click Remove.