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EVALUATION OF ENERGY SAVING INVESTMENTS IN BUILDINGS AS A SYSTEM OF INTERDEPENDENT PROJECTS

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ABSTRACT

During a design stage building designers have to do many decisions that will influence an energy consumption in a designed building. Investments to a building structure and HVAC system are a basis for a low consumption of an energy. The decision making process is considered as the system of investment decisions where one certain decision is a project. The program has been developed for the selection of solutions for defined restrictions. One example is presented for the evaluation of different possible combinations of energy saving projects in a real building.

INTRODUCTION

Building designers and HVAC system designers meet different requirements of future or present owners of the buildings. Owners usually work with limited budget for the building construction but currently they are interested in low operating costs. This conflict can be solved by careful evaluation of investments to all arrangements that ensure low energy consumption. The building designers should find the best solution for stakeholders.

A decision process is described in Figure 1. In the beginning the future energy consumption is influenced by the decision about *location* of the building. It means latitude and also altitude. The *site* is exact position, e.g. a distance from other buildings. The choice of *building structures* and a kind of the *heating system* is the typical decision influencing energy consumption. Another action is the choice of a *fuel* because it creates the preposition for a good control of the heating source. The picture is based on general feasibility study approach (Behrens and Hawranek 1996).

The whole process can be broken down to more decision activities on the higher resolution level and also includes many back loops. The design is an iteration process when the building designers have to revise their decisions according to current situation.

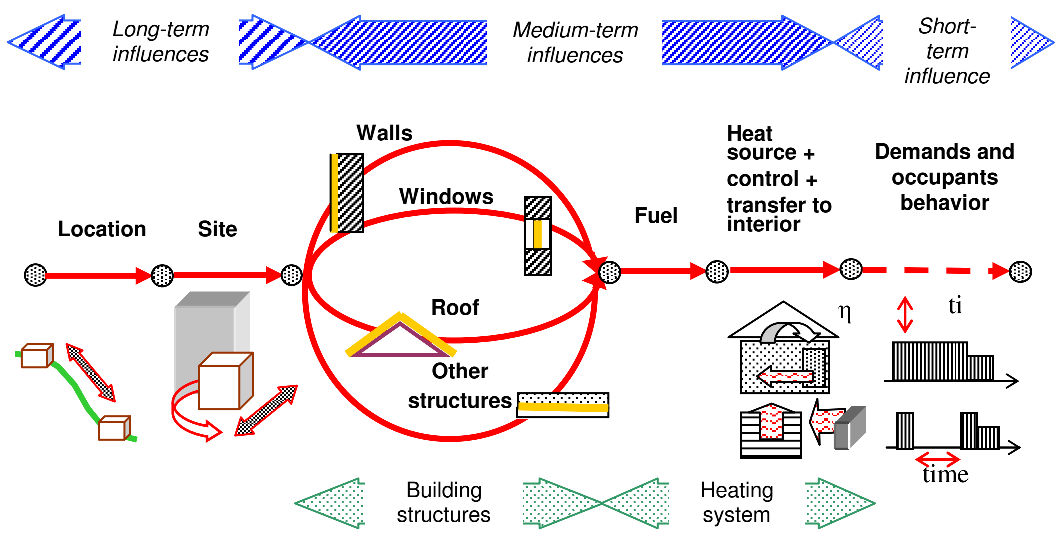


Figure 1 Decisions influencing energy consumption and operating costs

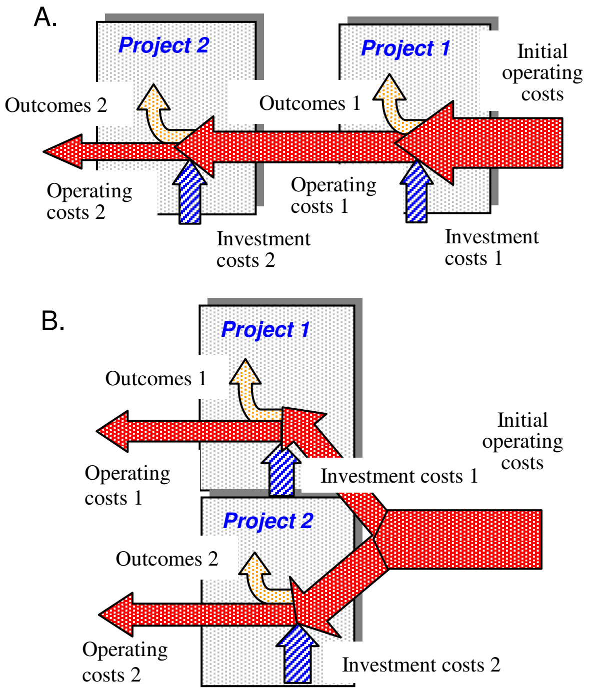


Figure 2 Basic generic structures - A) dependent projects, B) independent projects

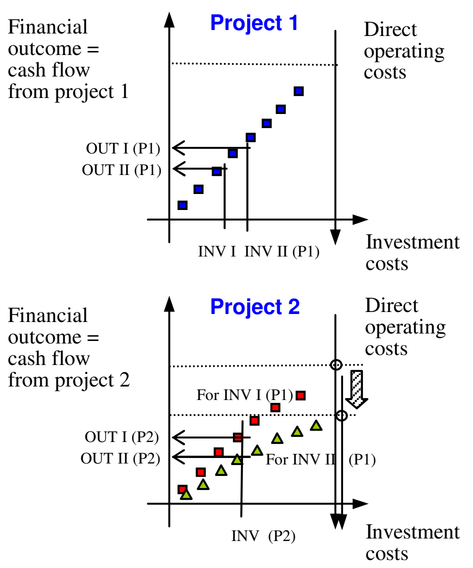


Figure 3 Influence of investment costs on outcome from dependent projects

METHOD

A decision making model is presented as the system of investment projects where same projects can influence financial outcomes from other projects. This fact is explained in Figure 2 where basic structures are presented. In the case *A* higher investments to *Project 1* will ensure higher energy savings and it means better financial outcomes from this project but at the same time it decreases the cash flow from *Project 2* (for the same level of investment costs in *Project 2*). The problem is described in Figure 3.

The conclusion is: to consider whole system of financial flows and projects as it is depicted in Figure 4. The structure creates the net where the node is the point of the decision and together with correspondent financial flows forms one single investment project. The network model is derived from the structure drawn in Figure 1.

The way of determining whether a project yields a return in excess of the alternative equal risk is to calculate the net present value (NPV). A positive NPV indicates that an investment should be accepted.

$$E(NPV) = \sum_{t=1}^{m} \frac{CF_t}{(1+i_t)^t} \qquad (1)$$

Other technique for use in making investment decisions is internal rate of return (IRR). IRR represents the interest rate earned on the investment over the course of its economic life. It is the discount rate that will cause the net present value of the investment to be zero (Drury 1995).

$$\sum_{t=1}^{m} \frac{CF_t}{(1+i_i)^t} = 0 \qquad (2)$$

Evaluating the single project or the combination of the projects is based on the calculation of annual cash flows. In practice we have to consider many restrictions that influence the result. In this case, typical restriction is a budget. It means we have to work with the limited amount of financial sources that can be spent for all energy savings arrangements.

The computer program has been developed for assessing all combinations of selected single projects. The number of the combinations is defined by Equation 3.

$$C_p = \sum_{k=1}^{n} \frac{n!}{k! \cdot (n-k)!} \qquad (3)$$

In the first step, the user of the program chooses the single projects that will be considered for the evaluation and also the limit of investment costs. The program calculates all combinations of the projects and the user can decide that combinations will be evaluted and compared. In next step, needed data for the calculation of direct operating costs and finanacial outcomes are loaded.

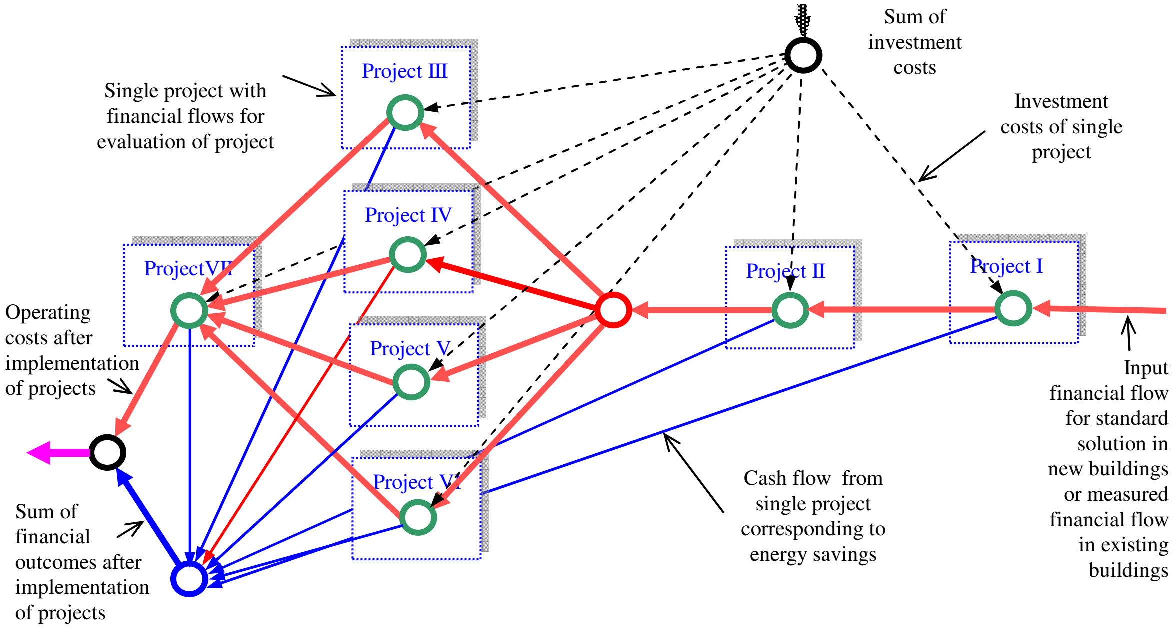


Figure 4 System of financial flows and projects

EXAMPLE

General description

As an example, the evaluation of energy savings projects was performed for one flat in 30 years old block of flats. Location: Czech Republic, Prague. Site: standalone block of flats. Flat is on the 3rd floor. Living area is 69 m^2. The heat source is a gas boiler. The boiler is located in the flat.

15 combinations of projects exist for four chosen single projects without the limit of the investment costs. For the limit 170 000 CZK, the number of the combinations is 14. The building user refused same combinations and therefore the final figure is 11.

Single projects

Project 1 - External thermal insulation of the building shell (80 mm thickness).

Project 2 – The replacement of old windows for new windows with better thermal parameters (U_{frame} = 1,13 W.m^{-2}.K^{-1}, U_{glass} = 1,4 W.m^{-2}.K^{-1}).

Project 3 – The installation of the window seal.

Project 4 – The replacement of old gas boiler for new boiler (η = 92%).

Combination of projects - independent projects

Project 5 – the combination of *Project 1-Thermal insulation* and *Project 2-Windows replacement.*

Project 6 – the combinations of *Project 1-Thermal insulation* and *Project 3-Window seal.*

Combination of projects - dependent projects

Project 7 – the combination of *Project 1-Thermal insulation* and *Project 4-Boiler replacement.*

Project 8 – the combination of *Project 2-Windows replacement* and *Project 4-Boiler replacement.*

Project 9 - the combination of *Project 3-Window seal* and *Project 4-Boiler replacement.*

Project 10 - the combination of *Project 1-Thermal insulation* and *Project 2-Windows replacement* and *Project 4-Boiler replacement.*

Project 11 - the combination of *Project 1-Thermal insulation* and *Project 3-Window seal* and *Project 4-Boiler replacement.*

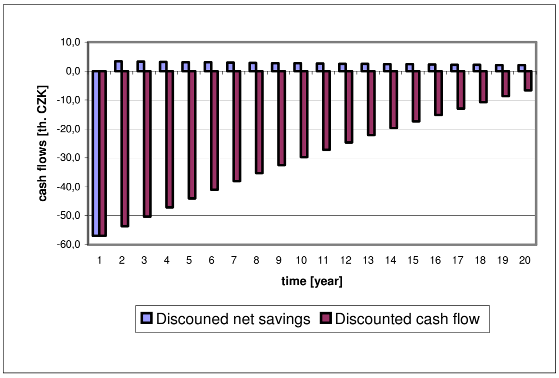
Input parameters for calculations of NPV and IRR parameters for all projects are in Table 1. The project lifetime corresponds to the expected life period of the building structures and the elements of HVAC systems. The fuel price is very uncertain parameter. In this case, the price increase was estimated 5% every year. It depends often on political decisions and therefore the prediction for long period is difficult task.

Table 1

Input values for all projects

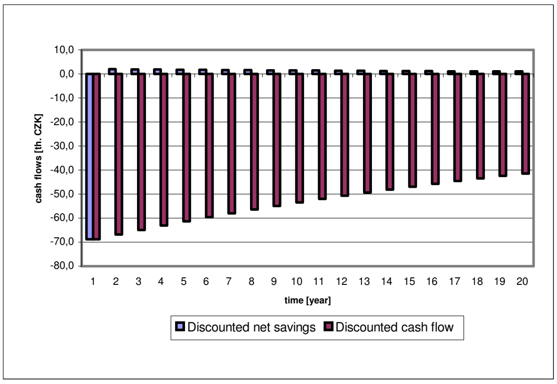
Project lifetime	[years]	20
Index of price increasing	[-]	1,05
Discount rate	[%]	8

Single projects



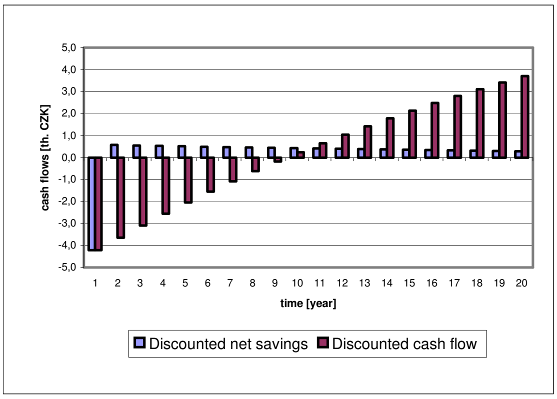
Investment cost	[10^3 CZK]	65,2
Savings 1. year	[10^3 CZK]	3,8
Net present value (NPV)	[10^3 CZK]	-6,7
Internal rate of return (IRR)	[%]	7

Figure 5 Project 1: Thermal insulation



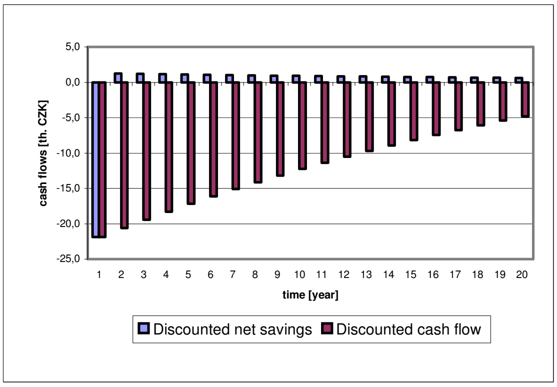
Investment cost	[10^3 CZK]	76,5
Savings 1. year	[10^3 CZK]	2,3
Net present value (NPV)	[10^3 CZK]	-41,5
Internal rate of return (IRR)	[%]	-

Figure 6 Project 2: Windows replacement



Investment cost	[10^3 CZK]	5,2
Savings 1. year	[10^3 CZK]	0,7
Net present value (NPV)	[10^3 CZK]	3,7
Internal rate of return (IRR)	[%]	17

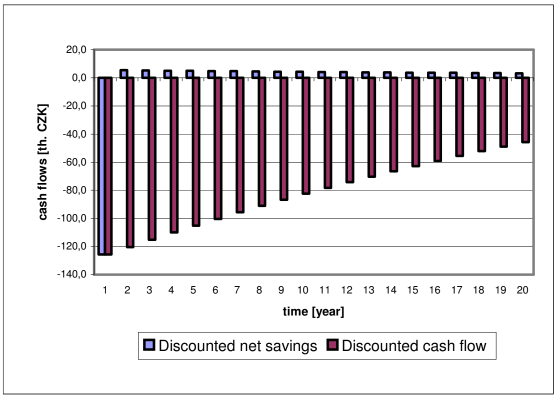
Figure 7 Project 3: Window seal



Investment cost	[10^3 CZK]	25
Savings 1. year	[10^3 CZK]	1,4
Net present value (NPV)	[10^3 CZK]	-4,8
Internal rate of return (IRR)	[%]	5

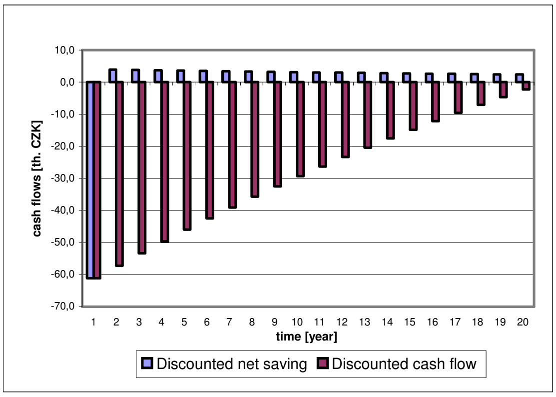
Figure 8 Project 4: Boiler replacement

Combinations of projects



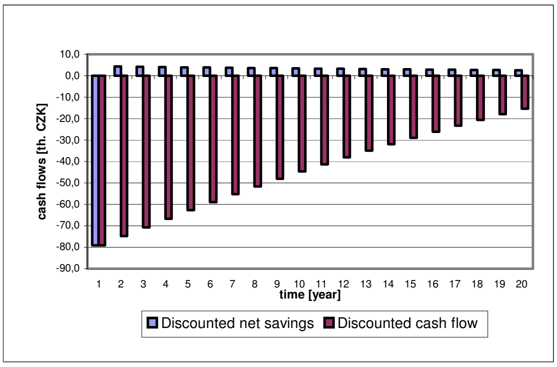
Investment cost	[10^3 CZK]	141,7
Savings 1. year	[10^3 CZK]	6,0
Net present value (NPV)	[10^3 CZK]	-45,7
Internal rate of return (IRR)	[%]	3

Figure 9 Project 5: Thermal insul. + windows repl.



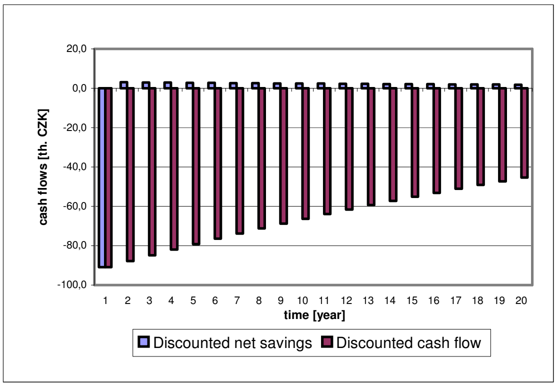
Investment cost	[10^3 CZK]	70,4
Savings 1. year	[10^3 CZK]	4,4
Net present value (NPV)	[10^3 CZK]	-2,3
Internal rate of return (IRR)	[%]	8

Figure 10 Project 6: Thermal insul. + window seal



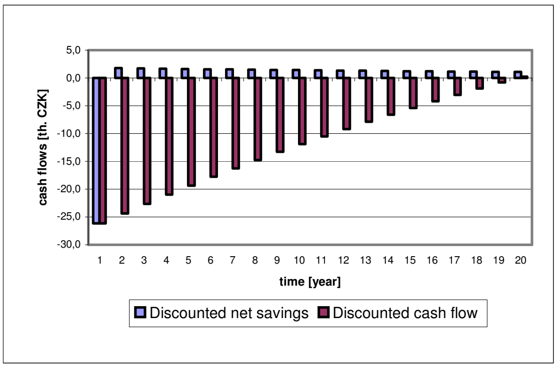
Investment cost	[10^3 CZK]	90,2
Savings 1. year	[10^3 CZK]	4,8
Net present value (NPV)	[10^3 CZK]	-15,3
Internal rate of return (IRR)	[%]	6

Figure 11 Project 7: Boiler replacement + thermal insulation



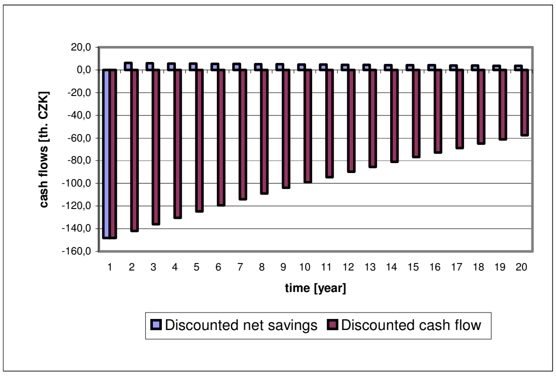
Investment cost	[10^3 CZK]	101,5
Savings 1. year	[10^3 CZK]	3,4
Net present value (NPV)	[10^3 CZK]	-45,4
Internal rate of return (IRR)	[%]	1

Figure 12 Project 8: Boiler + windows replacement



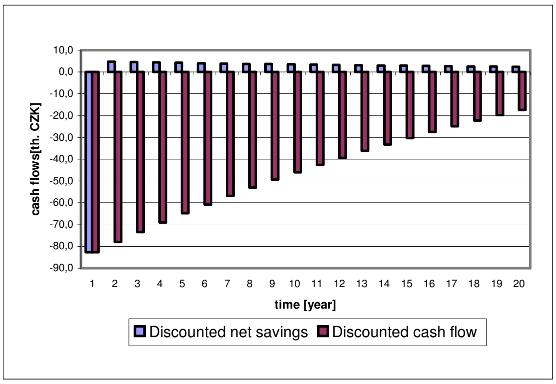
Investment cost	[10^3 CZK]	30,2
Savings 1. year	[10^3 CZK]	2
Net present value (NPV)	[10^3 CZK]	0,2
Internal rate of return (IRR)	[%]	8

Figure 13 Project 9: Boiler replacement + window seal



Investment cost	[10^3 CZK]	166,7
Savings 1. year	[10^3 CZK]	6,7
Net present value (NPV)	[10^3 CZK]	-57,5
Internal rate of return (IRR)	[%]	3

Figure 14 Project 10: Thermal insulation + windows replacement + boiler replacement



Investment cost	[10^3 CZK]	95,4
Savings 1. year	[10^3 CZK]	5,3
Net present value (NPV)	[10^3 CZK]	-17,4
Internal rate of return (IRR)	[%]	6

Figure 15 Project 11: Thermal insulation + window seal + boiler replacement

Table 2
Rank of projects according to Net present value and Internal rate of return

	Project	NPV[10^3CZK]	Project	IRR [%]
1	**3**	3,7	**3**	17
2	**9**	0,2	**9**	8
3	**6**	-2,3	**6**	8
4	**4**	-4,8	**1**	7
5	**1**	-6,7	**11**	6
6	**7**	-15,3	**7**	6
7	**11**	-17,4	**4**	5
8	**2**	-41,5	**5**	3
9	**8**	-45,4	**10**	3
10	**5**	-45,7	**8**	1
11	**10**	-57,5	**2**	-

RESULTS

Resultant values of main project parameters are in Figure 16. The rank of the projects is in Table 2.

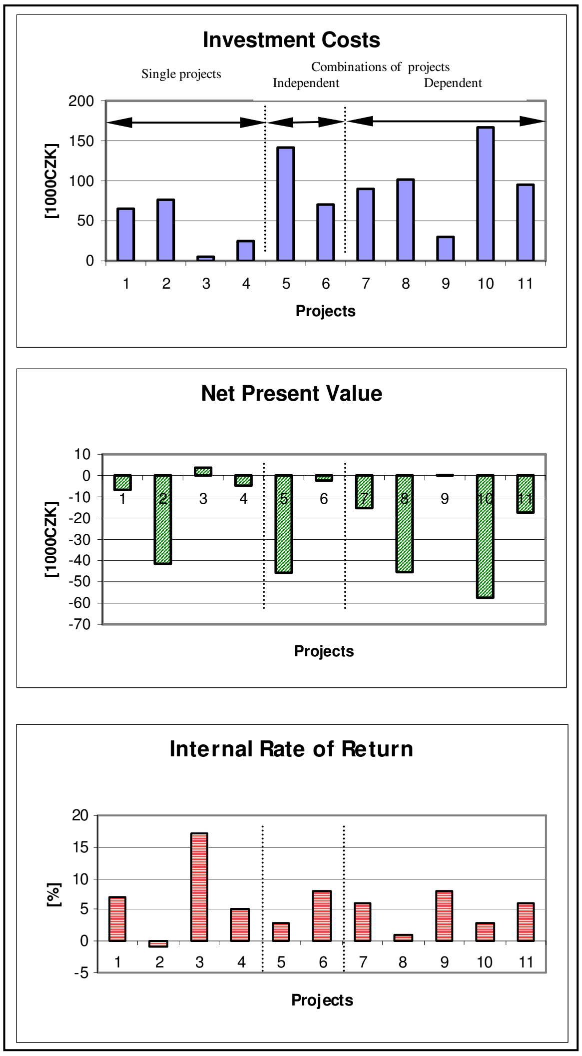


Figure 16 Comparison of projects

The results written in Table 2 are the basis for the decision about the implementation of projects. The application of the IRR and NPV rules lead to the different order. The NPV ranking depends on the discount rate. In case of the discount rate lower than certain value (usually lower than 10-12%, but it depends on evaluated projects), the order of projects is different. The discount rates for energy savings projects are usually under 10%. The investigation of cash flow increments gives the priority to the NPV rule (Drury 1995).

It is not easy to compare independent and dependent projects in the real example because usually there are not sets of the projects with equal investment costs. In described case study, it is possible to compare e.g. *Project 6* and *Project 7* or *Project 5* and *Project 10*. Independent projects reached better evaluation.

The projects are mutually exclusive and therefore only one project (combination of single projects) can be accepted. The best ranked *Project 3* has the lowest energy savings from all projects. The best energy saver *Project 10* has the worst NPV. As a compromise, *Project 6* was selected for the implementation. The project was realized three years ago. Financial outputs have been checked during this period with good agreement between calculated values and real values.

CONCLUSION

The paper was focused on the decision making process where building owner was the active element. It means, he was interested more in the profitability of the projects than in the maximum energy saved. Conclusions from the described problem:

- To define in the beginning the goals that should be reached by the implementation of the project. It means, to design these goals together with client (building owner).
- To prefer independent projects that ensure better investments effectiveness.
- The results can be changed by considering other financial outputs or non-financial benefits. E.g. increasing market price of the real estate or better functions of new windows.
- To consider the significant influence of the investment costs. It means, to spend enough time with the selection of the supplier. Decreasing initial costs can substantially change the results.
- The results are very sensitive to the price of fuel. This parameter influences strongly financial outputs from projects.

NOMENCLATURE

CF_t	cash flow for certain year,
m	life time of projects,
i_t	interest rate for certain year,
i_i	internal rate of return,
n	number of projects,
k	class of combination.

ACKNOWLEDGMENT

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