Building Simulation 2009

Eleventh International IBPSA Conference
Glasgow, Scotland
July 27-30, 2009

THE DYNAMIC MODEL OF THE INFLUENCE OF ENERGY PRICE CHANGES ON ENERGY SAVING INVESTMENTS IN BUILDINGS

Dalibor Vytlacil
Czech Technical University in Prague, Faculty of Civil Engineering
Thákurova 7, 16629 Prague 6, Czech Republic
vytlacil@fsv.cvut.cz

ABSTRACT

The paper describes the simulation model for the prediction of the dynamic behavior of the complex system. The system includes as the main element the energy saving projects together with the elements from the environment. The solution is based on the application of system dynamics that is useful method for the simulations in the field of socioeconomic systems. The relevant elements are oil price changes, energy distributor goals and a state policy in the field of the energy savings. The main output parameter is the number of realized energy conscious projects and saved energy during certain period. The model can help to design the energy policy and to predict the market with the projects.

INTRODUCTION

Energy saving projects and their environment

The reasons for the implementation of energy saving policy and energy saving projects in the building sector are:

- The efforts for decreasing direct costs of the building owners or the tenants living in energy ineffective buildings. Housing expenses are very strongly influenced by the increase in energy prices in past years. 30 % of total energy consumption in Europe is consumed in the buildings.
- Governments try to implement the energy policies with the goal to decrease the consumption of non-renewable resources. Also they want to ensure the energy security. It is expected the detection of new fossil fuel reserves but they will not be under control of main consumers.
- Important issue is decreasing greenhouse gases. The amount of CO_2 in air was increased by 20% during last 20 years.

The quantity of saved energy in the buildings depends on the technical quality of the concrete project but also on the number of realized projects during certain time period. Therefore it is important to understand the whole system and its dynamic behavior. The environment of the energy saving projects is described in the Figure 1.

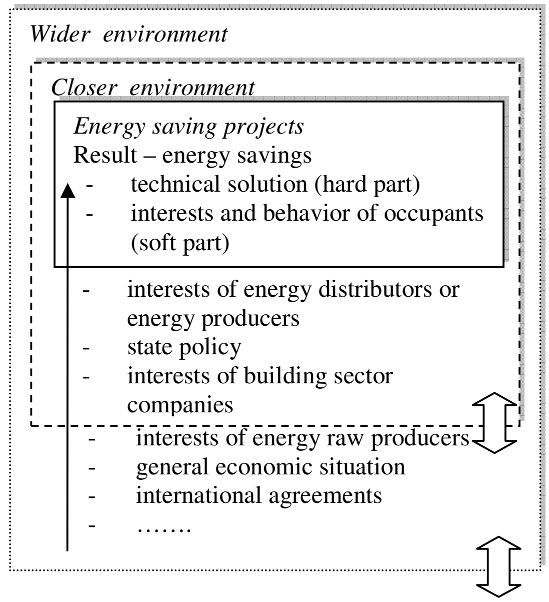

Figure 1 Elements of the environment of energy saving projects

The process of projects implementation starts by the increase of energy prices for final consumers that causes the demand for the energy conscious projects in existent buildings and also for the design of new low energy buildings. The projects are designed and after the evaluation, the feasible projects are implemented. It will create the profit for the building owners and for the construction companies.

Description of the building stock

72% of the floor space in the buildings in Czech Republic was built before 1975, 25% till 1990. In 2001 the amount of floor space was 363 million m^2, (Zemene and Rydlo, 2006).

In Figure 2 is the distribution of different size buildings according the time of the realization and concurrently the development of the requested thermal resistance for the walls and the roofs.

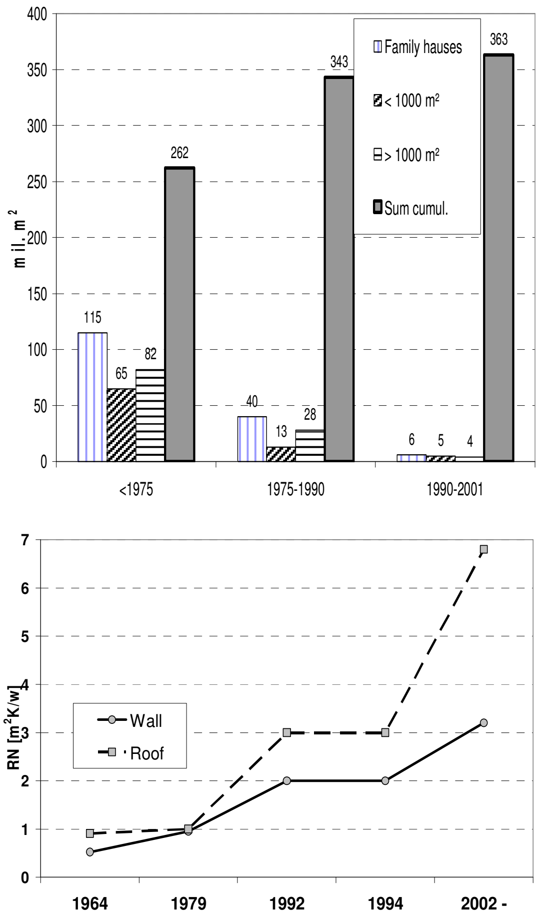

Figure 2 Realized buildings and requested thermal resistance over past years

The main goal of the research is to develop the dynamic model that will describe the changes of the important parameters concerning energy saving projects and the market with these projects during the next ten years. The main parameters that will be predicted: price of oil (world price and local customer price), number of realized projects, energy savings during the certain period. at the end of the text.

METHOD

System dynamics

The used dynamic model is based on the system dynamics method. The method uses stock elements that are influenced by flows. The assistant elements are converters which execute the auxiliary calculations in the model, (Meadows et al. 1992).

The first step is the design of the causal loops that describe the main relationships in the system. For investigated problem the causal loops are depicted in Figure 3. The significant task is to choose the relevant stock elements and relationships that will be included in the model. The most important relationships are drawn by the solid line.

The system include negative loops that should keep the price of the energy on the slightly growth level but the changes of the economic activity influences the demand very strongly. The model includes elements and has the structure that describes long time changes. Short time changes as the speculations in the oil price are not important for this kind of simulation and decision making.

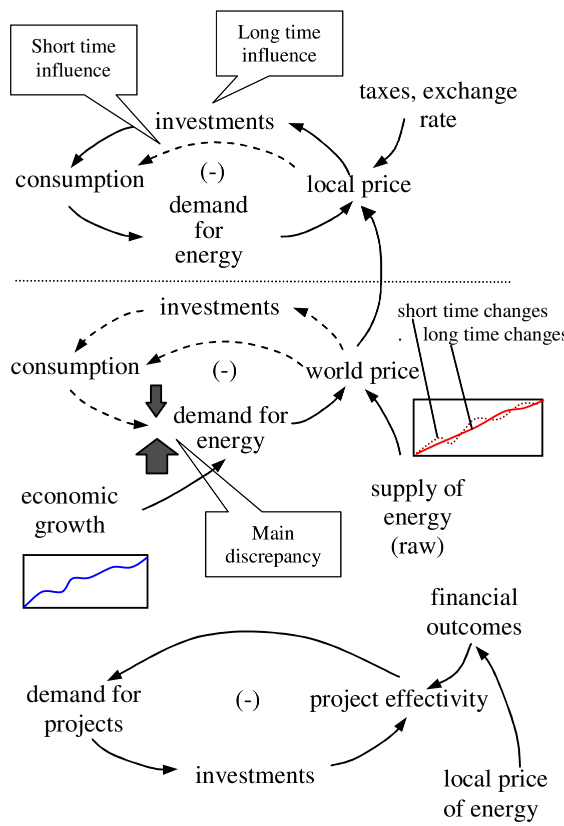

Figure 3 Main causal loops in the system

The example of system dynamics model with the main elements is in Figure 4.

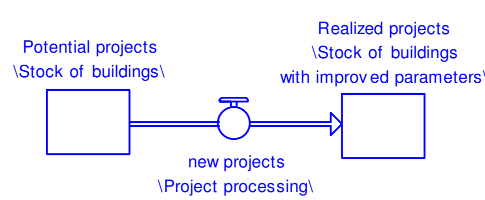

Figure 4 Example of stocks and flow

The changes in the stock elements are described by the Equation 1, (Sterman, 2000).

$$Stock(t) = \int_{t_0}^{t} [Inflow(s) - Outflow(s)] ds + Stock(t_0) \quad (1)$$

DESCRIPTION OF DYNAMIC MODEL

The selection of the relevant element is very difficult process because the model designer has still the feeling that some elements can be added to the model. The reason is that is not easy to recognize the boundary of the system. The system dynamics models should be extensive and relatively shallow, (Richmond, 2001). The model with chosen elements and with the names of main subsystems is drawn in Figure 5.

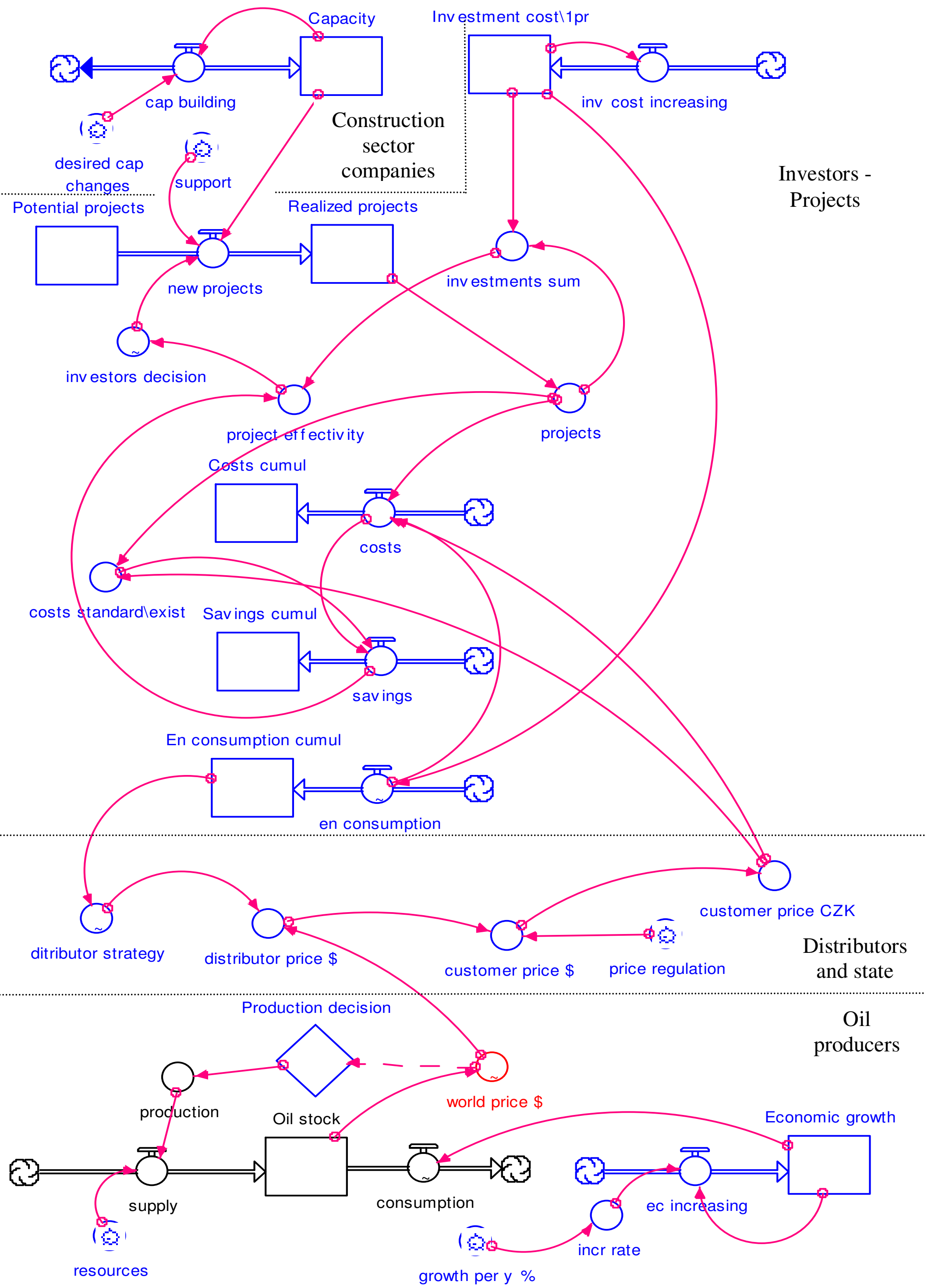

Figure 5 Dynamic model of the system

Subsystems in model

The designed subsystems represent the supply chain of the energy raw materials and the energy: *Oil producers → Distributors and state → Investors–Projects*. The last element of the chain is the energy consumer. The auxiliary subsystem is *Construction sector companies* for the description of the available capacity. There are the stake holders in the described problem. The main subsystem is *Investors-Projects* that includes another supply line concerning project processing. The flow is controlled according to investors' decision.

The model considers only long time changes of oil and therefore the subsystem *Oil producers* uses also long time prediction of the energy consumption. Regardless of the contemporary economic problems the subsystem is adjusted for the increase of the energy consumption. This assumption is explained in Figure 3. The fast growing economics of China and India will need more energy in the future. The influence of the energy savings is considered in the subsystem *Distributors and state* where the changes of the energy consumption affects the strategy of the local distributors.

Important model parameters

Oil stock, World price – the price of producers depends on the demand for oil and the rate of delivering energy raw to the stock. The supply is derived from the amount of the resources and from the goal of the producers to keep the price on the desired level. The demand is influenced by the economic growth in the world. The oil price is considered as the price for other energies because the prices are interconnected and they copy the oil price. The price is calculated in the beginning for one barrel but in the distributor subsystem it is converted to price for one MWh. *Customer price* – it is influenced by government strategy concerning the energy conservation, the environment protection and the state budget. Unit energy price can be increased by VAT and another consumer taxes.

Potential projects, Realized projects – the parameter floor space is transformed to the parameter standard project with the floor area $350m^2$. It allows us to consider also costs for HVAC system improvement. The number of new projects is influenced also by the capacity of the building sector companies and nowadays also by the capacity of thermal insulation materials producers. The element *support* represents the efforts of the government to support the implementation of energy conscious projects.

Project effectivity – the evaluation of the projects on the basis of the assessment the investment costs and financial outcomes from the project. The financial outcomes are calculated from the quantity of the saved energy and the energy price. *Investment costs* – this parameter is influenced by the inflation rate. The amount of the investment costs influences the energy consumption.

RESULTS AND DISCUSSIONS

The model was developed in the program Stella. This program is widely used for the simulation by means of system dynamics models. The simulation time was chosen 10 years. To consider longer time does not make sense because of high number of uncertain parameters influencing the next development.

The simulation was performed with the goal to predict the number of realized projects and the amount of the saved energy.

The calculated parameters are depicted in Figure 6. The simulation was done for these input values: *Support* (government support of project implementation) 1, it means without the support. *Price regulation* 1.19 (only VAT 19% was considered). *Economic growth* in world 3%. *Desired capacity changes* 4% (the change of the capacities of building sector companies).

Number of predicted realized projects after 5 years is 59627, in case of price regulation 1.38 is the figure 79909 and for 1.57 is the resultant value 100174.

Sensitivity analysis

The simulation allows us to perform high number of different calculations. Presented graphs in Figure 6 are only examples of the outputs. It is useful to use sensitivity analysis to identify the most important parameters that can influence output parameters. In this case the investigated output parameter is number of realized projects. The resultant values are in Figure 7 and Figure 8.

The results demonstrate considerable influence of the price regulation on the number of the realized projects in the time period 10 years.

Model limitation and next development

In reality, the stock *Potential project* is not constant parameter but it is still filled by the flow of the new buildings because their thermal parameters became obsolete after same time. Also, same buildings in the stock *Realized projects* will be moved in the future to the stock *Potential project*. New technical solutions can bring new opportunity for buildings where thermal performance was improved in the past years.

Important problem is the price setting in the local market. The price for the final consumers is influenced by many factors (e.g. price is based on long time contracts, politics of energy distributors).

Another issue is the model validation. The comparison of the real world outputs and the simulated outputs is much more complicated in large-scale soft (socioeconomic) systems then in hard systems. It is difficult to prepare the experiment. The reason is the high complexity of the problem and the changes of the exogenous variables during the period when the simulation is performed. The calculated outputs are from year 2007 and they will be compared with 2008 data.

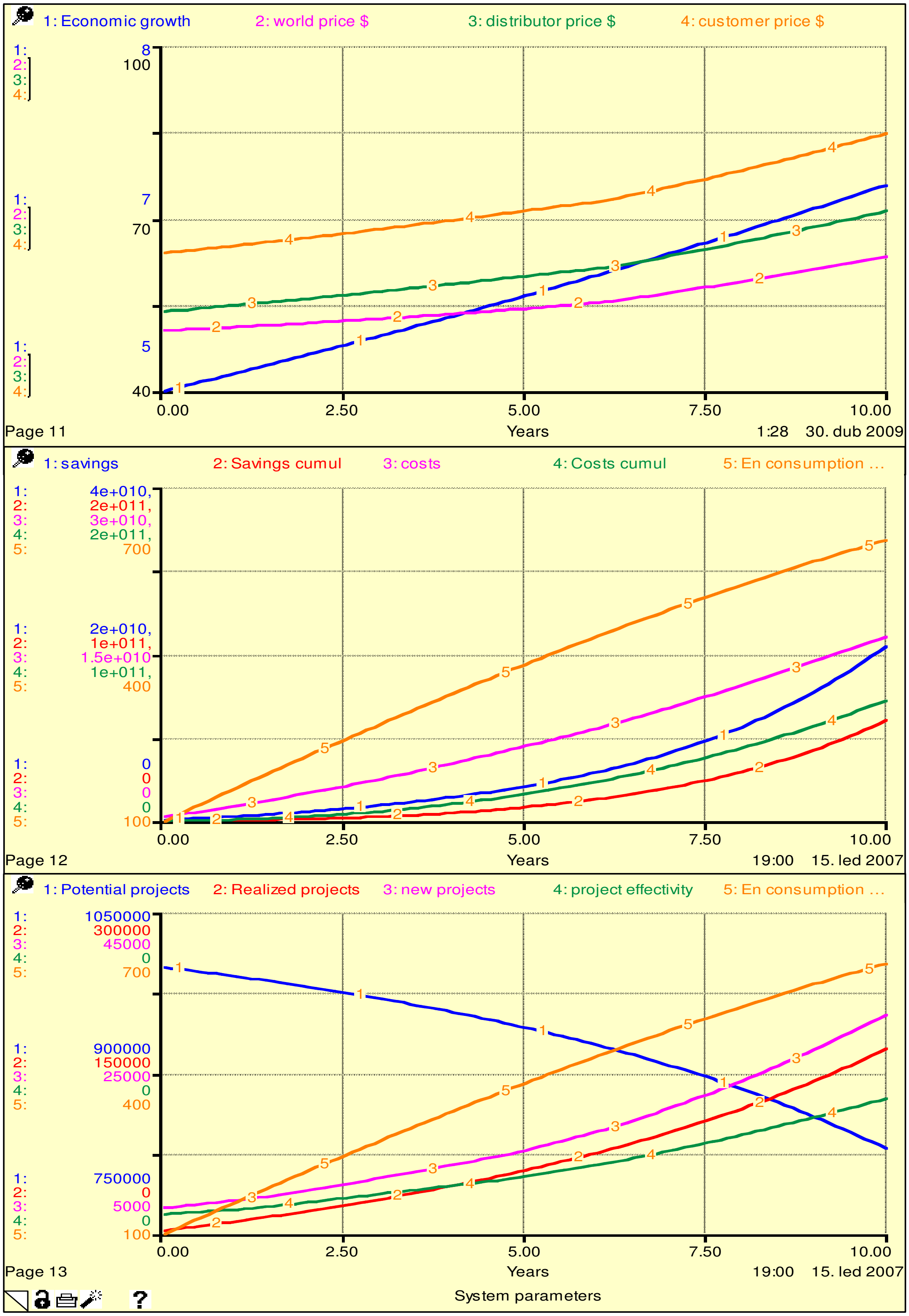

Figure 6 Output system parameters

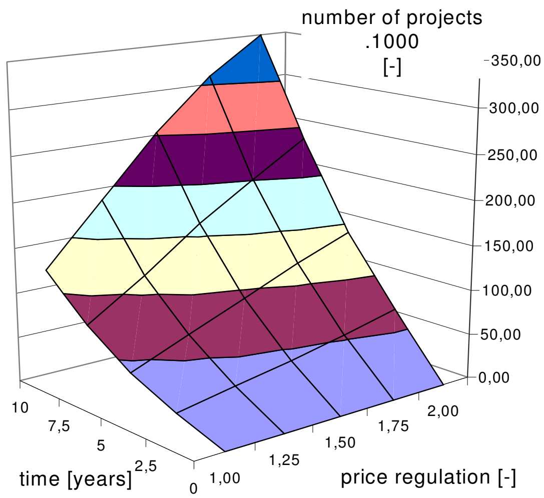

Figure 7 Sensitivity to price regulation

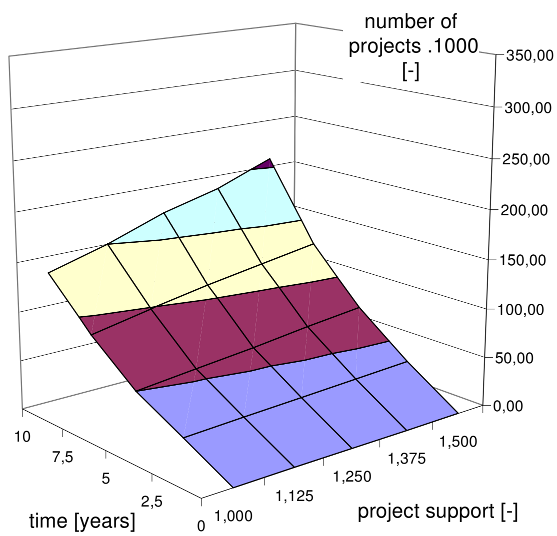

Figure 8 Sensitivity to project support

The comparison with 2009 data will be complicated because the government introduced the financial support of the energy saving projects in the buildings. This is the typical example of the change that will substantially influence the simulated outputs and it means to perform the simulation for different values of the investment costs. It is also big challenge to test the model for the step change. The dynamic behaviour of the system is very interesting in this case. It is possible to observe the consequences of this decision such as the changes of the construction works prices or the changes of the demand for materials and the need for higher capacity of the suppliers.

The application of the system dynamics models is still the exception. The typical solution is based on ad-hoc approach when the decision makers do not do the adequate analysis and do not consider the delays in the system and the impact of the proposed changes on other elements of the system.

CONCLUSION

The developed model helps to predict the dynamic behavior of the complex system with many parameters. It is the useful tool for:

- Policy testing. Output parameters can test different policy for the goal to decrease the energy consumption in the buildings. In the model we can change certain parameters but also it is possible to change the system structure, e.g. to connect the tax yield with the project support.
- Design of the capacity. The energy price variability affects the demand for project implementations and it evokes changes in the construction sector. Construction companies should predict the market of the energy saving projects. Consequently, material and component suppliers can predict the demand for their supplies. The thermal insulation material shortage in past years (2007, 2008) is good reason for solving capacity problem.

Results from the simulation shows that the main driving force in the system is the economic growth that overcomes the influence of the negative loops trying to keep the energy prices on the stable level. Nowadays, it is possible to observe new impulse for energy saving efforts and this is the energy security.

ACKNOWLEDGEMENT

This research has been supported by MSMT grant 6840770006.

REFERENCES

Meadows, H.M., Meadows, L.M., and Randers, J. 1992. Beyond the Limits: Confronting Global Collapse, Envisioning a Sustainable Future, Chelsea Green Publishing.

Richmond, B.M. 2001. An Introduction to System Thinking, High Performance System.

Sterman, J.D. 2000. Business Dynamics – System Thinking and Modeling for a Complex World, McGraw-Hill.

Zemene, P. and Rydlo, P. 2006. "Energy consumption decreasing by EPS in existent buildings and the advantage of layer structures in new buildings," Stavitel, 3, pp 53-56.