Application of system dynamics for design of national energy and climate plan

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Extended Abstract
EU member states must establish integrated national energy and climate plan (NECP) for the period 2021-2030 which show how countries will reach targets for cumulative energy savings and the share of renewable energy sources in the total final energy consumption. Energy systems currently experience a profound change – transition to carbon-neutral systems. Modeling of such systems requires understanding of technical, economic and social factors. This paper shows how system dynamics modeling can be applied to design of NECP, and it is demonstrated for the case of Latvia. Therefore, the presented study can be viewed as a contribution to development of socio-technical energy transition studies using system dynamics modeling approach. Dynamic problem is that the rates of energy efficiency improvements and increase of the share of renewable energy sources in the total final energy consumption, resulting from the existing policy instruments, may not be sufficient to reach the targets set in the plans. The presented study addresses that dynamic problem by using dynamic hypothesis that policy instruments have to address not only technological and economic factors but also social factors which are included in structure of the modeled system. Several policy scenarios are analyzed with the aim to find the policy instruments which enable to reach the targets. The model can be used also for other countries. The time span used for modeling was 2017 – 2030, and the statistical data of the year 2017 were used for calibrating the model. The policy instruments were designed in group modelling sessions with involvement of energy experts, owners of buildings and representatives of households, industry and other important stakeholders. The model includes energy supply and demand sectors as sub-models. Energy supply sector represents various energy (electricity and heat) supply technologies (e.g. wind, solar, natural gas-based, heat pumps) in terms of installed capacities, associated investments, operation and maintenance costs. As for the supply sector, investment choice between renewable or fossil fuel technologies is determined based on comparison of long-run marginal (LRMC) costs via *logit* function Subsidies (e.g. investment subsidies) make renewable energy technologies (RES) more competitive with fossil fuel technologies and imported electricity. Increased production from RES results in decrease of a risk premium, which accounts for uncertainty of running non-mature technologies, and can be modeled as additional costs of power production. In addition, increased capacity leads

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to decrease of technology costs due to the learning effect. As the risk premium and specific investment costs decrease, so does LRMC, resulting in increased investment in new RES electricity generation capacity, *ceteris paribus*. These are the main feedbacks associated with the energy supply.

Demand-side is sub-divided in submodels which represent different ownership of buildings as well as energy demand sectors. The main focus in the model is on behavior of consumers. Rate of energy efficiency improvements to most extent depends on human behavior – willingness to act, acceptance of technologies, trust, and similar factors. Demand-side models address these factors and barriers, at least partly, by comparing perceived net benefits from insulation of buildings and costs, composed by direct insulation costs and perceived uncertainty costs. The uncertainty costs are monetized non-financial barriers to insulation, e.g. mistrust to energy auditors and construction companies, inconveniences associated with organization of the process, etc.

Policy actions are based on analysis of barriers for energy efficiency activities in different sectors in Latvia. Aim of the policy actions is to reduce or eliminate those barriers. These policy instruments can be divided in four groups:

1) stimuli created by a state – legislation, conditions and similar motivating mechanisms;
2) information and education activities – education programs aimed at changing human attitude and behavior by providing information;
3) involving local communities – stimulating socially responsible behavior by using non-governmental processes which are effective in small social groups and communities;
4) change of value system – use of moral, religious and/or ethical arguments for achieving a desirable social behavior.

The results show importance of involvement of municipalities in taking responsibility for reaching energy efficiency targets since municipalities can be very effective in applying various policy instruments within their authority. The scenario using energy consumption tax is slightly better than the scenario which relies on the energy efficiency obligation scheme responsibility. However, this scenario could be one of the most difficult to implement since increase of taxes is politically very sensitive issue. This became apparent when results were discussed with the government authorities responsible for energy policy. Regardless of which policy scenario will be chosen, the additional funding is needed. The sources for this additional funding could be incomes from real estate tax, which is charged depending on energy consumption of a building, and energy consumption tax or additional tax on energy resources. As for the energy supply sector, the policy scenarios propose only one instrument – subsidies to heat pumps in district heating. Funding for the subsidies may be obtained by reducing tax reliefs on fossil fuels, mainly in agriculture. Other renewable energy technologies may not need additional subsidies since it is expected that these technologies will be competitive with fossil-based power production in future.