Modeling Residential Space Heating Energy for Romania

Ion Smeureanu, Adriana Reveiu, Marian Dardala, Titus Felix Furtuna, Roman Kanala

***Abstract*—**This paper proposes a linear model for optimizing domestic energy consumption in Romania. The particularity of the model is that it is putting in competition both tangible technologies and thermal insulation projects with different financing modes.

The model is optimizing the energy system by minimizing the global discounted cost in household sector, by integrating residential lighting, space heating, hot water, combined space heating – hot water, as well as space cooling, in a monolithic model. Another demand sector included is the passenger transport.

This paper focuses on space heating part, analyzing technical and economic issues related to investment decisions to envelope and insulate buildings, in order to minimize energy consumption.

***Keywords*—**Consumer behavior, energy modelling, Open Source Energy Modeling System (OSeMOSYS), MARKAL/TIMES Romanian energy model.

I. Introduction

REDUCING energy consumption has been an important issue for a long time. New solutions for decreasing energy consumption appear every year.

According to Eurostat, in 2013, the final end-use of energy consumption in the EU-28 shows three dominant categories: namely, transport (31.6%), households (26.8%) and industry (25.1%), followed by services (13.8%), agriculture and forestry (2.2%) and others (0.6%) [1].

For decades, energy and environmental planning models such as MARKAL, TIMES and OSeMOSYS have been used by policy makers to take and support long-term decisions [2].

MARKAL/TIMES framework has been developed under the auspices of the IEA-ETSAP (International Energy Agency Energy Technology Systems Analysis Program). It is used, on global to community level, for energy system modeling, and to facilitate investigation of scenarios about possible energy futures. TIMES is an updated version incorporating advanced features like flexible time step and better description of technologies, giving the modeler more flexibility.

OSeMOSYS is an open modeling framework, developed by cooperating institutions like Stockholm Environment Institute, International Atomic Energy Agency, UK Energy Research Center, and Royal Technical University of Sweden.

Energy modeling frameworks, implemented by software platforms like MARKAL/TIMES and OSeMOSYS, automatically generate hundreds of model equations, based on available technologies and their parameters, yields, capacities and on energy resources available.

A standard MARKAL/TIMES model addresses the entire energy flow, from raw material extraction and production of a variety of primary fuels, to energy conversion and transport through carriers, to the demand by end consumers. The objective function of such a model is minimizing the discounted total cost over a time period. The goal is to provide an optimum combination between technologies in competition, as well as all energy agents used, at minimal cost.

The model proposed in this paper aims to optimize household energy consumption, and consequently focuses only on residential end-use technologies, considering primary energy as virtual imports. The primary energy carriers are transformed into corresponding forms of consumer demand, like lighting, space heating / cooling, hot water or space heating combined with hot water system, and passenger transport.

Domestic energy consumption in Romania is about 2-3 times higher than in Western European countries. Our study is analyzing the potential of thermal rehabilitation of buildings. Building rehabilitation process started two years ago back in 2013. Due to Romania's weather conditions, the average household energy consumption expenditure varies between 15 and 20% of total expenditure of a household.

In 2012, the European Commission adopted new regulations on thermal insulation of buildings. Funding from the European Regional Development Fund is destined in priority for apartment blocks for disadvantaged and low-income families, on condition that the owners contribute at least 10% of the total cost of thermal insulation of the apartments block.

II. Considerations about the Energy Model Implementation for Romania

The presented model is based on the principle of economic equilibrium and finds the optimal investment vector in housing sector, ensuring the household energy needs, at the lowest price. This approach is suitable for a market economy and allows the modeler to adhere to the principles of sustainable development through environmental constraints. Paper [3] includes more arguments about the need for a sustainable energy model for Romania.

Both TIMES and OSeMOSYS modelling systems are used to accomplish our research goal. Although the complete model is developed and run in the TIMES framework, for this study

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OSeMOSYS open source system has been preferred. Compared to TIMES, OSeMOSYS system implements most of its key features, but also provides total control over the model equations allowing the modeler to modify the model structure during model development and calibration. The construction of the model starts by defining the useful demand through energy carriers to technologies back to the production side [4].

To model the residential space heating, a new system block named Romania MARKAL / TIMES is added. This block contains its own equations that describe technologies associated with heating of living spaces, from insulated buildings, completing existing equations from the basic OSeMOSYS model. The technologies for space heating used in the model are presented in Table I.

Heating costs may decrease by as much as 40% after a thermal rehabilitation, the original technologies implemented in the initial model were completed by thermal insulation technologies with their own technical parameters. Such an approach allows heating technologies to compete on minimal total energy system costs with each other, be they of different efficiency and fuel used, but also within the same fuel, investing in improved thermal insulation. The investments are in competition in function of the nature of the funds, as they can be redeemable or non-redeemable funds.

TABLE I
TECHNOLOGIES USED FOR SPACE HEATING MODEL

Technology		Input fuel	Demand
TSHENVFLAT / TSHFLAT	Space heating apartment insulated / not insulated	EHESH	DHSHT
TSHENVCONH / TSHCONH	Space heating concrete house insulated / not insulated	EHESH	DHSHT
TSHENVWOOH / TSHWOOH	Space heating wood house insulated / not insulated	EHESH	DHSHT
TSHENVVILL / TSHVILL	Space heating villa insulated / not insulated	EHESH	DHSHT

Energy agent used for residential space heating can be natural gas, biomass (especially wood), low temperature heat, oil products, coal, electricity through their own systems or combined heating and hot water.

A. Assumptions

- The model deals only with residential heating. Companies' offices, industrial and commercial spaces, warehouses are not included in this model.
- Energy consumption includes heating in winter time, and cooling during summer time.
- The amount of money that can be attributed from European Regional Development Funds (ERDF), for thermal insulation of buildings is subject to an upper bound negotiated for this kind of funds, and by the inexperience of Romanian associations and individuals to create and submit for approval projects of thermal insulation of buildings.
- Availability of government funds (FGOV) may also be upper bound by policies on consumption of certain efficient heating technologies.
- Funds of individual owners (FPRO) are restricted by personal income and by the share of family budget allocated for house insulating. The various categories of houses can benefit of different funds, like: European funds, government funds, funds owned by associations of owners. Construction of new thermal insulated houses cannot benefit of government funding.
- Restrictions of funds composition may exist for some categories of houses like: the share of co-financing with the government, or the owners should contribute to a thermal insulation project. From the total value of thermal rehabilitation projects, 50-60% in average is covered by European funds distributed through the Ministry of Regional Development and Housing, while the remaining amount of 40-50% comes from the State budget, local budgets, or from homeowners' associations [5].
- The lifetime of insulation technology for space heating varies for different types of houses: 20 years is the life time for apartment blocks, 30 years for concrete houses, 10 years for wood houses, and 30 years for villas [6].
- The availability of a new thermal insulation technology is restricted not only by the investment required, but also by the existing buildings still non-enveloped in each category, Fig. 1 [7].
- Space heating technologies can coexist in parallel as complementary technologies for each type of housing; namely they complement each other to cover total demand for each type of buildings. For example, the technologies related to insulated and non-insulated apartments refer to the same total demand; for this reason IsParallelTechnologySH parameter is enabled.
- It takes into account the nature of the grant funds (param IsIrredeemableFund).

Time is measured in years. To reflect the diurnal and seasonal variability of the energy consumption in Romania, the analysis was done on three seasonal time slices (winter, summer and intermediate) and two diurnal ones (day, night).

The 365 days of the year are distributed into winter time - 150 days; intermediate - 125 days; summer time - 90 days. Hourly distribution day/night is 9/15 hours during winter time, for intermediate season 12/12 and 15/9 hours in summer, respectively.

To describe new processes and specific technologies, we introduce new datasets and parameters. Some of these have been estimated based on statistical research "CEnG: energy consumption in households in 2009" held between 2010-2011, under coordination and partial funding of Eurostat [7].

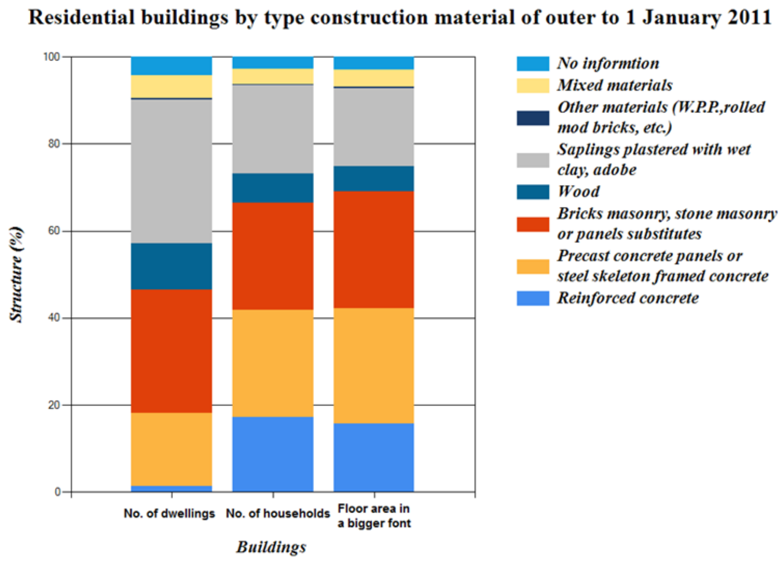

Fig. 1 The structure of the housing as of 1.1.2011 in terms of number of dwellings, number of households and floor area

For the heating sub-system:
407.4 * 10 ^6 sqm
130 kWh/sqm
52962 * 10 ^ 6 kWh/year-> **190.66 PJ**
For cooling sub-system:
20 kWh/sqm
1.43 * 10^ 6 sqm-> 0.0936 PJ

Fig. 2 displays the overall Reference Energy System diagram used to model lighting and space heating, in Romania. Reference Energy System resumes all the technologies and energy flows from the supply side, virtual energy imports of energy, to the end-use demand.

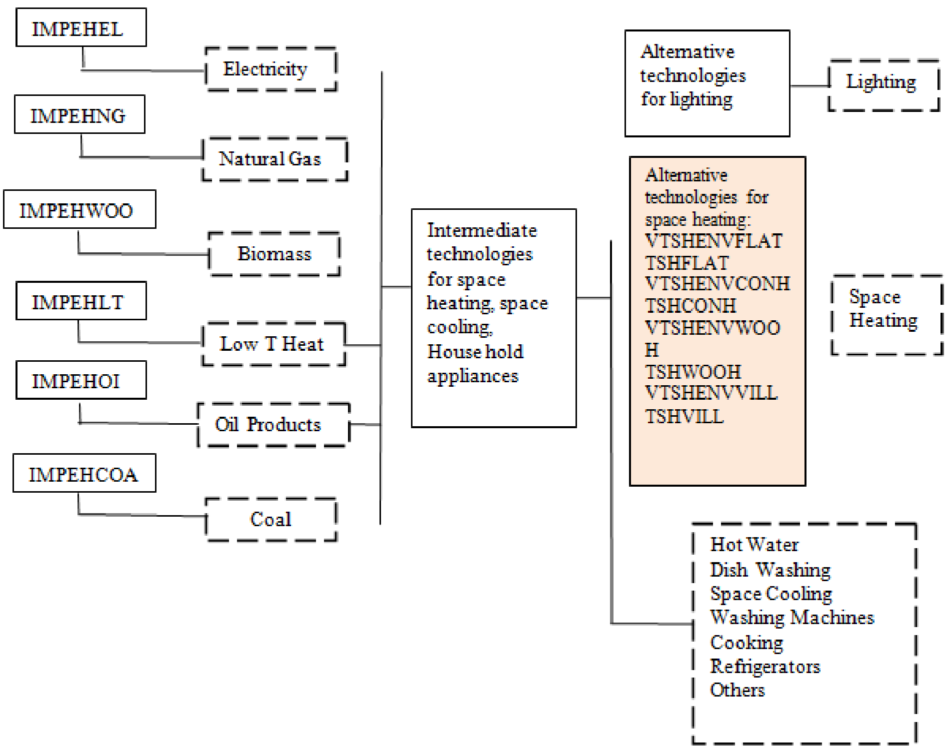

Fig. 2 Proposed Reference Energy System for lighting and space heating

III. Some Results

The described energy model, implemented both in MARKAL/TIMES and OSeMOSYS modeling frameworks provides some quite interesting results.

Although the share of wooden houses is significant, projects for insulating wooden houses are rather rare because of limited financial resources of owners, but also because of absence of a coherent local policy to support small projects to insulate wooden houses.

Actual observed investment vector for each space heating technology may differ from the optimal investment path computed by the model. Indeed, the decision maker, typically the owner, may have preferences of a certain investment behavior, be it under-optimal. For this reason the model should be updated every year with observed results that become the actual installed residual capacities at the beginning of the optimization period.

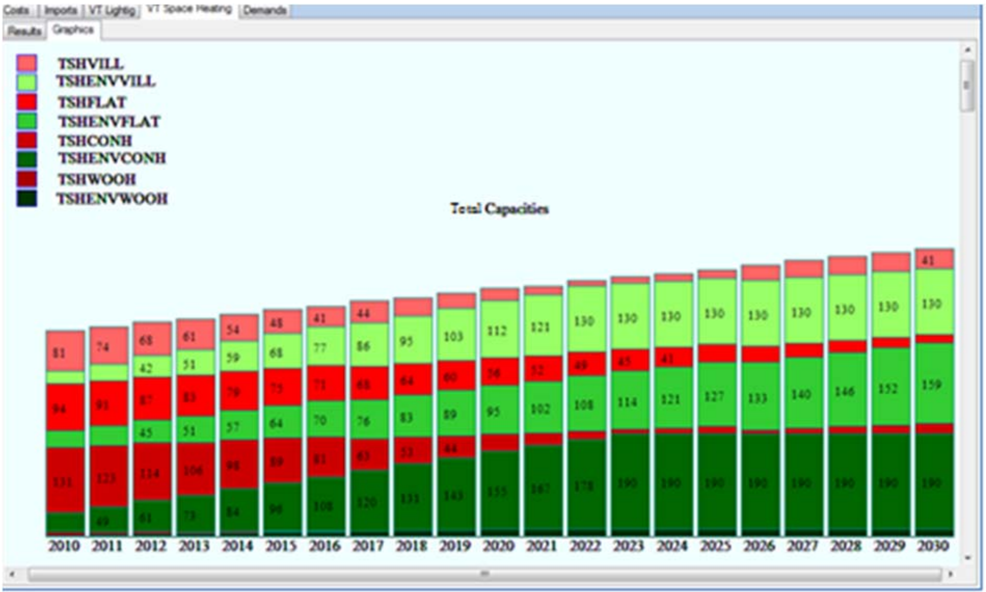

Fig. 3 Space heating demand cover

Space heating demand cover presented in Fig. 3 helps us to conclude that about eight years from now is still justified to continue the thermal insulation of buildings: mainly for apartment blocks, as well as for individual houses, made of concrete.

Fig. 4 presents the dynamics of installing capacities of competing technologies for space heating for the modeled time horizon 2010 - 2030.

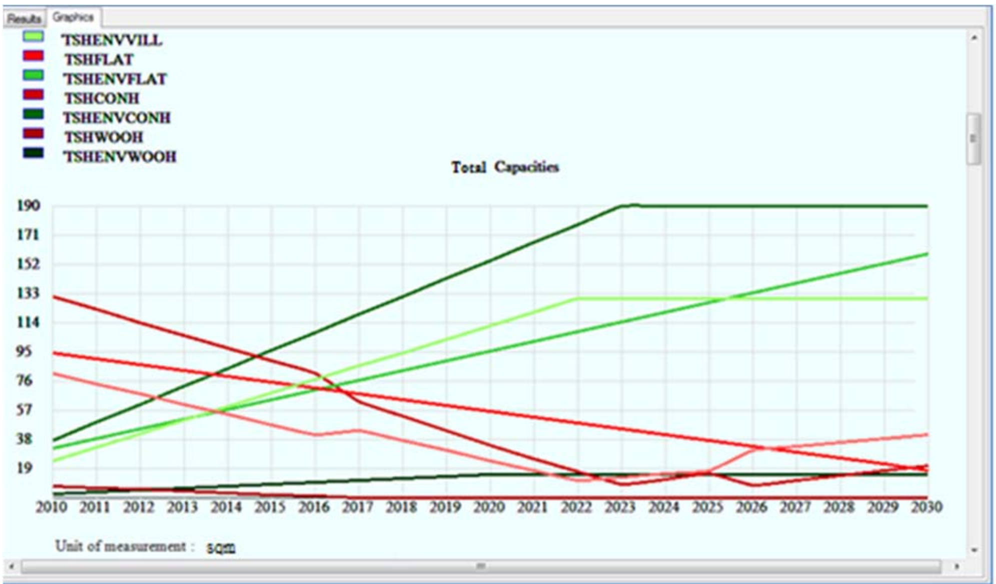

Fig. 4 Dynamics of thermal insulation technologies for space heating

IV. Conclusions and Future Works

The model should be refined and completed with more detailed and updated data about techno-economic issues and about consumer behavior, as proposed in [8].

In order to encourage the investment in thermal insulation, outreach campaigns about funding opportunities could be run.

The future versions of the model should also consider the share of 25% the share of renewables in heat production, proposed by Directive promoting the renewable heating and cooling until 2020.

Finally, in order to better assess the heating consumers' behavior, the tangible technology "residential heating" could be decomposed into three separated virtual technologies interconnected by virtual energy flows as proposed in [9]: envelope of the building, heating system and energy services consumer behavior.

Acknowledgment

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