International Journal of Energy and Environmental Engineering
ISSN: 2008-9163 eISSN:2251-6832
Vol.2 / No.4 (pp.83-94) / Fall 2011

The Impact of Renewable Energy and Energy Efficient Technologies, what to choose in case of limited supportive actions: a case study

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Received: 2 Mar. 2011 Accepted: 5 Jun. 2011

ABSTRACT

Research topics dealing with the application of the MarkAl model have been quite common in the last 20+ years. Every new paper has added new insight into the potential of using such a model for a variety of purposes. Not only global but also local applications have shown both limits and benefits when dealing with manifold energy-environmental-resources optimal management.

The aim of this work is to strengthen the idea that such models, even with the limits that have been underlined, can continue to contribute as a valid tool to assist local policy makers to have a better/objective idea of the impact and potential of certain actions. Besides, it provides a non-biased tool in case incentive resources run out and a diverse portfolio of actions to achieve set environmental targets does exist. In times where economic crises strike every sphere of political and civil actions, it is more important to be able to rely on objective instruments to support choices at every level. Thus the local level becomes more and more strategic.

The paper deals with an application of the Standard MarkAl model to a Northern Italian province (190 municipalities and half a million people), in order to give useful circumscribed information on the results coming out from a simple, but interconnected, optimized energy model, when a previous skimming has been performed to identify the target actions of possible incentives.

The choice is to benefit only few actions, in order to make the effect of it keener.

In this case the two competing actions in the residential sector are (i) fostering more efficient buildings vs. (ii) additional support for renewable technologies.

The scope of the applied research is to give economic and environmental indexes useful to decide where to invest the limited local resources. For this scope different energy development scenarios have been analyzed and their performance indicators identified.

Developing consistent local energy plans, by using a consolidated bottom up approach and by a combination of long-term planning strategy based upon technological development and replacement is still far from a routine procedure from a local policy makers' standpoint.

The study focuses on the thermal use of energy in the residential sector, being it the main target of the EPB Directive (2002/91/EC), whose impact, along with the role of renewable energies, are investigated with and without a public support.

Also, the role of the public commitment is highlighted in terms of effective policy that could drive the technological competition and the real estate market to achieve the optimal configuration of the energy system (the lowest cost and the lowest environmental impact), by means of subsidies for thermal solar and biomass technologies.

Keywords

local energy policy, renewable energy , MarkAl model.

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1. Introduction

The attention paid on energy and environment is rising in the everyday political agenda, even at a local level. As focused on the Agenda 21 document, approved at the Rio Conference in 1992, local administrations can play a fundamental role in acting for sustainability, according to the well-known motto "think globally act locally", and the inspiring principles of the Local A21 process is the suitable tool to design a strategic road map to sustainability. Thus, an effective local energy planning is an essential step in such a process, whether it is a GIS-based approach to supporting rural community energy planning as in [1] or more complicated models like in [2] [3], just to cite few. This is also recognized in developing countries where decentralized energy planning (and production) models are in the interest of efficient utilization of resources [4][5].

The aim of this work is to analyze the outcome of complex local energy model by providing few indexes. They should allow a technically based quantification of the efficacy of certain local actions, which would be implemented– with an emphasis on the residential sector- to comply with the broader European 2020 commitments. This work is in the same stream of [6] where the authors propose a framework of local energy sustainability indicators to be used both as an assessment and as an action-planning tool.

The case study deals with the modelling of the reference energy system of the Province of Pavia, Northern Italy, 190 municipalities with half a million people living there: different energy development scenarios have been compared by providing a strategic assessment of measures for the local energy planners, through an optimization model.

The tool is Standard MarkAl, a dynamic energy model generator based on linear programming and developed by the Energy Technology Systems Analysis (ETSAP).

It being a bottom up model, particular importance has been attached to building up the energy demand/energy service in terms of heating, hot water and cooking requirements. This has been performed by diligently collecting all the available information from the Provincial Inspection database for residential boilers, matching them with the building construction type, vintageand the consistency of the building stock from scattered information out of the 2001 National Census. 6 different building types have been modelled in order to assess the average energy efficiency (energy rating). All this information has been used to gauge the model in its final energy consumptions at the base year [7].

The study focuses on the thermal energy uses in the residential sector: the main driver is the assessment of the impact of the Energy Performance Buildings Directive (2002/91/EC) and the role of renewable energies, with and without the public aid.

Incentives are considered both to comply with the 2001/77/EC directive and to reach the EU target, being fixed by the 7224/1/2007 Rev1 document of the Council of the European Union (20% of renewable energy by 2020).

A careful application of the technical procedures (European and National standards) and uses of statistics have been carried out in order to calculate the residential thermal demand, being included in the model [7].

The energy rating system for buildings (A-rated, B-rated, …) is considered as an exogenous driver in the assessment of the energy demand and three interesting scenarios have been evaluated and analytically compared in terms of costs and environmental impacts to get qualitative/quantitative information in support of local policy actions.

This approach represents the real novelty in these kinds of studies; for the first time the attention is focused on an engineered demand assessment, rather than economic. The demand modelling has been carried out by the assessment of the thermal demand, according to technical standards and procedures: information on buildings and their technological installations have been used to build up a set of typical end-users, different from those models whose projections only depends upon the simple increase in the size and number of dwellings over the years. The analysis of results should thus give more comprehensive information on the technological transformation and on the optimal investments allocation.

2. Context

There is no novelty in using models for shaping and analyzing energy policies as well as assessing environmental policies.

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The economic interest in studying the match between supply and demand grew as of the late 70's and according to manifold scopes of models spread across the scientific communities. Recently, the features characterizing such papers can be described by dealing with bigger and bigger models [8][9][10][11][12][13][14][15] or by being quite local [2][3][16][17][18][19].

The comprehensive huge models (country, or bunch of countries or continents) are mainly interested in (i) investigating the role of new supply resources and technologies, (ii) the performances of different policy actions (i.e. the tax or emission caps, the tradable permits system, etc.), (iii) emission reduction and recently (iv) the evolution of energy market. These models, while dealing with energy supply shortages, energy security and local environmental protection seem to lack in the explanation of some details and often choose to look at issues with a top down approach.

GMM (Global MarkAl Model) is an example of a multi- region model used to analyze trends of macro economic indexes. For instance, Rafay and Kypreos in [16] analyze the impact of external costs (the costs of environmental and health damages due to different pollutants) on the power generation system. The study focuses on the structural changes of power generation.

Another multi-regions model is the Western European MarkAl model [13, 18]. In [18] different scenarios, investigating different solutions in the achievement of emission reduction targets, are shown. Country models are not made up of geographic aggregations but put more emphasis on technologies and demand aggregation. Country models are often used in order to study market penetration of new technologies or to study impacts of national/international energy policy. Using the SWISS-MarkAl model Schulz et al. [9] analyze the economic conditions, making the new biomass technologies more competitive in the energy market and providing projection of future technology investments. A market penetration analysis of hydrogen fueled vehicles with a MarkAl model is proposed by Endo in [8] to validate the hydrogen energy roadmap of Japan. He also studies the effect of different carbon taxes in order to achieve the environmental international goals. With a similar approach Endo focuses his attention on photovoltaics plants [14]. In [11] Murphy et al. use CIMS hybrid model to analyze the impact on the Canadian industrial sector of an economy-wide compulsory GHG reduction policy; results focuses on technological competition. A different approach in energy system analysis by models is performed by Krukanont [10]; the case study of Japan shows how to run optimization models with a stochastic analysis.

Local models try to solve local problems and although they should be looked at as the core of bigger models (sub regions), actually, they are not. The valuable features of local models lie in their being strongly detailed, thus allowing a more accurate analysis. On the other hand, they do often consider the local energy system as a close system, narrowing a comprehensive understanding of the drivers of the interconnected energy markets. In a recent paper Chen Changhong et al. [17] report results of a study on local energy policies to reduce air pollutants in China. An interesting example of local model is the Basilicata-MarkAl model: paper [2] and [3] discuss the role of local communities in achieving the Kyoto Protocol goals. The same model is also used to assess the optimal configuration of the waste management system for the Basilicata Region [19].

3. Methodology and input data

The Province of Pavia (PP) spreads over 2.965 km^2 area, southwest of the Lombardy Region, hosting 190 municipalities and roughly half a million people. In the year 2000, PP imported about 95% of electricity: the little endogenous production was based on hydropower plants and fossil-fired power plants. As of 2005, the outlook of energy production changed, by new fossil-fired power plants being operated. The province now is an electricity exporter. The overall energy consumption in the base year (2003) is about 100 PJ, of which 12.4% deals with the thermal energy use in the residential sector. The residential thermal use is split up into (i) autonomous heating, (ii) centralized heating, (iii) cooking and (iv) sanitary hot water. Table 1 shows the final energy consumptions of PP in 2003, according to a sectoral division of resources, while in table 2 the residential thermal consumption is summarized by fuel. The modelling is based on the ALEP

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(Advanced Local Energy Planning) methodology, being developed under the aegis of IEA (Annex 33) and aiming to develop consistent local energy plans. It integrates different tools and analysis techniques: reliable and comprehensive databases, classical statistical analysis and modeling tools (optimization and simulation). The tool of the ALEP methodology is the MarkAl bottom up model generator.

The Standard MarkAl model is a multi-period linear programming (LP) formulation of a reference energy system (RES). One of the objective functions in the LP model is the discounted sum, over the considered time horizon, of the net total costs made up of investments, operational and maintenance costs, technologies and balance between imported/exported resources. The total cost of the energy system is the sum of costs incurred in primary extraction, transformation, transmission, distribution, including taxes and subsidies, taking into account the efficiencies of all intermediate technologies.

The constraints are represented by the link between supply and demand of energy (energy flows, production of electricity, production of heat, conversion of energy, end-users technologies and energy services) and its environmental significance (pollutant emissions). The features of the model deal with meeting the useful energy demand, curbing the emissions, the balance amongst energy carriers, the capacity production issue (residual and bounds), etc..

The formulation of MarkAl is written in GAMS modelling language. One of the main hypothesis in a standard MarkAl run is that all exogenous parameters are known with certainty (perfect foresight), meaning that all investment decisions are taken in each period with full knowledge of future events.

The MarkAl energy economy consists of:

1. Demands, representing the energy services (e.g., space heating,) that must be satisfied by the system;
2. Energy sources (e.g. imports), representing methods of securing various energy carriers;
3. Technologies either transforming one energy carrier to another or into an useful energy service;
4. Commodities consisting of energy carriers, energy services, materials, and emissions that are either produced or consumed by theenergy sources, technologies and demands.

The relationships among these various entities can be described by using a network diagram referred to as a Reference Energy System (RES). In the MarkAl RES a node represents a source, technology, or demand, and a link (arc) represents a commodity (energy carrier, material, energy service). An emission is represented by an open ended link pointing away from the emitting node.

4. The main assumptions of the model

The PP MarkAl model is currently partially detailed, meaning that it does not include the whole energy system, yet, and only the residential thermal sector is well described. It thus occurs that the results do not benefit of any feedback and/or integration with other subsectors. On the other hand this model is so well detailed that it can give useful information about the focused energy system development. The selected sector is being developed and detailed in its whole energy framework; a comparison between the output of such model and the results from the overall province model will give a better understanding of the subsector links and scale factors. The studied region includes (i) 2 areas; (ii) 4 final energy demands for each area; (iii) 54 demand technologies; (iv) 7 commodities (energy carriers plus CO_2 emissions).

Table 1: Final energy consumption of the PP in 2003 (ktoe).
The civil sector accounts both for the residential and the commercial sector

	Agricolture	Industry	Civil	Transportation	Electricity Production	Total	%
Electricity	12.3	277.2	260.1	13.1	-	562.7	25%
Natural Gas		690.3	360.3	1.8	85	1137.4	49%
Gasoline	2		-	133.9	-	135.9	6%
Gasoil	23.3	4.5	16.4	160.4		204.6	9%
LPG	-	-	11.5	5.8		17.3	1%
Heating Oil		133.9	4.9	0.2	-	139	6%
Petcoke		104	-	-	-	104	5%
Total	38	1210	653	315	85	2301	-
%	2%	53%	28%	14%	4%		

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Table 2: Residential thermal consumption, split up into demand and commodities. (1 Mtoe = 41.86 PJ)

	Electricity	Natural Gas	Heating Oil	LPG	Total
Autonomous Residential Heating Consumption [ktoe]	1.46	166.50	5.04	2.99	175.99
Centralized Residential Heating Consumption [ktoe]	-	41.63	12.27	1.22	55.12
Total Residential Heating Consumptions [ktoe]	*1.46*	*208.14*	*17.31*	*4.21*	*231.11*
Residential Hot Water Consumption [ktoe]	8.16	23.70	0.65	0.42	32.94
Residential Cooking Consumption [ktoe]	1.02	16.64	-	-	17.66
Total Residential Consumption [ktoe]	*10.63*	*248.48*	*17.96*	*4.63*	*281.70*

Fig 1 shows an aggregated version of the RES of the PP MarkAl model.

The two considered areas distinguish between the city of Pavia and the rest of Province, to take into account the known differences between the two.

The modelled demands for each area are:

- Residential heating demand – autonomous;
- Residential heating demand – centralized;
- Hot water demand;
- Cooking demand.

The assessment of the thermal heating demands represents the novelty of this model with respect to other similar studies. The statistical census data (Istat 2001) provide a large amount of information and figures about the dwellings features, vintages, building construction type and used technological systems, total inhabited area, etc. etc.

First assumptions come from these information and allowed to rank the existing buildings in 6 main categories, defined by different energy performances, according to the combination of construction kinds (walls and windows transmittance index, age).

Next, the heating demand of each category has been calculated by means of an Excel Model, based upon the National Technical Standard UNI 7357.

$$Q_h = Q_t(K_t) + Q_v - \eta * Q_g \qquad (1)$$

Qh represents the heating demand, meaning the amount of heat (not the consumption) needed for the seasonal heating (kWh);

- Qt is the amount of energy lost through the building surfaces (walls and windows) and depends on the transmittance (Kt) of the layers;
- Qv is the amount of energy lost by venting;
- Qg is the energy from free contribution and η is a seasonal factor for the free inputs, taking into account the dynamic behavior of the building.

Next, any building category has been rated, according to the regional ranking system, based upon its heating demand and technological installations.

In order to split the PP heating demand into autonomous and centralized, the statistical census data have been matched with the local administration boiler inspections database figures.

As being a technologically driven model, the technologies, characterizing the use and conversion of energy in the system, have been divided into four categories:

Residual: They represent the installed capacity in the base year. Special attention has been paid to the modelling of residual technology: this has been pursued through the boiler inspection data base elaboration. Information on residential boilers have been split up by input energy carrier and age and classified by their measured efficiency. The model cannot invest on residual technologies. The residual capacity decreases according to the equipment life time.

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Standard: They are the less expensive and the less efficient technologies (e.g. gas boilers). They are identified by their input energy carrier.

Efficient: They represent the most efficient technologies but ask for greater investments (e.g. condensation boilers, district heating)

Renewable: The considered renewable energy technologies for the residential sector are biomass boilers and different kind of solar thermal systems (natural circulation solar collectors, forced circulation solar collectors, vacuum pipe collectors, condensing boiler and solar-thermal combination).

5. Results

5.1 Scenario assumptions

As far as the scenario assumptions are concerned, the main driver is the rating system (A-rated, B-rated, …) and the EPB Directive (2002/91/EC) impact. Time horizon spans from 2000 to 2030, being divided into 11 periods, of 3 year each. The model inputs are gauged on the year 2000 because of the ISTAT (National Institute for Statistics) referring figures. Money discount rate is set at 4 %. The rate of new buildings entering the model is 0.6 %/y and the rate of renovated buildings is 1.5 %/y.

Our interest focuses on the understanding of the potential benefit, achieved by tightening the request of higher energy standards for buildings and the role of the public commitment. From this perspective we studied three possible evolution of the rating system in terms of investments, consumption and emissions.

In the BASE (reference) scenario the main assumption deals with no improvements in the buildings efficiency: the heating demand distribution is kept constant all over the considered period and the heating demand grows linearly.

In the 311 scenario the new and renovated buildings are more efficient than in the base year and most of them are going to be C-rated; according to calculations the demand keeps quite constant in the whole considered period.

In the CA scenario most of the new and renovated building fall in the A-rated consumption range and the heating demand drops off. Table 3 shows 311 and CA scenario assumptions. After the analysis of the possible evolutions (BASE, 311, CA), a better investment analysis has been assessed. By taking into account the 311 scenario, as the reference layout of the energy system, the analysis has been performed comparing two different investments: i) on efficient buildings (CA scenario); ii) on renewable energies. For this purpose a new 311+ scenario, that takes into account subsidies for renewable, has been considered.

Higher investment costs for renewable technologies mean public subsidies are needed in order to comply with 2001/77/EC directive and to reach the target of 20% renewable by 2020 over the useful installed capacity.

Out of the results it is inferred that wood chip boilers would need a support of 17 €$_{2003}$/kW in order to achieve the share of 13% in 2020, while the solar thermal technology would need an average of 23 €$_{2003}$/kW to supply the remaining 7%. This subsidy, to ensure durable results, should be kept alive from 2009 onwards. The same result for wood chip boiler can be achieved by dropping off the price of the energy carrier by 2 €$_{2003}$/GJ (biomass NHV = 15,000 kJ/kg).

Table 3: 311 and CA scenario assumption for the evolution of residential heating demand.

RENOVATED AND NEW BUILDINGS RATING TREND ASSUMED IN 311 AND CA SCENARIO				
BUILDING EFFICIENCY RATING	RENOVATED BUILDINGS 311 Scenario	RENOVATED BUILDINGS CA scenario	NEW BUILDINGS 311 scenario	NEW BUILDINGS CA scenario
A	5%	5%	10%	70%
B	15%	15%	15%	20%
C	80%	80%	75%	10%
D	0	0	0	0
E	0	0	0	0
F	0	0	0	0
G	0	0	0	0

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5.2 Scenario Comparison

The main scenarios (BASE, 311 e CA) provide quite similar results, with respect to fuel use distribution, nevertheless important information can be drawn from a detailed analysis. The consumption trend of the three main scenarios is summarized in Table 4.

In the BASE scenario the overall demand grows in the considered period by 17% but the total net consumption decreases by 2%. In the 311 scenario the total demand decreases by 6% from 2003 to 2030 while consumptions drop off 24%; in the CA scenario the demand has an higher reduction (-10%) and consumptions decrease by 27%. In all scenarios the first half period is characterized by a strong decrease of consumptions. The annualized costs (summarized in Table 5) show the same trend, meaning that the fuel price remains a strong driver of the residential heating energy system.

These results can be explained by analyzing the distribution of the installed capacity of the demand technologies. An example is given in fig. 2 where the technologies competition in scenario 311 is shown.

With no bounds on the use of district heating (LTH), it would grow very fast, reaching out 70% of the supply in 2020, while the installed capacity is idling. For the sake of the optimization of the system the technological effort is gathered in the first half period.

Table 4: Total consumption (*fossil* + *wood chips*) and demand trend in the main scenarios.

Scenario		2020 (vs. 2003)	2027 (vs. 2020)	2027 (vs. 2003)
BASE	Consumption	-7%	3%	-4%
	Demand	10%	6%	17%
311	Consumption	-21%	-4%	-22%
	Demand	-3%	-2%	-6%
CA	Consumption	-23%	-5%	-26%
	Demand	-7%	-3%	-10%

Table 5: Annualized costs in different scenarios. They are indexed on the existing buildings (m^2).

ANNUALIZED COST (€$_{2003}$/m^2)			
SCENARIO	2010	2020	2030
BASE	13.09	11.82	11.61
311	12.74	11.08	10.60
CA	13.20	11.45	10.93

Fig 3 shows how consumptions decrease in the 311 scenario and the potential importance of the district heating.

This evolution can be explained by being the cogeneration a very efficient technology, in fact from a strict economic point of view it would be the ideal solution: it shows low investment rates (M€/GJ) and high efficiency. But these outcomes alone do not provide sufficient answers to our questions, yet.

A decreasing demand and higher specific investment costs mean renewable technologies take very little share in the residential sector consumption, unless remarkable environmental bounds are set. The share of the demand covered by renewable technologies is the same in the three different scenarios. In next tables, figures for the 311 scenario and for the new 311+ scenario are reported. The evolution of the installed capacity for significant technologies in 311 and 311+ scenarios is shown in Table 6. The total installed capacity is higher in 311+ because the availability factor of the technologies (in particular solar) is lower; this assertion became clear analyzing the net contribution of the technologies in satisfying the demand: the total value (that represents the total heating demand) is almost the same in the two scenarios (see Table 7). The district heating level is higher in the 311 than in 311 + scenario where it is replaced by wood chip boilers and solar (588 MW vs. 536 in 2020 and 604 vs. 584 MW in 2030). It is noteworthy to highlight that the installed capacity of standard fossil fuelled boilers is the same both in 311+ than in 311 A comparison between the 311, 311+ and CA scenarios, reported in Table 7, shows the specific fuel consumption (GJ/m^2) and CO_2 emissions (kg/m^2) indexes of the related scenarios. Taking the 311 system configuration as a reference, from 2003 to 2020 an higher fuel consumption reduction is achieved with subsidies on renewable (311+ scenario: -26% in 2010, -45% in 2020) rather than with subsidies on more efficient buildings (CA scenario: -25% in 2010, -44% in 2020) while at the end of the considered period better results can be achieved with a subsidy on more efficient buildings. Similar results can be inferred by analysing the CO_2 emission specific index.

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Therefore, a further analysis has been performed in order to find the best allocation for public subsidies. Figures on the fossil fuel saving potential, the CO_2 saving potential, the CO_2 reduction costs and the energy saving costs are reported in Table 8.

Taking as reference 311 scenario, the fossil fuel saving potential is higher in the 311+ energy system configuration than in the CA one (1.30 vs. 0.41 PJ in 2012, 2.71 vs. 1.05 PJ in 2020, 3.44 vs. 1.69 in 2030 PJ). As a consequence, also the CO_2 emissions saving potential is higher in 311+ than in CA.

Moreover the cost of a saved fossil GJ in the 311+ scenario is lower than the same values in CA (19.24 vs. 146.93 €$_{2003}$/GJ in 2012; 21.10 vs. 92.05 €$_{2003}$/GJ in 2020; 21.77 vs. 71.97 €$_{2003}$/GJ in 2030).

Otherwise the cost of any additional PJ saved in the CA, due to investments in more efficient buildings, can be read as the amount of the subsidy needed in order to greatly spread an A-rated configuration amongst the new and renovated buildings. Similar comments can be produced from the CO_2 reduction costs analysis (0.18 vs. 1.52 M€$_{2003}$/kt in 2012; 0.20 vs. 0.93 M€$_{2003}$/kt in 2020; 0.20 vs. 0.73 M€$_{2003}$/kt in 2030).

Making a qualitative comparison between significant indexes in 311, 311+ and CA, in medium-long term planning, the CA residential thermal system configuration is less convenient than the 311+ system configuration. Through 2030, the 311+ scenario is better performing than CA, fossil fuel and CO_2 saving potential are higher and the CA overall cost is higher in the whole considered period. These results support the concept that, under the exposed conditions, the best public commitment allocation should be foreseen on renewable energies thus, supporting renewable energies can be considered as the most effective action both in the medium and in the long term planning.

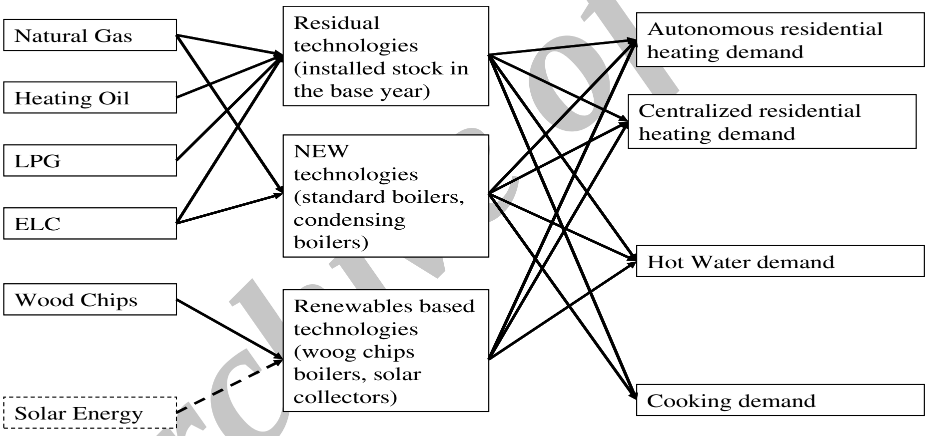

Fig. 1: Part of the RES of PP MarkAL Model (thermal residential sector)

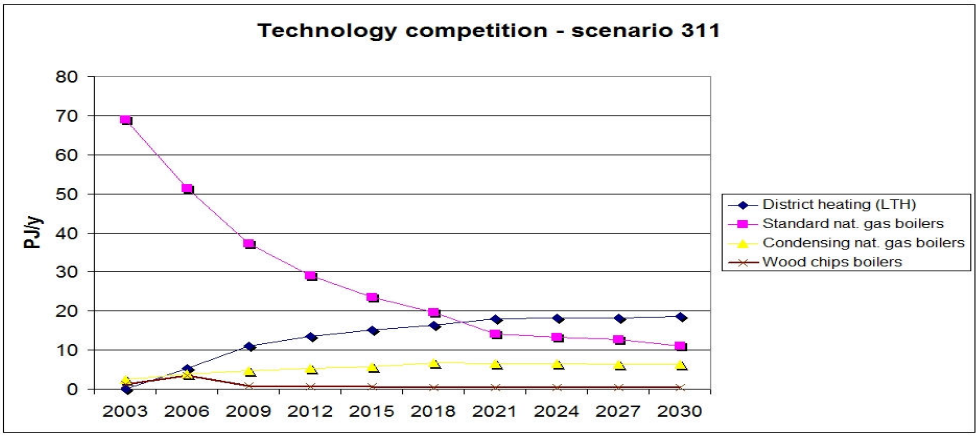

Fig 2: Technology competition in 311 scenario. Installed capacity.

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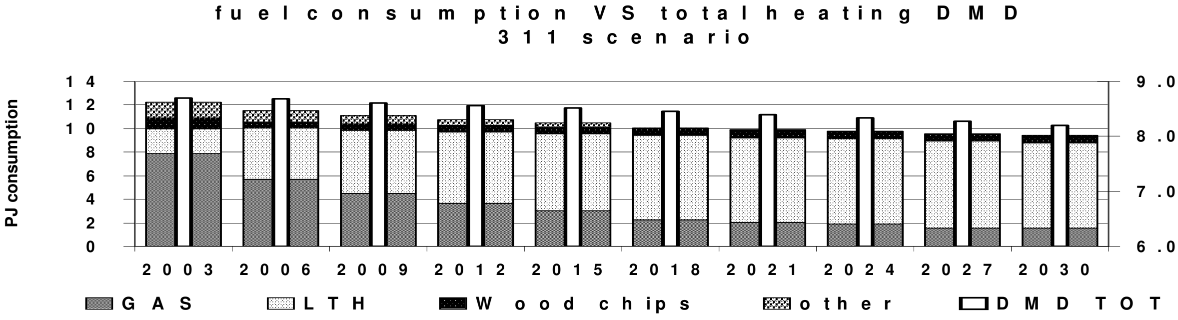

Fig. 3: Total consumption by fuel consumption VS total heating DMD 311 Scenario

Table 6: Technologies distribution in 311 and 311+ scenario. Installed capacity (MW) vs. Contribution on the satisfaction of the demand.

SCENARIO	TECHNOLOGY	USEFUL INSTALLED CAPACITY (CAP) [MW]		CONTRIBUTION ON THE SATISFACTION OF THE DEMAND (CDM) [PJ]	
		2020	*2030*	*2020*	*2030*
	District heating (boiler equivalent)	588	604	6.51	6.66
	Wood chips	13	14	0.05	0.05
311	Solar	-	-	-	-
	Fossil fuel (natural gas, heating oil, LGP)	348	209	1.08	0.74
	TOTAL	949	828	7.64	7.45
311+	District heating (boiler equivalent)	536	584	5.91	6.43
	Wood chips	173	76	0.61	0.27
	Solar	55	104	0.19	0.35
	Fossil fuel (natural gas, heating oil, LGP)	348	209	1.23	0.74
	TOTAL	1113	974	7.94	7.79

$CDM = CAP \cdot CF$, CF is the availability factor

Table 7: Fuel consumption and CO2 emissions in 311, 311+ and CA.

FOSSIL FUEL AND CO_2 EMISSIONS COMPARISON (311, 311+ and CA)				
SCENARIO	INDEX	2012	2020	2030
311	Fossil Fuel Consumption (GJ/m^2)	0.356	0.254	0.223
	CO_2 emissions (kg/m^2)	27.372	22.674	20.803
311 +	Fossil Fuel Consumption (GJ/m^2)	0.345	0.241	0.218
	CO_2 Emissions (kg/m^2)	26.198	21.254	20.274
CA	Fossil Fuel Consumption (GJ/m^2)	0.352	0.246	0.213
	CO_2 Emissions (kg/m^2)	26.999	21.929	19.847

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Table 8: Comparing scenarios: 311 vs. CA; 311 vs. 311+. Consumptions (GJ) and emissions (E) related to costs differences (C)

SIGNIFICANT INDEXES COMPARISON - Reference Scenario 311

FOSSIL FUEL CONSUMPTIONS ANALISYS

INDEX	COMPARED SCENARIOS	2012	2020	2030
Fossil Fuel Saving Potential (FSP) [PJ]	311+ - 311	1.30	2.71	3.44
	CA – 311	0.41	1.05	1.69
Cost of a Saved PJ of Fossil Fuel (CSF) [M€$_{2003}$/PJ]	311+ - 311	19.24	21.10	21.77
	CA – 311	146.93	92.05	71.97

CO$_2$ EMISSIONS ANALISYS

	COMPARED SCENARIOS	2010	2020	2027
CO$_2$ Emission saving Potential (ESP) [kt]	311+ - 311	136.91	289.38	368.95
	CA – 311	39.88	103.30	165.29
Cost of a saved kt of CO$_2$ (CSE) [M€$_{2003}$/kt]	311+ - 311	0.18	0.20	0.20
	CA – 311	1.52	0.93	0.73

Index summary

$FSP_y = \sum_{i=2003}^{y} F_i(Rs) - F_i(As)$ is the fossil fuel saving potential in the year y;

$ESP_y = \sum_{i=2003}^{y} E_i(Rs) - E_i(As)$ is the emission saving potential in the year y;

$CSF_y = CC_y / FSP_y$ is the cost of a saved PJ of Fossil Fuel ;

$CSE_y = CC_y / ESP_y$ is the cost of a saved kt of CO$_2$..

$F(S)_i$ the S scenario fossil fuel consumption in the year i;

$E(S)_i$ the S scenarioCO$_2$ emission in the year i;

Rs is the Reference Scenario, *As* is the Alternative Scenario;

$CC_y = \sum_{i=2003}^{y} CC_i(As) - CC_i(Rs)$ is the cumulated difference of the scenario cost in the year y.

6 .Final remarks

In this paper the authors report the results, coming out from a first energy modeling of the thermal use of energy in the residential sector for a local provincial area.

The scope of the modeling and optimization for the cited area is twofold: (i) to find out what can be the role of a tightening in the application of the EPB directive in terms of energy savings and costs; (ii) to highlight the role of the local public commitment with respect to renewable energies.

The results show that under the expressed conditions the implemented tool can give useful insight in terms of efficacies (environmental and economic), and, in case of scarse supportive actions, fostering renewable with additional incentives is surprisingly more effective than pushing on more efficient houses. Further developments are being scheduled to the fore, in order to complete the whole region RES. This should provide better understanding of what can be done in terms of supportive actions for local energy policies, by benefiting from a more comprehensive representation of all sensitive sectors.

References

[1] van Hoesen J, Letendre S, Evaluating potential renewable energy resources in

Arc

www.SID.ir

Poultney, Vermont: A GIS-based approach to supporting rural community energy planning, Renewable Energy 35 (2010) 2114-2122.

[2] Salvia M, Pietrapertosa F, Cosmi C,Cuomo V, Macchiato M, Approaching the Kyoto targets: a case study for Basilicata region (Italy), Renewable & Sustainable Energy Reviews 8 (2004) 73-90.

[3] Pietrapertosa F, Cosmi C, Macchiato M, Marmo G, Salvia M, Comprehensive modelling for approaching the Kyoto targets on a local scale, Renewable & Sustainable Energy Reviews 7 (2003) 249-270.

[4] Ojha K, Need of independent rural power producers in India-an overview, Clean Technologies and environmental policy 12 (2010) 495-501.

[5] Fielden D, Jacques J.K, Changing the management perspective on energy systems: How small clusters - And islands - Can achieve greater cost and energy efficiencies, International Journal of Energy Resources 21 (1997) 767-786.

[6] Neves A.R, Leal V, Energy sustainability indicators for local energy planning: Review of current practices and derivation of a new framework, Renewable & Sustainable Energy Reviews 14 (2010) 2723-2735.

[7] Muliere G, Modeling of energy conversion and end users systems: local long-term planning and optimization, PhD Thesis University of Pavia – Department of Electrical Engineering (2010).

[8] Endo E, Market penetration analysis of fuel cell vehicles in Japan by using the energy system model MARKAL. International Journal of Hydrogen Energy 32 (2007) 1347 –1354.

[9] Schulz T.F, Barreto L, Kypreos S, Stucki S., Assessing wood-based synthetic natural gas technologies using the SWISS-MARKAL model, Energy 32 (2007) 1948-1954.

[10] Krukanont P, Tezuka T, Implications of capacity expansion under uncertainty and value of information: The near-term energy planning of Japan, Energy 32 (2007) 1809-1824.

[11] Murphy R, Rivers N, Jaccard M, Hybrid modeling of industrial energy consumption and greenhouse gas emissions with an application to Canada, Energy Economics 29 (2007) 826-846.

[12] Tietze-Stockinger I, Fichtner W, Rentz O, A model to minimize joint total costs for industrial waste producers and waste management companies, Waste Management & Research 22 (2004) 466-476.

[13] Gielen D.J, de Feber M.A.P.C, Bos A.J.M, Gerlagh T , Biomass for energy or materials? A Western European systems engineering perspective, Energy Policy 29 (2001) 291-302.

[14] Endo E, Ichinohe I, Analysis on market deployment of photovoltaics in Japan using energy system model MARKAL, Solar Energy Materials & Solar Cells 90 (2006) 3061-3067.

[15] Tseng P, Lee J, Friley P, A hydrogen economy: opportunities and challenges, Energy 30 (2005) 2703-2720.

[16] Rafaj P, Kypreos S , Internalisation of external cost in the power generation sector: Analysis with Global Multi-regional MARKAL model, Energy Policy 35 (2007) 828-843.

[17] Changhong C, Bingyana W, Qingyan F,.Green C, D.G. Streets, Reductions in emissions of local air pollutants and co-benefits of Chinese energy policy: a Shanghai case study, Energy Policy 24 (2006) 754-762.

[18] Morales K.E.L.R, Response from a MARKAL technology model to the EMF scenario assumptions, Energy Economics 26 (2004) 655-674.

[19] Salvia M, Cosmi C, Macchiato M, Mangiamele L, Waste management system optimization for Southern Italy with MARKAL model, Resources Conservation and Recycling 34 (2002) 91-106.

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