Managing local resources: the role of electricity from biomass based cogeneration

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ABSTRACT

The aim of this work is to analyze and compare different energy development scenarios in order to provide a strategic assessment of measures for the local energy planners of an Italian province of half a million people, as of the results of an optimization bottom-up model (MarkAl Standard). The main features of the whole energy system are: (i) detailed modeling of the residential sector (final energy demands and technologies);(ii) detailed modeling of the electricity supply sector; (iii) detailed modeling of biofuels production sub-sector. The model provides tools for an integrated analysis of the system, focusing both on the achievement of the EU 20-20 targets and on the role of cogeneration from local and imported biomass.

The study is based on the assessment of the feasible use of local biomass for non industrial customer and the analysis is technologically performed from the policy maker's standpoint: the results will look at (i) the economic conditions making the new technologies more competitive, (ii) the role of decentralized power generation and (iii) the sustainability of using endogenous or imported biomass.

The residential sector has been analyzed in terms of costs and energy saving potential, with an emphasis on the impact/role of the White Certificates scheme and on the *free riders* effect.

The case is solved by analyzing scenarios, related to the defined local Standard-MarkAl model.

The results are focused on the impact of the partial achievement of two of the EU commitment for the year 2020: 20% share of electricity (for non-industrial use) from renewables and a 20% reduction in the residential electricity consumptions.

The impact of alternative technologies and the role of the public commitment is highlighted in terms of effective policy that could drive both the technological competition and the real estate market to achieve the optimal configuration of the energy system by means of subsidies for renewable technologies (solar, biofuels, …) and for more efficient end-use technologies.

1.INTRODUCTION

The PPMM (Province of Pavia Standard MarkAl Model) provides an integrated analysis of the considered energy system and it is focused on the civil energy demands; this choice comes from the need for local policy makers to have useful (usable) information for a sustainable energy planning.

The aim of this research work is to analyze and compare different energy development scenarios dealing with the potential of different electrical-based technologies, through an optimization model. The approach consists of an assessment of the economic incentives and of the minimum technological features, aiming to support a wider spread of some low carbon technologies. The impact of local and imported biomass use is investigated by analyzing their role on the energy planning of the territory and on the potential of the distributed generation, without involving the food versus fuel competition. Two different scenarios have been considered: the reference scenario (a.k.a. BASE) and the alternative scenario (a.k.a. S2T20), when the EU commitments for the year 2020 should be achieved: that is 20% of the delivered electricity (non-industrial use) from renewables and 20% reduction in the residential electricity consumptions. The two scenarios are compared from a technological and economical standpoint in order to get useful information on the main drivers of the system.

The tool is Standard MarkAl, a dynamic energy model generator based on linear programming. MarkAl has been often used for local energy system 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. Interesting examples of this application are the Shanghai model (Chen Changhong et al. (2006)) and the Basilicata-MarkAl model (Salvia et al., 2004) (Pietrapertosa et al., 2003) (Salvia et al., 2002).

2.METHODOLOGY AND INPUT DATA

The covered area hosts 190 municipalities and roughly half a million people in the Lombardy Region (Italy). Since 2005, the outlook of energy production has changed, by new fossil-fired power plants being operated, so that the province is now an electricity exporter. Table 1 shows the final energy consumptions of the area in 2003, according to a sectoral division of resources.

Consumptions (final energy) have not changed notably since 2003, the baseline year for the calibration of the model. Natural gas accounts for 49% in the final energy consumption and, in particular, the civil sector covers 27% share of the whole consumptions.

The modeling is based on the advanced local energy planning methodology (ALEP) and it integrates different tools and analysis techniques: reliable and comprehensive databases, statistical data and modeling tools (optimization and simulation).

The tool is MarkAl, a dynamic bottom up energy model generator based on linear programming. The Standard MarkAl model is a multi-period linear programming (LP) formulation of a energy system, undertaking continuous developments along the years. The objective function is the discounted cost function over the considered time horizon, that is the sum of several items such as (i) the net total costs of investments for energy conversion technologies, (ii) their operational and maintenance costs, (iii) fuel costs and (iv) a balance between imported/exported resources. The total cost of the energy system is the sum of costs incurred in primary extraction, conversion, transmission, distribution, including taxes and subsidies, taking into account the efficiencies of all intermediate technologies.

Concurrent conversion technologies are built into a database frame and the optimization tool allows to choose the optimal alternative with perfect foresight (perfect means that the foresight is based on a full knowledge of the energy demand), over the periods and accordingly with the set of imposed constraints, by minimizing the cost function.

The MarkAl energy economy consists of (i) demands, representing the energy services (e.g., space heating,) that must be satisfied by the supply system, (ii) energy sources (e.g. import, mining), representing methods of securing various energy carriers; (iii) technologies either transforming one energy carrier into another or into an useful energy service, (iv) commodities consisting of energy carriers, energy services, materials, and emissions that are either produced or consumed by the energy sources, technologies and demands.

The relationships amongst these items 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). The aggregated version of PPMM is shown in figure 1. The PPMM RES includes the description of the general energy system and mainly the residential thermal and electricity end use sector and the power generation sector are well described. The other final energy demands are represented by macro-boxes in the RES. It thus occurs that the results do not benefit yet of any feedback and/or integration with other macro-sectors but this configuration of the model can give useful information about the focused energy system development and changes into the infrastructures.

Final Energy Consumption of the Province of Pavia in 2003 (ktoe)

	Agricolture	Industry	Civil*	Transportation	Electricity Production	Total	%
Electricity	12.3	277.2	260.1	13.1	-	562.7	24%
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%
Glp	-	-	11.5	5.8	-	17.3	1%
Oil	-	133.9	4.9	0.2	-	139	6%
Petcoke	-	104	-	-	-	104	5%
Total	37.6	1209.9	653.2	315.2	85	2300.9	
%	2%	53%	28%	14%	4%	100%	100%

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

3. PPMM MAIN ASSUMPTIONS

The main features of the PPMM relate to: (i) the representation of the chosen energy system; (ii) detailed modeling of the residential thermal sector (final energy demands and technologies); (iii) detailed modeling of electricity supply technologies (both fossil and renewable fueled); (iv) evaluation of the biomass availability and constraints implementation.

The studied region includes 20 final energy demands, 11 commodities (energy carriers plus CO_2 emissions), more than 80 demand technologies and 6 conversion technologies for combined heat and electricity production.

From figure 1 it is inferred that the energy demands deal with (i) the residential heating demands (both from autonomous and centralized systems), (ii) residential hot water demand, (iii) cooking demand, (iv) residential electricity demand, split up into lighting, refrigerators, washing machines, dishwashers, air conditioner demands (v) agricultural thermal and electrical demand, (vi) the civil (not residential) thermal and electrical demand and (vii) the industrial thermal and electrical demand, eventually.

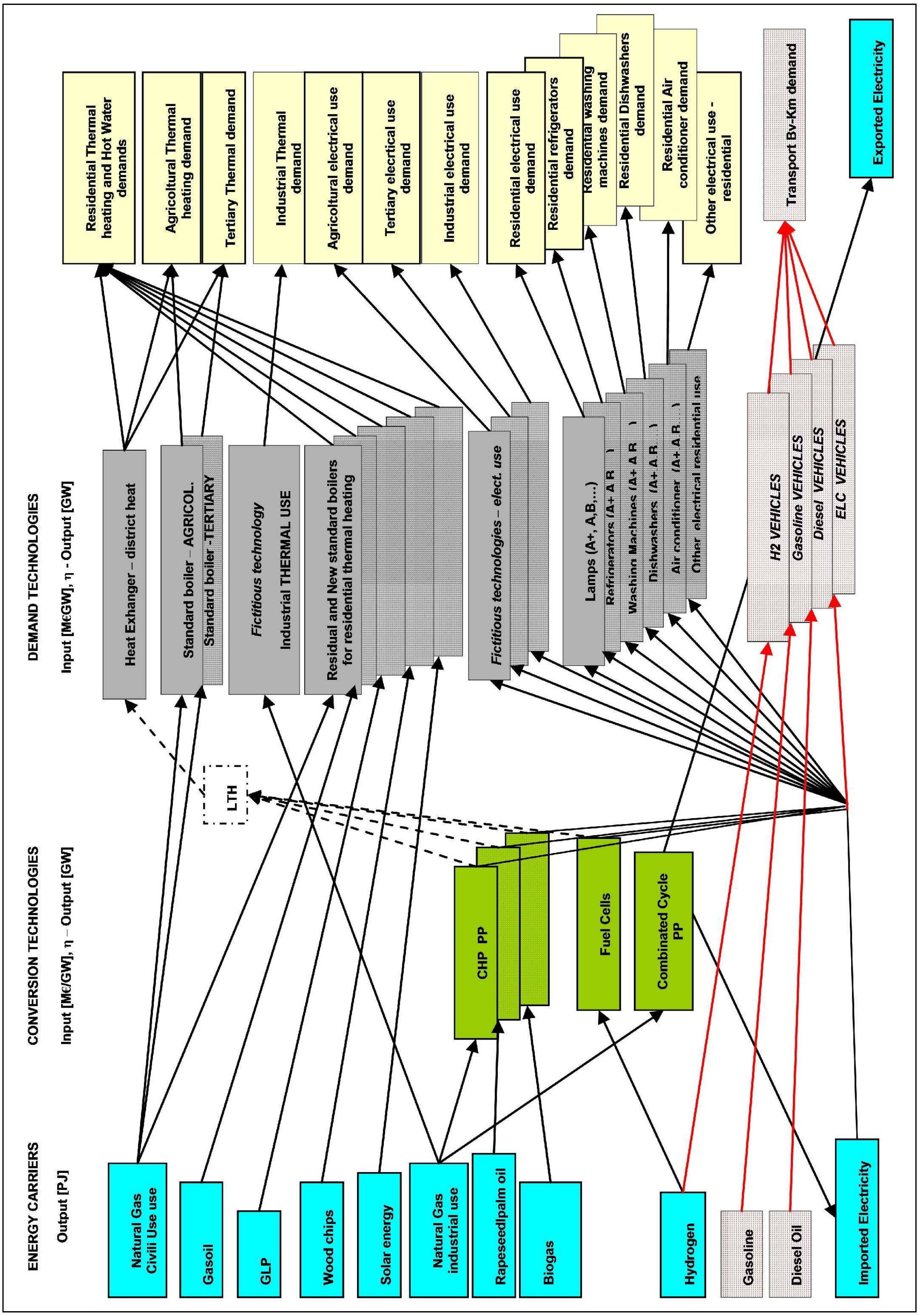

Fig.1: Aggregated PPMM RES (transportation not included yet).

3.1 The agricultural, tertiary and industrial demands assessment

The agricultural, tertiary and industrial demands (thermal and electrical) projections have been assessed from historical consumption data: starting from the base year (2003) consumption, projections to 2030 follow the historical trend. These information have been elaborated from the Local Administration documents and databases.
The demand technologies for agricultural, tertiary and industry electrical use and for industrial thermal use are represented by "fictitious" technologies with efficiency (EFF) equal to 1 and investment cost (INVCOST) equal to 0; thus, no efficiency improvement and no technology substitution are considered for this macro-sectors; this choice is driven by the current focus of this paper, which is the residential sector. The modeled thermal demand technologies for the agriculture and the tertiary sectors are represented by standard boilers (EFF=0.7; INVCOST=2.9 M€/PJ/y – 91€/kW). These technologies are in competition with district heating from cogeneration plants (CHP).

3.2 The residential thermal sector assessment

The residential thermal sector has been carefully described (both demand assessment and technology modeling): the heating demand has been carried out by the assessment of the thermal demand, according with technical standards and procedures.
Figures from the 2001 Census (ISTAT 2001) has been used to assess the residential heating demand, they provide information and data on residential dwellings with respect to the built environment, vintage and material features. These information allowed to rank the existing buildings in 6 main categories, defined by different energy performances, according to the combination of different buildings components (walls and windows transmittance index, age). Then the residential heating demand of a standard building for each category (and so on for the whole area) has been calculated by means the procedure described in the National technical standard UNI 7357.
The projection of the residential heating demand is based on the assumed increase in the size and number of dwellings over the years and has been set accordingly with Law 311/06, imposing new energy performances for new and renovated buildings. The increasing factors are set to 0.6% new dwellings/year and 1.5% renovated dwellings/year (ENEA, F.IN.CO., 2004).
This approach is noticeably different from those models whose projections only depend upon the simple increase in the size and number of dwellings over the years, as reported in the MarkAl Macro Italy Model (Contaldi et al, 2008).
PPMM includes 54 residential thermal demand technologies (including district heating), represented by 4 categories:
(i) R*esidual*
They represent the installed capacity in the base year (PJ/y). Special attention has been paid to the modeling of residual technology: this has been pursued through the boiler inspection database elaboration.
(ii) Standard
They are the less expensive and the less efficient technologies (e.g. gas boilers). They are identified by their input energy carrier.
(iii) Efficient
They represent the most efficient technologies but ask for greater investments (e.g. condensing boilers, district heating)
(iv) 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.).

3.3 Residential electricity demand assessment

One of the focus of this paper is the potential in energy saving of residential end use technologies and the improvement of the whole system efficiency, according with the economic impact of the technological replacements and with the EU-2020 commitments. The residential electricity end use demand has been split up into 6 categories: (i) lighting demand (Glm), (ii) refrigerators demand (10^6 devices), (iii) washing machines demand (10^6 devices), (iv) dishwashers demand (10^6 devices), (v) air conditioners demand (10^6 devices), (vi) other end use technologies (TV, electronic devices, etc…) (10^6 devices).

The residential electricity end use projections are based on the increase in the size and number of dwellings over the years (0.6% new dwellings/year).

The lighting demand to be satisfied has been set to an average of 200 lm/m^2 (lux) for the considered period (2003-2030) while, for the other devices, the demand projections have been assessed by analyzing ISTAT data and (ENEA, 2004) data; two indexes have been considered (i) the increasing factor (added devices/year) and (ii) the single-device house share (see table 2).

5 different technologies for lighting and 23 demand technologies for the other electricity residential demands have been considered, according to the European efficiency rate scheme (A++,A+,...).

In Table 3 and 4 the average yearly consumption and the investment cost for each technology are reported as well as the features of the modeled lamps.

	Share of houses, with devices (2003)	3 years increase factor (%)
refrigerators	100%	4%
washing machines	100%	0.5%
dishwasher	32%	4%
air conditioner	15%	1.5%

Table 2: Statistical indexes used for the assessment of the residential electricity end use demand in the base year.

	refrigerators		washing machines		dishwashers		air conditioners	
ranking index	consumption [kWh/a]	INVCOST [€/device]	consumption [kWh/a]	INVCOST [€/device]	consumption [kWh/a]	INVCOST [€/device]	consumption [kWh/a]	INVCOST [€/device]
A++	160	800	▨	▨	▨	▨	▨	▨
A+	250	500	190	500	▨	▨	350	800
A	304	350	220	450	250	550	500	550
B	406	280	275	400	300	500	600	480
C	516	220	325	350	330	450	650	420
D	▨	▨	▨	▨	380	400	▨	▨
Other (<D)	600	160	475	200	440	350	750	300

Table 3: Main features of the modeled residential electricity demand technologies.

	efficiency [lm/W]	Investment cost [M€/(Glm/y)]
Bulb lamp	12	1.8
Halogen lamp	15	2.6
Linear fluorescent lamp	65	6.6
Compact fluorescent lamp	60	9.6
LED	250	38.9

Table 4: Main features of the modeled lamps for the residential lighting system.

3.4 Evaluation of the biomass availability

In the PPMM, 4 biomass energy carriers have been considered for CHP plants: (i) endogenous rapeseed oil production, (ii) rapeseed oil imported from neighboring areas, (iii) endogenous biogas production and (iv) palm oil imported from outside European countries.

As far as the rapeseed oil local availability concerns, the evaluation has been done by considering a maximum of 5000 ha of available local land (from the Agricultural Local Administration documents and databases). This is the amount of land that could not be used for any agriculture purposes (for instance the interdicted areas); so that the model does not have to face the food versus energy culture competition.

The resulting assessment drives to define the proper upper bound for the local rapeseed oil production, which is set to 0.18 PJ/y (annual rapeseed oil production is set to 0.8 t/(ha.y)).

The availability of exogenous rapeseed oil has been set to 0.36 PJ/y, assuming to rely on production coming from an importing area far less than 150 km. The potential biogas production (0.43 PJ/y) is inferred considering the anaerobic digestion of local farm animal waste, only. So far, no other agricultural waste has been considered in the model.

Imported palm oil has been included as an exogenous energy carrier with no bound on availability.

CO_2 associated emissions has been considered for exogenous rapeseed oil and palm oil in order to take into account the emissions due to their transportation, while endogenous rapeseed oil and biogas, whose upper bound is related to agricultural thermal demand, are considered only for *in situ* utilization (no emission factor). Imported rapeseed and palm oil emission factors have been set, according with (Schmidt J.H., 2007).

3.5 Conversion technologies

The energy conversion technologies are mainly small (< 1MWe) sized cogeneration units for distributed combined generation of heat and power (CHP). The considered technologies are reciprocating engines (natural gas, palm/rapeseed oil, biogas-fueled) and gas turbines (natural gas and biogas-fueled).

The main features of the conversion technologies are summarized in Table 5.

Tech.	**Fuel**	**INVCOST [M€/GW]**	**Fixed O&M Cost [M€/GW]**	**ENVACT** CO_2 emission factor **[kt/PJout]**	**Efficiency (Electrical+ Heat recovery)**	**REH - Electricity over Heat Recovery rate**
Reciprocating engines	Natural Gas	700	21	159	85%	0.7
	Biogas	750	22.5	-	85%	0.7
	Rapeseed	1000	30	0.3 (*)	80%	0.78
	Palm oil	1000	30	4.7	80%	0.78
Gas Turbine	Natural gas	500	15	279	60%	0.5
	Biogas	550	16.5	-	60%	0.5

Table 5: Main features of the modeled CHP plants. (*) to be considered only for imported rapeseed oil.

4. RESULTS

4.1 Scenario assumptions

In the reference scenario (BASE) time horizon spans from 2003 to 2030, being divided into 10 periods, 3 year each. Money discount rate is set at 4%.

The model does not include the residual conversion technologies of the two big power plants (1.2 GWe) located in the province, making the production of electricity to be threefold the total electricity consumptions of the area: the basic idea, aiming to understand the potential role of distributed generation, entails to consider this production in the same way as imported electricity.

In PPMM the endogenous electricity production is treated as an imported carrier, to compete with distributed generation production, and no renewable share in imported electricity is assumed.

This choice allows the optimization tool to be free to invest also on concurrent distributed generation technologies.

The BASE scenario includes also two different kinds of subsidies, according to the current Italian law situation: (i) the traceable chain supply biomass (representing a sort of European import) subsidy (TC), affecting both biogas and rapeseed oil use (0.28 €/kWh_e equal to 27.22 M€/PJ on rapeseed oil consumption and 15.56 M€/PJ on biogas consumption); (ii) the green certificates (GC) for palm-tree oil technologies (0.12 €/kW_e - 12.3 M€/PJ on palm oil consumption).

Fuel costs and considered subsidies are shown in Table 6.

As far as the residential electricity of some end use technologies concerns, some market assumptions have been done to take into account the non-perfect foresight of the real customers, with respect to the future market share of each technology. The optimization model can not simulate a real market; as a matter of fact, by allowing the PPMM be free to invest, only the most efficient technologies would enter the model with an instantaneous technology substitution. Lower and upper bounds on technologies capacity have been imposed in order to smooth investments trend; the assumptions are shown in Table 7.

In the alternative scenario (S2T20) the aim is to *partially*[1] fulfill the EU commitments for the year 2020: (i) 20% share of electricity (for non-industrial use) from renewables, (ii) 20% reduction in the residential electricity consumptions, compared to the reference scenario.

In order to achieve the first goal, the economic conditions allowing palm oil technologies to become competitive has been investigated by applying an additional subsidy to the system.

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[1] *Partially* means that the share is assessed only on the residential consumption and not on the whole system electricity consumption

Scenario Assumptions					
Lighting demand technologies	**BASE**	**S2T20**	**Refrigerators**	**BASE**	**S2T20**
Bulb lamp - ending year	2011	2011	A++ rated refrigerators - MINIMUM % increase every 3 years	7%	25%
Halogen lamp - ending year	2027	2018	% of A++ rated refrigerators in 2006	3%	5%
Linear fluorescent lamp - MINIMUM % increase every 3 years	5%	5%	A+ rated refrigerators - MINIMUM % increase every 3 years	7%	11%
Compact fluorescent lamp - MINIMUM % increase every 3 years	20%	5%	% of A+ rated refrigerators in 2003	5%	5%
LED lamp - % increase every 3 years	5%	20%	A rated refrigerators - MINIMUM % increase every 3 years	1%	1%
% of compact fluorescent lamp in 2012	1%	1%	B rated refrigerators - % decrease every 3 years	-2%	-11%
% of compact LED lamp in 2015	3%	5%	C rated refrigerators - end year	2024	2018
Upper bound for LED lamps - % on demand	50%	70%	Other refrigerators (<C rated)	2021	2015
Washing machines	**BASE**	**S2T20**	**Air conditioners**	**BASE**	**S2T20**
% of A+rated washing machines in 2006	5%	5%	A+ rated air conditioners - MINIMUM % increase every 3 years	10%	25%
A+ rated washing machines - MINIMUM % increase every 3 years	5%	25%	% of A+ rated air conditioners in 2009	10%	15%
A rated washing machines - MINIMUM % increase every 3 years	10%	3%	A rated air conditioners - MINIMUM % increase every 3 years	15%	5%
B rated washing machines - % decrease every 3 years	-5%	-20%	B rated air conditioners - % decrease every 3 years	-5%	-10%
C rated washing machines - end year	2024	2018	C rated air conditioners - end year	2027	2021
Other (<C rated) washing machines - end year	2021	2015	Other (<C rated) air conditioners - end year	2024	2018
Dishwashers	**BASE**	**S2T20**	**Other end use devices**	**BASE**	**S2T20**
A rated dishwashers - MINIMUM % increase every 3 years	20%	30%	Very high efficiency devices (A+ rated) - MINIMUM % increase every 3 years	2%	10%
B rated dishwashers - MINIMUM % increase every 3 years	5%	-5%	% of very high efficiency devices (A+ rated) in 2009	5%	15%
C rated dishwashers - % decrease every 3 years	-5%	-16%	High efficiency devices (A rated) - MINIMUM % increase every 3 years	10%	5%
D rated dishwashers - end year	2024	2018	% of high efficiency devices (A rated) in 2009	5%	5%
Other (<D rated) dishwashers - end year	2018	2015	Low efficiency (≤B rated) - % decrease every 3 years	-8%	-30%

Table 7: Scenario assumptions on the household appliances market.

In the S2T20 scenario (2010-2030) an upper bound on palm oil CHP plants capacity has been set with the aim of achieving the 20% share of renewable electricity production by the year 2020, From 2020 onwards PPMM is free to invest on whatever technology can be instrumental to the system.

The 20% reduction goal is achieved by allowing the PPMM to invest more in efficient technologies (see Table 7).

	Cost [M€/PJ]	Subsidy [M€/PJ]	
		Base	S2T20
Natural Gas	15.5	-	-
Natural Gas (industrial use)	8.1	-	-
Electricity	25.3	-	-
Biogas	5.0	27.22	27.22
Rapeseed Oil (endogenous)	11.9	27.22	27.22
Rapeseed Oil (imported)	20.1	27.22	27.22
Palm Oil	17.9	12.30	27.80

Table 6: Fuel costs and subsidies [M€/PJ].

4.2 Results and comments

In the actual PPMM structure, agricultural, tertiary and industrial electricity demands and thermal demands in industry are not detailed, thus the results do not consider the technology competition and substitution in those sectors. Results related to the distributed generation competition and biomass utilization are focused on non industrial energy use; the industrial sector is considered as a black box.

In the BASE scenario, the model invests on CHP systems for a good share of consumption; in 2020 cogeneration can satisfy more than 80% of the non industrial electricity demand and 11.2% of the PP thermal demand (58% of the residential thermal demand). As a matter of fact, cogeneration is a very efficient technology and from a strict economic point of view would be the ideal solution, even if the operating conditions are set quite conservative (CF=0.2 equivalent to 1800 operating hours per year). The technology shows low investment rates (M€/GJ) and high efficiency. Electricity from natural gas-fueled CHP accounts for the majority of the final demand (62.45%) while the renewable share in electricity production in 2020 is 7% (biogas 1%, endogenous rapeseed oil 2%, 150km-radius importing area rapeseed oil 4%). It follows that endogenous resources are not enough to achieve the 20% target on the use of renewables. This goal could be achieved only by importing palm-tree oil, thus the minimum installation in 2020 is calculated, as being in the range of 200 MWe. The minimum assessed additional incentive needed in order to make the palm oil CHP competitive is 15.5 M€/PJ (S2T20 scenario). The additional subsidies represent the economical effort to fulfill the commitment and 200 MWe can also be considered as the threshold of allowable permits for new renewable-fed power plants. The need of additional subsidies proves that mainly big-sized power plants can benefit from Green Certificates, being characterized by lower investment cost (M€/MW), higher electrical efficiency and higher CF value, despite of having a lower total efficiency (no heat recovery is considered for such plants). In Table 8 some results of the impact of cogeneration (fossil-fueled and renewable based) both on electricity and heat consumption of the considered users are reported for the two scenarios in the years 2020 and 2030. Only in the S2T20 the threshold of 20% renewable electricity by 2020 is achieved (last line in the left table). After 2020 the are no bounds on CHP technologies and in 2030 the renewable share goes up to 59%; this value can be considered as the total renewable potential for electricity production in PP.

Another interesting result is that despite of the value of additional incentives (which is twofold on the imported biomass), still the 20% share of renewable on heating consumption is far to be reached by 2020 and 2030. More efforts are thus needed in the described context.

		2020	**2030**			**2020**	**2030**
	CHP electricity production /Non Industrial ELECTRICITY Consumption				***CHP thermal production /Non Industrial THERMAL Consumption***		
BASE	fossil-fueled electricity	62.46%	54.58%	BASE	thermal demand from fossil fuels	11.24%	10.45%
BASE	electricity from renewables	7.73%	6.70%	BASE	thermal demand from renewable	0.27%	0.25%
				BASE	thermal demand from ALL renewable	5.50%	5.12%
S2T20	fossil-fueled electricity	58.59%	24.96%	S2T20	thermal demand from fossil fuels	9.90%	4.49%
S2T20	electricity from renewables	20.54%	58.83%	S2T20	thermal demand from renewable	2.13%	6.69%
				S2T20	thermal demand from ALL renewable	7.36%	11.56%

Table 8: The role of the CHP production in the two scenarios.

In Table 9 some significant indexes of the scenario comparison analysis are summarized.

Figure 3 (on the left side) shows a growing difference of fossil fuel consumptions between the BASE and the S2T20 scenario in the whole considered period: in 2020 the fossil fuel saving potential of S2T20 is equal to 49 ktoe that is nearly a half of gas consumption for electricity production in 2003. In 2030 this potential is almost threefold (137 ktoe). As a consequence, the CO_2 reduction potential shows nearly the same trend (207 kt in 2020 and 741 kt in 2030).

The cost of a saved ktoe in 2020 is 0.8 M€$_{2003}$/ktoe, comparable with the cost of natural gas for residential use (0.65 M€$_{2003}$/ktoe), but it noticeably grows in 2030 (1.36 M€$_{2003}$/ktoe), reaching quite the same value as in 2010 (1.31 M€$_{2003}$/ktoe). In figure 4 the trend of this key index is reported: (i) from 2012 to 2020 it decreases against an increase of the fossil fuel saving potential (figure 3, left side), this means that the BASE and S2T20 costs grow at the same rate (figure 3, right side), (ii) from 2020 to 2030 the index increases as well as the fossil fuel saving potential (figure 3, left side), this means that the S2T20 cost grows faster than the BASE cost (figure 3, right side).

Similar results can be inferred from the CO_2 reduction cost analysis: the CO_2 reduction potential grows in the considered period (122 kt in 2010, 207 kt in 2020 and 741 kt in 2030) but the cost of a saved kt (figure 5) decreases in the first part of the period (0.26 M€$_{2003}$/kt in 2010 vs. 0.19 M€$_{2003}$/kt in 2020) and grows in the second part (0.25 M€$_{2003}$/kt). Nevertheless, these conclusions will be better investigated by means of different scenario runs.

The 2020 configuration of the system (20% of electricity production from renewable) seems to be the one with the best investment-effectiveness rate and this result suggests that to achieve more ambitious objectives (i.e. the fossil fuel consumption reduction) other solutions have to be found.

The share of CO_2 reduction (compared to the BASE scenario) in 2020 is only next to 7%; this means that the S2T20 configuration is not enough to get to the 20% overall reduction: fundamental role is played by the improvement of the efficiency of the electricity utilization in tertiary and industrial sectors. The goal is achieved by 2030 when the share of renewable in electricity demand (non industrial use) is 68% (Table 8), nevertheless this evolution is not likely to happen without deeply affecting the bio-fuel prices.

Scenario Comparison			
	2010	**2020**	**2030**
	PPMM Fossil Fuel Consumption (FFC) [ktoe]		
BASE	1437	1653	1912
S2T20	1413	1605	1774
	Δ FFC, Δ SC		
Δ Fossil Fuel Consumption (FFC) - (ktoe) **$[FFC^{(BASE)} - FFC^{(S2T20)}]$**	24	49	137
Δ Total System Cost (SC) - (M€$_{2003}$) **$[SC^{(S2T20)} - SC^{(BASE)}]$**	32	39	188
	Δ E, Δ E%		
Δ Total CO_2 emission (E) - (kt) **$[E^{(BASE)} - E^{(S2T20)}]$**	122	207	741
$[E^{(BASE)} - E^{(S2T20)}]/ E^{(BASE)}$	4%	6%	20%
	2010	**2020**	**2030**
Cost of saved toe [M€$_{2003}$/ktoe]	1.31	0.80	1.36
Cost of saved kt of CO_2 [M€$_{2003}$/kt]	0.26	0.19	0.25

Table 9: Scenario comparison: fossil fuel consumptions and costs.

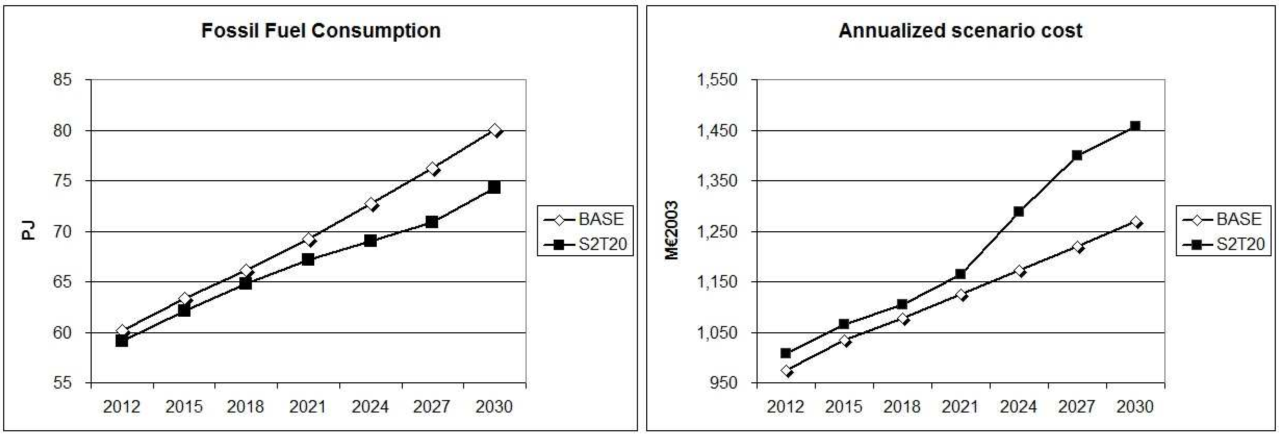

Fig.3: Scenario comparison key index (left) fossil fuel consumption (right) annualized scenario cost.

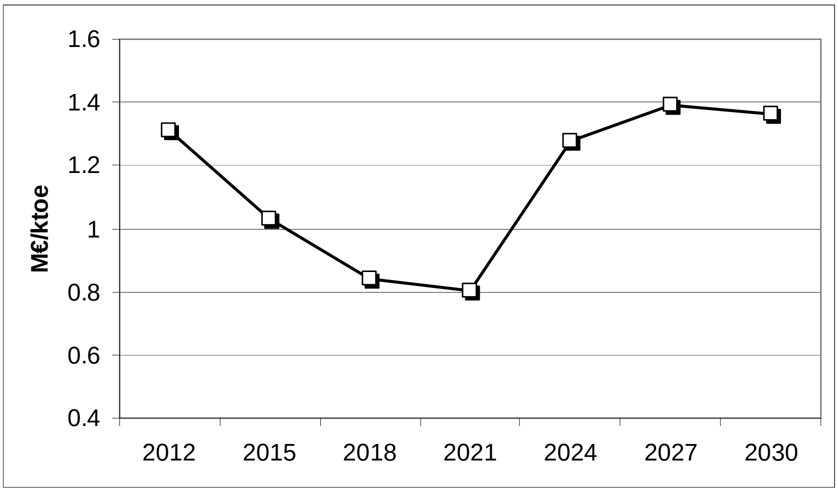

Fig.4: Cost of a saved fossil fuel ktoe.

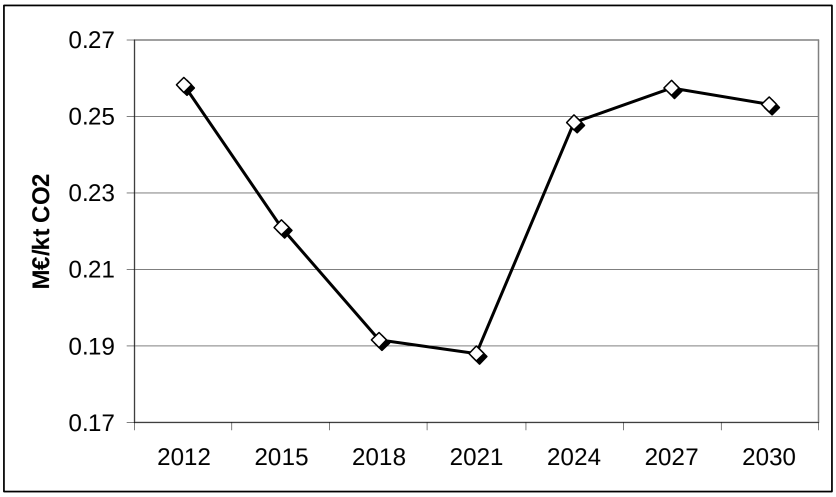

Fig.5: Cost of a saved kt of $CO_{2.}$

By focusing the attention on the electricity use in the residential sector, the most considerable result is that the system cost is nearly the same in the two scenarios, as it is shown in Table 10. This means that the most efficient technologies are still competitive and a low subsidy is needed in order to make them enter the market, overcoming the bigger initial investment. The gap between the cumulated cost (from 2003 to 2020) of the residential sector in the BASE and S2T20 scenarios, that could represent the total amount of an additional subsidy, is assessed in the range of 1 M€ (average annual value is 0.06 M€).

The cumulated value of achievable white certificates (100 €/saved toe, over a 5 year period), from 2003 to 2020, coming from the 20% reduction in the electricity consumption in residential sector, can be estimated in 15 M€ (average annual value is 0.83 M€), thus the *“free riders”* total profit reaches 14 M€ (average annual value is 0.78M€).

	Residential Electrical Sub System annualized Cost (**RESSC**) [€/households number]		
	2010	**2020**	**2030**
BASE	416	494	521
S2T20	414	502	521

Table 10: Scenario comparison: Residential Electrical Sub System annualized Cost.

5. CONCLUSIONS

Energy saving is a difficult goal to achieve because it involves many aspects, such as technical – economic – behavioral which are strictly related to and dependent upon each other. Energy saving is the best, the less expensive and the best performing action to pursue and it can allow up to 20-30% of saving in the next decade by distributed investment both in industry and in buildings.

The use of MarkAl for the energy planning of urban and industrial areas and systems allows to evaluate the potential penetration level of technologies by means of different scenarios, taking into account both economic, social, environmental and technical issues.

Results show that biomass-based distributed generation can play a key role in energy saving but a careful managing of the local resources is necessary for the sustainable development of a local territory: endogenous resources have to be exploited without jeopardizing (or minimizing) the use of land cultivated for food producing and, on the other hand, imported biomass utilization has to be limited with a maximum threshold of allowable permits for new power plants. Moreover, results prove that subsidies are necessary in order to make the renewables and the most efficient end-use technologies enter the energy market but Green Certificates and White Certificates further investments that maximize the investor benefits to the detriment of the optimal utilization of resources.

Though further studies on the sensitivity of fuel prices need to be performed, along with more detailed studies on the modeling, this can be considered a quite important result because it stresses, once more, the importance of cogeneration for the environment and for the reduction of fossil fuel consumption.

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