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Answering The Question Of Local Biomass Deployment: The Use Of Energy Modelling With Case Study For Non Industrial Customers

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Biomass-based energy carriers can play a non marginal role in a local energy system, but the impact must be carefully evaluated. The authors will report the results of an energy planning case study (for an Italian province of half a million people), based on the assessment of feasible use of local biomass, related with the energy modeling of the territory, by focusing on non industrial energy end use. From the policy maker's standpoint the interesting issue can be twofold: how many decentralized biomass power plant can be authorized without jeopardizing (or minimizing) the use of land, currently cultivated for food producing? How sustainable is the use of imported biomass from Far East countries in a local-limited context?

The case is solved by analyzing scenarios, related to the defined local Standard-MarkAl model. By assigning different weights (both from the energy, environmental and economic standpoints) to different biomasses and technologies, the results give some advices on how to evaluate potential disputes through an optimization approach.

1.Introduction

The aim of this work, a case study for an area of 190 municipalities and half a million people, is to analyze and compare different energy development scenarios, by providing a strategic assessment of measures for local energy planners, through an optimization model. The focus of this work is on both the use of local and imported biomass and their impact on the energy planning of the territory and on potential of the distributed generation. The tool is MarkAl, a dynamic energy model generator based on linear programming. In a interesting study with similar focus Schulz et al. used the SWISS-MarkAl model (2006) in order to analyze the economic conditions, making the new biomass technologies more competitive in the energy market and providing projection of future technology investments. An interesting example of local model is the Basilicata-MarkAl model: in (Salvia et al., 2004) and (Pietrarosa et al., 2003) the role of local communities in achieving the Kyoto Protocol goals is discussed. The same model is also used to assess the optimal configuration of the waste management system for the Basilicata Region (Salvia et al., 2002).

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The PPMM (Province of Pavia Standard MarkAl Model) is focused on civil energy demands; this choice derives from the need for local policy makers to have useful (usable) information for a sustainable energy planning.
The emphasis of the present study is put on the role of biofuels in the energy-economic for a local energy system, without involving the food versus fuel competition.

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 changed, by new fossil-fired power plants being operated, so that now the province is an electricity exporter. According to a sectoral division of resources, industry accounts for the 55% of the final energy consumption, the civil sector for 27% and the rest is shared amongst transportation, electricity production and agriculture, for a total of 2.4 Mtoe (year 2003).
The modelling 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 of the ALEP methodology is the MarkAl bottom up model generator. The Standard MarkAl model is a multiperiod linear programming (LP) formulation of a reference energy system (RES). One of the objective functions in the linear programming 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.
Concurrent technologies are made available on the database for the future and the optimization tool chooses the optimal alternative with perfect foresight along the periods and accordingly with the set constraints, by minimizing the cost function. The novelty in such use of optimization models lies in tailoring ALEP to small communities, allowing the use of a very flexible and objective tool which can also give very local answers. The data of consumption/resources and the options on current and future concurrent technologies, but also the constraints, are set in the model subjected to calibration at the base year. The more the technologies, the better the analysis that can be performed: in this case the focus is on biomass and distributed generation potential.
In Fig. 1 the aggregated version of PPMM's RES is shown.

3.The PPMM assumption

The PPMM includes the description of the general energy system and mainly the residential thermal 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 macrosectors but this configuration of the model can give useful information about the focused energy system development and changes into the infrastructures.

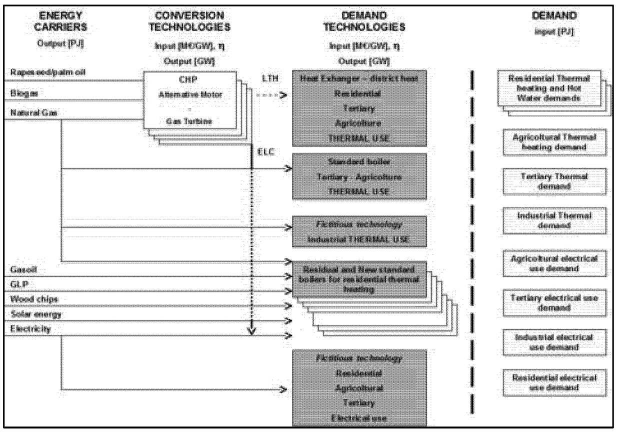

Figure 1: Aggregated version of the PPMM Reference Energy System.

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 regions include (i) 2 distinguished areas to take into account the known differences; (ii) 10 final energy demands, 12 commodities (energy carriers plus CO2 emissions), 64 demand technologies and 6 conversion technologies for combined heat and electricity production.

From Fig.1 it is inferred that the energy demands deal with (i) the Residential heating demands (both from autonomous and centralized systems), (ii) hot water demand, (iii) cooking demand, (iv) agricultural thermal and electrical demand, (v) the civil (not residential) thermal and electrical demand and (vi) the industrial thermal and electrical demand, eventually.

The agricultural, tertiary, industrial demands (thermal and electrical) and the residential electrical demand projections have been assessed from historical consumption data: starting from the base year (2003) consumption, projections to 2030 follow the historical trend. These information, along with data on the current used technologies, 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; so no efficiency improvement is considered for this macro-sectors and the choice is driven by the current focus of this paper. The modeled demand technologies for agricultural and tertiary thermal use 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).

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: information on buildings and their technological installations have been used to build up a set of typical end-users, (Anglani et. al., 2008).

This approach is noticeably different from those models whose projections only depends upon the simple increase in the size and number of dwellings over the years.

PPMM includes 54 residential thermal demand technologies that can be divided in 4 categories: 1) residual (technologies in the base year), 2) standard 3) efficient 4) renewable.

As far as it concerns the rapeseed oil local availability, the evaluation has been made considering the availability of 5000 ha of land (value elaborated from the Local Administration documents and databases). This is the land that could not be used for 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 the proper upper bound in local rapeseed oil production, which is set to 1.1 PJ/y .

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, nevertheless CO_2 associated emissions has been considered in order to take into account the emissions due to its transportation. Palm oil emission factor has been set, according with (Schmidt J.H., 2007).

The energy conversion technologies are mainly small/medium sized cogeneration units for distributed combined generation of heat and power (CHP). The considered technologies are alternative motors (natural gas, palm/rapeseed oil, biogas-fuelled) and gas turbines (natural gas and biogas-fuelled). The main features of the conversion technologies are summarized in Table 1

Table 1: Main features of the modelled CHP plants

Tech.	**Fuel**	**Investment Cost [M€/GW]**	**Fixed O&M Cost [M€/GW]**	**Envact** CO_2 emission factor **[kt/PJ_{out}]**	**Efficiency (electrical+ thermal)**	**REH Ratio of electricity to heat produced from CHP**
Alternative Motor	Natural Gas	700	21	159	85%	0.7
	Biogas	750	22.5	-	85%	0.7
	Rapeseed O.	1000	30	-	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

4. Results

4.1 Main 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 at understanding the potential role of distributed generation, entails to consider this production in the same way as imported electricity.

This choice allows the optimization-tool be free to invest also on concurrent technologies. The BASE scenario includes also two different kinds of subsidies, available at the current situation: (i) the green certificates (GC) for palm-tree oil technologies (12.1 M€/PJ on palm oil consumption); (ii) the short chain supply biomass subsidy (SC), affecting both biogas and rapeseed oil use (28.9 M€/PJ). In the alternative scenario (RES20) the aim is to fulfil one of the EU commitment for the year 2020. The objective of RES20 is to deliver the 20% of the electricity (non-industrial use). Fuel costs and considered subsidies and bounds on utilization are shown in Table 2.

Table 2: Fuel costs and subsidies [M€/PJ]

	Cost [M€/PJ]	**Subsidy [M€/PJ]**		**Bound on the resource use [PJ/y]**
		Base	**FER 20**	
natural gas	15.5	-	-	-
natural gas (industry)	8.1	-	-	-
electricity	25.3	-	-	-
biogas	5.0	28.9	28.9	0.4
rapeseed oil	20.1	28.9	29.9	1.1
palm tree oil	17.9	12.1	27.6	-

4.2 BASE - RES20 the scenarios comparison: results and comments

In this paper the comments on results are focused on non industrial energy use; industrial sector is considered in PPMM as a black box with no influence on the distributed generation competition. In the BASE scenario, the model invests on CHP systems for a good share of consumption; in 2020 cogeneration can satisfy 65% of the non industrial electricity demand and the 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 their operating conditions are set quite conservative (CF=0.2 equivalent to 1800 operating hours per year). It shows low investment rates (M€/GJ) and high efficiency. Electricity from natural gas CHP accounts for the majority of the final demand (64%). Biogas CHP systems, whose upper bound is related to agricultural thermal demand, represent the only share of renewable in the BASE scenario. For being competitive the vegetable oil CHP plants need an additional subsidy.

The minimum calculated additional incentive needed is 1 M€/PJ for the rapeseed oil and 15.5 M€/PJ for the palm oil (RES20 scenario). This subsidy makes rapeseed oil competitive allowing it to get to its upper bound. In RES20 the share of non industrial electricity demand, supplied by local renewable resources (biogas and rapeseed oil) reaches 6% in 2020: 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 and the minimum installation in 2020 is calculated in being in the range of 300 MW_e. The additional subsidies represent the economical effort to fulfill the commitment and 300 MWe can also be considered as the threshold of allowable permits for new renewable-fed power plants.

In Table 3 some results of the impact of cogeneration (fuelled-base 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 RES20 the threshold of 20% electricity by 2020 is achieved (last line in the left table). Another interesting result to underline is that despite of the 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. More efforts are thus needed.

Table 3: Final results of the simulation. Role of CHP production in the two scenarios

		2020	**2030**
	CHP electricity production /Non Industrial ELECTRICITY Consumption		
BASE	fossil-fuelled electricity	61,10%	64,18%
BASE	electricity from renewables	3,75%	3,20%
RES20	fossil-fuelled electricity	49,57%	21,06%
RES20	electricity from renewables	21,76%	52,22%

		2020	**2030**
	CHP thermal production /Non Industrial THERMAL Consumption		
BASE	thermal demand from fossil fuels	12,03%	11,18%
BASE	thermal demand from renewable	0,74%	0,68%
BASE	thermal demand from ALL renewable	5,97%	5,55%
RES20	thermal demand from fossil fuels	9,76%	4,49%
RES20	thermal demand from renewable	3,01%	7,37%
RES20	thermal demand from ALL renewable	8,24%	12,24%

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