Bottom-up and top-down approaches in energy efficiency estimation. The case of Italy.

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Abstract

This paper studies the role that energy efficiency improvements can have in Italy. After a wide discussion of the situation of the European Union and Italy in the context of the climate change issue, it proposes two kinds of simulations which aim to measure possible energy efficiency improvements: bottom-up and top-down simulations. They can be seen as complementary methods for studying the savings that can be obtained through energy efficiency. The estimations show that the possible gains are huge, both in energy and monetary terms. Thus, their exploitation should be considered as a fundamental step of the Italian climate change policy.

1. The EU and climate change

A discussion about energy efficiency, especially if it is referred to a specific country such as Italy, cannot avoid the consideration of a wider picture. In particular, before showing some quantitative evaluations, the consideration of the meaning of energy efficiency for the European Union and Italy would be useful.

In 1990 the EU emissions accounted for 20% of the world total; in 2005 for 15%, while, according the reference scenario of the last World Energy Outlook of the International Energy Agency IEA (IEA 2009), in 2030 they will account for 9%. Here, we face two reverse trends: declining weight of the EU's emissions, increasing emission cutting targets. The last EU package on climate change sets two main targets:

- "A reduction of at least 20% in greenhouse gases (GHG) by 2020 – rising to 30% if there is an international agreement committing other developed countries to comparable emission reductions and economically more advanced developing countries to contributing adequately according to their responsibilities and respective capabilities.
- A 20% share of renewable energies in EU energy consumption by 2020" .

In such a context, "the EU goal of saving 20% of energy consumption by 2020 through energy efficiency is a crucial part of the puzzle" (European Commission, 2008). We believe that the EU package is characterised by at least two main dimensions that should be carefully considered: a) strategy; b) efficiency. As far as strategy is concerned, it seems that through the energy package the EU speaks to the other countries, especially the US, and tries to influence their approach to climate change. By setting strong and uneasy targets for itself, the EU tries to push the other countries to do the same. To some extent, the EU increased its stake in the climate change negotiations game and assumed a riskier position. If the EU is successful in meeting its targets, there exists the possibility that other countries will follow it, though it is not a certainty. Until now, i.e. just after the Copenhagen meeting, no country decided to follow the EU. On the other hand, if the EU fails in its effort to cut its emissions, the other countries will have a very strong incentive not to follow Europe. In such a case, unless very severe and catastrophic natural events occur and alter people's perception, it will be the end of the mitigation strategies and the victory of adaptation ones. Thus, the EU plan is a key knot of a wider game in which the fate of mitigation and adaptation is at stake or, to use other words, the destiny of climate change prevention. With reference to this point, some questions that could be asked are the following: is a reduction of greenhouse gases of at least 20% by 2020 a feasible target? To what extent is the European Union confident in its strength of meeting the target? Does the reduction target represent just a strategic and a provocative bet? Unfortunately, no long time series of emissions reduction which could shed light on such an issue exist. Nevertheless, there is a reference case. The Kyoto Protocol was signed in December 1997. Since that date to 2010, the central year of the first commitment period, there are 13 years. Since today (2010) to 2020, there are again 10 years. In the first 13 years, Europe will cut its emissions of about 8% (base year 1990). In the second period, the EU should cut emissions by at least 20% (base year 1990) and the figure could be increased to 30% as part of a satisfactory international agreement on reducing worldwide emissions. This means that the effort that the EU will have to face will be at least about 2.5 times larger than the current one. If we consider the difficulties that many countries face in meeting the first commitment period target, and the fact that some countries (e.g. Italy and Spain) are not meeting the target, we have to conclude that the new European goal is a visionary one. Nevertheless, it is a part of a wider package which includes strong renewable energy expansion and energy efficiency measures. Moreover, also the EU-ETS will help since, starting in 2013, the emissions caps will be heavily reduced. A forecast about the result of the European strategy is impossible; certainly, it represents a revolution and, as such, the possibility of a failure cannot be excluded. A positive interpretation of the EU plan is the following: the EU understands that the world is entering a new phase of its history, the "low carbon era", and such a phase requires a totally new approach to the use of energy (see Bosetti V. et al 2008). Thus, the UE just anticipates strategies that also the other big countries will have to implement in the next future, and in doing so it will have benefits in terms of cost reduction. Nevertheless, also a negative interpretation is possible: in anticipating the other world regions, the EU sets a very ambitious target that is beyond its power. In the case of failure, the whole international climate change struggle will be damaged.

The second aspect of the EU package that should be considered is energy efficiency. According to the last World Energy Outlook of the International Energy Agency (IEA 2009), the largest part of the future, possible carbon abatement which is required in order to generate the so called 450 ppm. scenario - i.e. the scenario that limit the temperature increase in 2° C, as agreed in the Conference of Copenhagen – will come from energy efficiency (see Tab. 1). This is true for the world as a whole as well as for the most important countries, e.g. US, EU and China.

Tab. 1 – Abatement (Mt.CO2) and required investment (Billion $2008) for World, USA, UE and China in the IEA 450 ppm. scenario

	World		USA		EU		China	
2010-2020	**Abat.**	**Invest.**	**Abat.**	**Invest.**	**Abat.**	**Invest.**	**Abat.**	**Invest.**
Energy Efficiency	2517	1999	548	475	206	392	728	266
Renewables	680	527	43	36	80	113	279	208
Biofuels	57	27	0	0	1	4	0	1
Nuclear	493	125	101	62	143	0	168	63
CCS	102	56	57	33	16	9	3	1
Total	**3849**	**2734**	**749**	**606**	**446**	**518**	**1178**	**539**
	World		**USA**		**EU**		**China**	
2021-2030	**Abat.**	**Invest.**	**Abat.**	**Invest.**	**Abat.**	**Invest.**	**Abat.**	**Invest.**
Energy Efficiency	7880	5586	1141	955	438	709	3195	1210
Renewables	2741	2260	288	330	256	268	715	485
Biofuels	429	378	136	127	50	60	35	28
Nuclear	1380	491	206	77	253	88	366	107
CCS	1410	646	593	300	250	126	243	68
Total	**13840**	**9361**	**2364**	**1789**	**1247**	**1251**	**4554**	**1898**

Source: IEA 2009

Now, by establishing a target of energy saving equal to 20% of energy consumption by 2020, again the EU seems to be on a path which anticipates the IEA scenario. Reversely, the IEA scenario confirms the EU's view and the key role of energy efficiency. In order to deepen such a role, in the paragraphs that follow we will consider some quantitative analyses referred to Italy.

2. Italy, energy and the Kyoto Protocol

Within the EU, Italy has a specific position. According to the European Environment Agency (EEA 2007), with existing measures the EU-15 absolute gap between the 2010 projection and target is 175.2 Mt. CO_2, of which 101.6 are originated in Italy. In other words, almost 60% of the EU-15 surplus comes from Italy. Even if the international economic crisis lowered Italian emissions and decreased the level of the gap from the target, it is still on the range of 50-60 Mt.CO_2. In order to understand the basic characteristics of the Italian energy system and the role that energy efficiency can play, it is useful to look at the Italian situation with reference to the Kyoto Protocol. The main contribution to carbon emission growth comes from the energy supply and transportation sectors. If we compare, for all the 6 Kyoto gases, the projections to 2010 relative to the base year, energy supply emissions increase by 28%, while those of transport rise by 37%. On the contrary, industrial processes decrease by 9%, while the other sectors' (agriculture, residential and commercial) emissions increase just by 1%. It is clear that the control of emissions in the energy and transportation sectors is the major challenge. Imposed by the EU, the European Trading System (ETS) is playing a useful role in mitigating the emissions of the energy sector. For instance, the Italian National Allocation Plan (NAP) for the second period (2008-2012) introduces emission caps which are about 17% lower than those included in the first NAP.

Other key aspects of the Italian situation are the following:

- low energy intensity, compared to other European countries. High level and volatility of energy prices have been strong incentives for Italian firms to control energy intensity.
- Since 1987, nuclear plants for electricity generation are banned as a result of a specific voting decision. Nevertheless, the current Government favours the building of new nuclear plants.
- Italy is currently catching up with other industrialized countries as regards the spread of some energy-intensive household equipments and appliances (such as for instance air conditioning), showing a faster growth than neighbour countries. A white certificate scheme was started in 2005: it set energy saving targets equal to 0.10 Mtoe in 2005, 0.20 in 2006, 0.40 in 2007, 0.80 in 2008, 1.60 in 2009. Although the experience seems to be positive, the targets are quite low and could be increased in the future years (for overview and evaluation see Lees 2007).

Moreover, the expansion of renewable energy embedded in the 20-20-20 package (European Commission 2008a) could play an important role. Table 2 synthesised the main figures provided by the Italian Government in the Position Paper (Italian Government, 2007). The figures show a huge increase but it is not enough to reach the national target 17% of TFC (Total Final Consumption). According to the Government, in the electricity sector the total potential installed capacity for renewable electricity generation by 2020 is equal to about 46,000 MW, i.e. about 104 TWh. This means that renewables are able to replace about 9 Mtoe of Total Primary Energy. According to the Government, other 15.6 Mtoe must be considered: they should come from biofuels (4.20, 3.59 of

which imported), biomass for the civil sector, cogeneration and district heating (9.32), solar heating (1.12) and geothermal (0.96). In 2005 the equivalent figure was 2.4 Mtoe. Thus, without imported biofuels, the estimation of total national renewable energy potential to 2020 is equal to 20.97 Mtoe: the growth in renewable energy is assumed to increase by about 3 times. 20.97 Mtoe would be equivalent to about 12%-13%. In other words, the official Italian Government document states that the national potential is lower than the national target.
Moreover, as far as the year 2020 is concerned, the emission reduction target for sectors not covered by EU ETS is -13%, compared to 2005 (European Commission 2008b).

Table 2: Italian Government renewable energy potential assessment.

Electricity	**State of implementation 31/12/2005**		**Total potential energy available by 2020**	
	Power (MW)	**Energy (TWh)**	**Power (MW)**	**Energy (TWh)**
Total Hydro	17,325	36.00	20,200	43.15
Total Wind	1,718	2.35	12,000	22.60
Total Solar	34	0.04	9,500	13.20
Total Geothermic	711	5.32	1,300	9.73
Total Biomass	1,201	6.16	2,415	14.50
Total Wave and Tidal	0	0	800	14.50
Total	20,989	49.87	46,215	104.18
Total Primary Energy Replaced	4.29 Mtoe		8.96 Mtoe	
Heating, Cooling, Biofels	**State of implementation 31/12/2005**		**Total potential energy available by 2020**	
	Power (TJ)	**Energy (Mtoe)**	**Power (TJ)**	**Energy (Mtoe)**
Total Geothermal	8,916	0.21	40,193	0.96
Total Solar	1,300	0.03	47,000	1.12
Total Biomass	78,820	1.88	389,933	9.32
Total Biofuel	12,600	0.30	176,000	4.20
Total	101,636	2.4	653,127	15.6

Source: Position Paper (Italian Government, 2007)

Given such a situation of a wide distance from the Kyoto target which role can energy efficiency play? In order to answer, we perform such simulations which are based on two rather different approaches. In the first simulations, we tried to measure the dimension of energy efficiency potential in some specific areas. Thus, we follow a bottom-up approach which derives the total potential by summing up the effects of specific interventions (e.g. insulation in the residential sector). In the second group of simulations, we move from the consideration of entire economic sectors and derive the total effects of energy efficiency interventions by deriving them by means of changes in energy intensity.

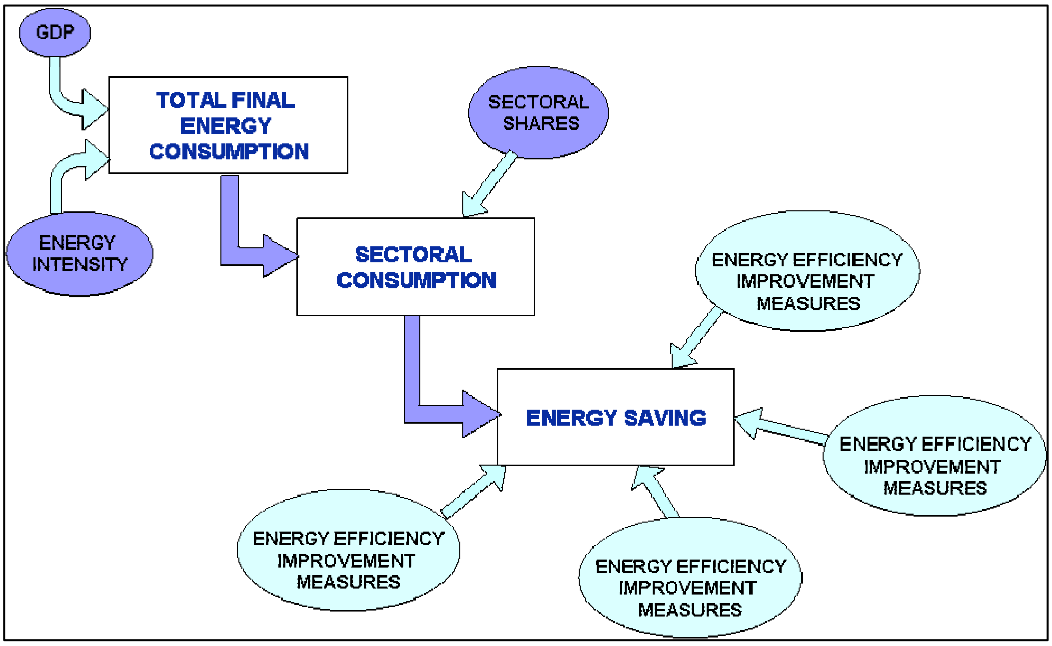
3. Bottom-up simulations

Energy Efficiency (EE) is a ratio between an output of performance, service, goods or energy, and an input of energy. Energy Efficiency improvement is an increase in energy end-use efficiency as a result of technological, behavioral and/or economic changes. In order to evaluate a relevant part of the Italian energy efficiency potential, we built a system dynamics model (i-think software), SEED-M model (Simulating Energy Efficiency Development – Measures). SEED-M refers to Italy and runs from 2008 to 2020. It considers four main energy efficiency measures:

- residential sector: building insulation
- residential sector: highly efficient appliances
- residential and tertiary sectors: lighting (new efficient bulbs)
- transport sector: fuel efficient tyres.

Figure 1 represents the general structure of the model

Fig.1: SEED-M general structure



Starting from TFC (Total Final Consumption), the model derives the sectorial consumption of each energy source and then evaluate the impact of chosen EE measures.

Residential Sector: insulation

For each EE measure, the SEED-M model considers different implementation scenarios. As far as insulation is concerned, the buildings efficiency depends on the numbers of insulation measures implemented. Of course, efficiency improvement and residential TFC leads to efficiency savings in residential sector. We define the gross annual investment cost, based on the number of actions and their average cost (around 15,000 Euros), while the average net investment cost is the difference between the gross investment cost and the efficiency saving. The model includes also a rebound effect simulation: since EE measures lowers the energy bill, someone could use (or waste) more energy than before. In our simulations building efficiency is decreased by an estimated rebound effect coefficient (20%). We focus on two scenarios

- Scenario 1 → insulation increases EE by 1,3%

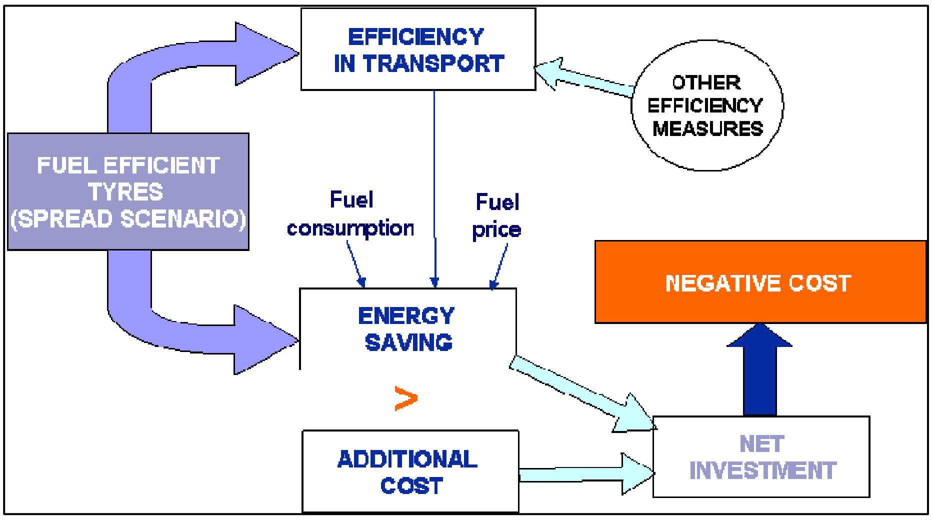
- Scenario 2 → insulation increases EE by 4,7%

While the other measures generate an energy saving that exceed the gross investment cost (net investment cost is negative), insulation measures are too expansive (net investment cost is positive) and should be supported by a public incentive policy (see. Tab. 3).

Transport sector: tyres

In Italy the transport sector represents more than 30% of TFC and, consequently, it has a great impact on national GHGs emissions. Studying energy and environmental measures for the transport sector s very challenging: that is why energy efficiency measures in this sector could be highly relevant. Almost 30% of vehicles fuel consumption depends on tyres (this share is needed to overcome the asphalt friction). So, fuel efficient tyres could have a significant impact on vehicle consumption. Figure 2 resumes the structure of this part of the model.

Fig. 2: transport sector – fuel efficient tyres diffusion



Residential and tertiary sectors: lighting

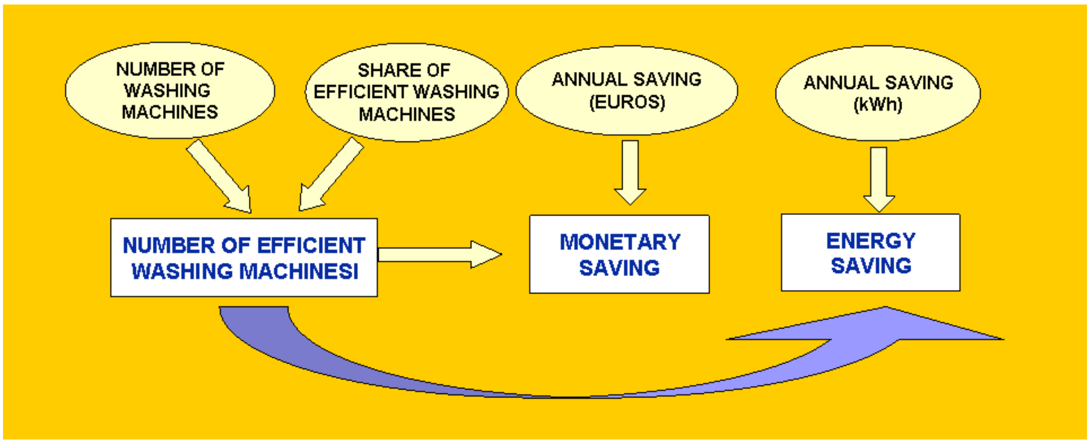
New efficient bulbs consume between 50 and 80% less than traditional ones. In December 2008 EU decided to ban traditional incandescent bulbs starting from 2012. The model performs different new bulb spread scenarios, as shown in Table 3. SEED-M could also include a public distribution of efficient bulbs free of charge.

Residential sector: appliances

From the 1st of January 2010 appliances belonging to efficiency class lower than A are out of sale. EU estimates that efficient appliances should be almost 100% in 2020.

Figure 3 represents this part of the model.

Figure 3: residential sector



SEED-M Scenarios

SEED-M is a very flexible model and could potentially simulate a huge number of scenarios. In this poster we focus on three of them. Table 3 sums up their main variables while tables 3 and 4 report some preliminary results.

Tab. 3 – SEED-M scenarios

Variable	Pessimistic scenario	Moderate scenario	Optimistic scenario
GDP growth rate	*+0,5%*	*+1%*	*+2,5%*
Efficient bulbs annual spread rate	*+1,5%*	*+3%*	*+3% with free distribution*
Efficient tyres spread	*Stable*	*Increasing*	*Strongly increasing*
Share of implemented measures in residential sector	*Stable*	*Increasing*	*Strongly increasing*

Tab.4 - SEEM pessimistic scenario: main results

	Final Consumption (Mtoe)	Energy Saving (Mtoe)	CO_2 Reduction (Mton)	Net investment in lighting (Mil€)	Net investment in transport (Mil€)	Net investment in buildings (Mil€)	Net investment in appliances (Mil€)
2012	146,09	11,26	28,96	- 3.672	- 1.134	2.513	- 606
2016	149,04	17,76	45,54	- 7.536	- 1.813	2.156	- 695
2020	152,04	24,49	61,68	- 11.483	- 2.005	2.373	- 1.119

Tab.4 - SEEM optimistic scenario: main results

	Final Consumption (Mtoe)	Energy Saving (Mtoe)	CO_2 Reduction (Mton)	Net investment in lighting (Mil€)	Net investment in transport (Mil€)	Net investment in buildings (Mil€)	Net investment in appliances (Mil€)
2012	158,07	11,99	30,76	- 4.080	- 1.780	2.530	- 606
2016	174,48	22,33	57,97	- 9.585	- 4.765	3.302	- 695
2020	187,90	37,55	98,01	- 16.775	- 11.760	1.910	- 1.119

As already said before, while insulation investment is quite expansive and should be supported by public incentives, the other three measures have a negative net investment cost, since the energy saving exceed the cost of investment. Moreover we should also consider the benefit coming from avoided CO_2 emissions.

To conclude, according to the bottom up simulations:

- there is room for large saving opportunities from efficient lighting and appliances;
- there are satisfactory results from tyres labeling, even if the big issue in this sector is the definition of mandatory limits for vehicles emissions;
- heat insulation of building is still expensive and needs subsidies;
- even in the optimistic scenario the model never forecast a 20% energy efficiency improvement in 2020: further measures are needed.

A last point which is very important to stress is that the above numbers must be read as technical potential: they represent the upper bound of possible saving. We are aware that it is not feasible to reach this frontier: there are many political, economic and technological constraints that cannot be overcome in a few years. Anyway, to achieve even a small part of this potential could be a great result for Italy.

4. Top-Down simulations

The top-down simulations were performed through a system dynamics model of 5 end-use sectors: agriculture, residences, services and Public Administration, industry, transportation. Industry is composed of 11 sub sectors: steel and iron, non ferrous metals, mining, food, mechanical industry, textiles, building, glass, chemicals, paper, other manufactures. The model uses system dynamics as a tool (i-think software), but indeed it is largely based on parameters which are econometrically estimated outside the model. In fact, for each sector and sub sector, on the basis of about 40 years of energy statistics, the model estimates the demand of electricity, coal, oil, natural gas, fuel oil, renewables. For all sectors, a part from transportation, the demand of energy is function of energy prices and value added of the sector or sub-sector, or GDP. Energy prices, value added and GDP variations translate in energy demand through appropriate parameters that are econometrically estimated. The model base year is 2008. On the basis of each sector's economic history, a Business As Usual (BAU) scenario to 2020 is developed. The assumed annual sectors' growth rates range from 0.008% (Chemicals) to 1.8% (non-ferrous metal). Services growth at a rate of 0.8% per year, agriculture at 1.2%. On average, GDP grows at a rate of 0.67% per year.

As a calculation of the possible energy and emission savings, we implemented simulations that assume a 1% year reduction in the energy intensity coefficients of the different sectors and sub sectors. The simulations do not aim to describe a probable and realistic scenario but just to give some quantitative information about a possible future, in which energy efficiency improvements play an important role; due to this, we decided to use the 1% value for all the sectors and sub sectors. Even if energy intensity cannot be thought of as a measure of energy efficiency - since it is affected not only by it but also by other elements such as changes in economy structure, agents' behaviour and climate - we believe that in macro simulations it can represent a good proxy of energy efficiency and conservation benefits.

Table 5 and 6 provide the main results of simulations. For all the sectors, they show energy savings benefits (Mtoe), monetary total benefits (energy plus carbon emission reductions), monetary energy benefits and carbon emission benefits. These three last results are expressed in terms of billions Euros. Savings of energy are monetised by expressing all the energy in terms of toe and assuming an oil price equal to 50 $/bbl. Similarly, for emissions we assumed a price equal to 20 Euros/ton. CO_2. The results are impressive: given a BAU scenario, by performing a 1% year reduction in the energy intensity coefficients of the different sectors and sub sectors, we could get in 2020 reductions in energy consumption equal to 4.3 Mtoe in residences, 2.8 Mtoe in services, 5.8 Mtoe in industry, 6.9 Mtoe in transports, i.e. about 20% of reduction in energy consumption. In 2020 the benefits could be equal to about 3 billions Euros. With reference to the Kyoto and 2020 targets (non EU-ETS sectors), it is worth stressing the relevant contribution that a 1% year reduction in the energy intensity coefficients can give: in 2020, the reduction for the EU non ETS sectors would be about 17% of the emissions of year 2005, i.e. more that the -13% target.

Table 5: Energy savings (Mtoe) and benefits (Billions Euros) (Agriculture-AG, Residences-RS, Services-SE)

	AG ENSAV	AG BEN	AG ENBen	AG CO_2Ben	RS ENSAV	RS BEN	RS ENBen	RS CO_2Ben	SE ENSAV	SE BEN	SE ENBen	SE CO_2Ben
2010	0.14	0.04	0.04	0.01	1.21	0.38	0.33	0.05	0.69	0.20	0.19	0.02
2015	0.31	0.10	0.08	0.02	2.74	0.85	0.75	0.10	1.68	0.50	0.46	0.04
2020	0.48	0.16	0.13	0.02	4.32	1.33	1.18	0.16	2.80	0.83	0.76	0.07

ENSAV: Energy Savings (Mtoe); **BEN**: Total Benefit, i.e. ENBen + CO_2Ben; **ENBen**: Energy reduction benefits; **CO2Ben**: CO_2 reduction benefits; **AG**: Agriculture; **RS**: Residences; **SE:** Services (monetisation at 50$/bbl and 20 Euros/ton CO_2)

Table 6: Energy savings (Mtoe) and benefits (Billions Euros) (Total Industry, Transportation)

	ID ENSAV	ID BEN	ID ENBen	ID CO_2Ben	TR ENSAV	TR BEN	TR ENBen	TR CO_2Ben
2010	1.64	0.62	0.45	0.17	1.85	0.61	0.5	0.11
2015	3.72	1.26	1.01	0.25	4.38	1.44	1.19	0.25
2020	5.85	1.93	1.59	0.34	6.95	2.29	1.89	0.4

ID: Industry; **TR**: Transportation (monetisation at 50$/bbl and 20 Euros/ton CO2)

5. Conclusions

The main conclusions of this paper can be summarised as follows:

- There is significant potential for reducing consumption, especially in energy-intensive sectors such as construction, manufacturing, energy conversion and transport.
- At the end of 2006, the EU pledged to cut its annual consumption of primary energy by 20% by 2020. It seems that through the energy package the EU speaks to the other countries, especially the US, and tries to influence their approach to climate change.
- In 2007 Italy accounted for almost 60% of EU-15 surplus with reference to Kyoto target. The main contribution to carbon emission growth comes from the energy supply and transportation sectors. Energy efficiency policies could play a crucial role to address those sectors and help Italy to deal with EU-ETS and Kyoto.
- Both simulations approaches lead to a huge potential for energy saving in residential, transport and industry sectors. Even if it is only a technical potential, there is room for concrete actions.
- Even if a complete and comprehensive evaluation of the total energy efficiency potential is beyond the scope of this paper, their exploitation should be considered as a fundamental step of the Italian climate change policy.

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