Designing energy efficiency policies aimed at minimizing end-user barriers: a scenario analysis for the Italian Building Sector

Edoardo Croci, IEFE – Università Bocconi, edoardo.croci@unibocconi.it

Federico Pontoni[1], IEFE – Università Bocconi, federico.pontoni@unibocconi.it

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SUMMARY

Introduction

The effectiveness of Energy Efficiency (EE) measures can be hindered by the presence and the strength of technical, economic and social barriers. Hence, policy-makers have to design and implement specific policies that can overcome these barriers, in order to unfold the full potential of energy efficiency actions. Italy is characterized by cross-cutting EE barriers, particularly in the building sector. Most of EE barriers have to do with end-users: they can be educational (for instance, residential consumers do not know the existence of energy efficient technologies); cultural (i.e. low social value of saving), and they can as well be economic barriers. For instance, due to the persistent economic stagnation, household investments in EE have plummeted. The building sector accounts for 35% of the Italian final energy consumption and it is expected to contribute significantly for the achievement of the 2020 and 2030 targets. Hence, there is the need to promote further EE measures and to introduce relevant policies aimed at effectively overcoming end-user barriers.

Our analysis aims at: 1) defining the most important end-user barriers to EE actions in the residential sector; 2) estimate their quantitative effect in terms of reduced savings with respect to the potential ones; 3) model the quantitative effect of specific policies aimed at minimizing the effect of end-user barriers.

The scenario analysis unfolds as follows: section 2 discusses our methodological approach, detailing how we defined and quantified the impact of end-user barriers, how we modeled energy consumption in the residential sector and how we determined the quantitative effect of the barriers; in section 3 we discuss our findings.

Methodology

We model energy consumption in the residential sector with the The Long-range Energy Alternatives Planning (LEAP) modeling system, a comprehensive bottom-up energy-environment analysis tool. LEAP scenarios are based on comprehensive accounting of how energy is consumed, converted, and produced in a given sector/economy under a range of alternative assumptions with regard to population, economic development, technology, fuel prices, costs of energy-consuming and energy conversion equipment, and

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[1] Corresponding author: via Rontgen 1, Milano. Phone 00390258363817.

other factors. Energy scenarios are self-consistent storylines of how an energy system might evolve over time in a particular socio-economic setting and under a particular set of policy conditions.

Using LEAP, scenarios can be built and then compared to assess their energy requirements, social costs and benefits, and environmental impacts. With its flexible data structures, LEAP allows for analysis rich in technological specification and in end-use details. For modelling the building sector, we built a comprehensive dataset on residential and commercial buildings (size, type, age, geographical location and renovation rate), energy consumption (heating systems and fuels, electric appliances) and technical and economic specifications of EE technologies that can be adopted.

EE end-user barriers have been assessed with a multi-step procedure. The objective was to understand what prevent end-users from adopting specific EE technologies and actions when EE technologies are more economically efficient and even when policies are already in place. Hence, in our analysis, the lack of a specific EE enabling policy is not considered, because it is not an end-user barrier, but an institutional one (or in other words, we cannot blame the end-user for that). On the other hand, the lack of knowledge of a specific policy measure represent an end-user barrier. To do so, we set up a focus group in order to categorize relevant end-user barriers. The categorization was designed to link one (or more) specific end-user barrier to a specific EE technology/action.

As a second step, we carried out a survey targeting stakeholders in the EE sector. Stakeholders had to indicate the strength of different barriers in hindering the penetration and adoption of each single surveyed EE technology/action. As a third step, by means of a multi-criteria analysis, we ranked the barriers according to their absolute importance. Finally, we adopted the Analytical Hierarchical Process (AHP) for quantifying the impact of barriers. A number of advantages characterizes the AHP method: first, it is based on a mathematical theory of value, reason and judgment (Eakin H., Bojorquez-Tapia L.A., 2008; Kablan M.M., 2004); secondly, it allows to decompose a problem into elements (Ishizaka A., Labib A., 2011; Berrittella et al., 2008); finally, its hierarchical structure of criteria allows users to focus better on specific criteria and sub-criteria when determining the respective weight coefficients (Ishizaka A., Labib A., 2011). In the end, AHP allows pair-wise comparisons among the objects that need to be assessed (in our case, EE barriers) and it has already been successfully implemented in other policy analyses, in order to estimate the quantitative impact of barriers (Sunil L. et al., in press; Sara J. et al., 2015). To our knowledge, it is the first time that AHP is implemented for quantifying the impact of end-user barriers in the energy efficiency sector. Moreover, it is the first time that it is used to model end-user behavior. The result of the AHP is a vector of coefficients that represents the strength of each single barrier in hindering the adoption of each single technology.

The final step of our methodology has been the internalization of the vector in the LEAP modelling tool, in order to obtain barrier-constrained scenarios as well as scenarios in which we introduce policies that overcome end-user barriers.

Assumptions

Population

The Eurostat projections for Italy[2] were used in the scenario-building. More specifically:

Table 1: Eurostat population projections for Italy.

Years	2015	2020	2030
Expected population	60,944,960	61,961,266	64,115,332

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[2] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=proj_13npms&lang=en

Projections are based on the demography and migration data that Eurostat collects from EU Members States' National Statistical Institutes (NSIs) and also from almost all non-EU Member States in Europe (including EFTA countries and Candidate countries to the EU). Data are collected at national and at regional level[3]. Household size is derived from the same source.

Table 2: Eurostat household size projections (people per household).

Years	2015	2020	2030
Expected household size	2.44	2.40	2.20

Gross Domestic Product

Gross Domestic Product (GDP) assumptions are based on the long-term forecasts made by the International Monetary Fund's World Economic Outlook[4].

Table 3: IMF GDP forecasts for Italy at current prices.

Forecasts for Italy	2015	2020	2030
GDP at current prices (€ billions)	1,636.37	1,809.86	2,169.11
GDP growth average (%, yoy)		1.15%	0.85%

Building Stock

Residential sector

According to the 2011 census, dwellings occupied by residents are 24,141,324. From 2001 to 2011, there was an increase in the absolute value of 2,488,036 units (+11.5%). The highest increase was registered in the North (48% of all new units). The geographical distribution is shown in the table below.

Table 4: Geographical distribution of Italian dwellings occupied by residents.

Region	Number of dwellings occupied by residents	Percentage
North West	6,827,379	28.2
North East	4,777,305	19.8
Centre	4,793,525	19.8
South	5,185,891	21.4
Islands	2,611,318	10.8
TOTAL	24,141,324	100

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[3] http://ec.europa.eu/eurostat/web/population-demography-migration-projections/methodology

[4] http://www.imf.org/external/pubs/ft/weo/2016/01/weodata/index.aspx

The average square meters per resident are 40.7, a significant increase compared to 2001 (36.8), with the highest value in North East Italy of 44.3 sqm and a minimum in Southern Italy with 36.9 sqm.

72.1% of Italian families live in a home they own. This is one of the highest percentage in the World and it shows a very pulverized ownership of buildings, particularly in cities.

At the end of 2013, the overall residential housing stock is 33,806,919. Hence, in Italy there are almost 10 million non-permanently occupied homes, of which more than 4 million are holiday homes. All Italian dwellings are contained in 11.7 million buildings. Over 60% of the building stock is more than 45 years old, implying that it was built prior to Law 376 of 1976, the first Italian law on energy efficiency.

For the BAU, we take into account only dwellings occupied by residents and, therefore, we exclude from our analysis all non-occupied houses as well as holiday houses. On the one hand, consumption of holiday houses is certainly non-negligible; on the other, energy consumption in the holiday house generally implies an almost complete halt in consumption in the primary dwelling. Hence, in our analysis, we just fail to take into account energy performance differentials of dwellings and possible changes in energy consumption behaviour during holiday time. Moreover, holiday house occupation is shrinking to less than a month per year (ISTAT, 2015) and it is almost evenly distributed in summer and wintertime, so there is no season bias.

The increase in occupied dwellings, which will reach more than 29 million in 2030, is therefore driven by the population increase and the reduction of household size. Moreover, we expect the average square meters per resident to increase of almost 17% by 2030, following the same trend experienced in these last 15 years.

Energy consumption of Italian households is provided for and constantly updated by ISTAT and ENEA. We have used the data for the construction of the LEAP dataset. The mean final energy consumption of an Italian household is 1.2 tep. For all scenarios we have modelled all end-uses: space heating, air-conditioning, cooking, lighting, water heating and appliances.

Table 5: Percentage distribution of total energy consumption by end-use.

Percentage distribution of total energy consumption by end-use	
Space heating and cooling	76%
Cooking	5%
Water heating	7%
Appliances, illumination and other electric uses	12%

Table 6: Electricity end-use

Type of end-use	Percentage
Entertainment	18.6
Refrigerator/freezer	18.4
Illumination	11.4
Washing machine	10.3

Electric water heating	9.8
Air conditioning	6
Dish washer	5.4
Electric cooking	4.7
Other	15.4
TOTAL	100

For the BAU, we presume that policy measures and instruments already implemented will not change.

For the space heating, existing buildings are divided into two categories: single-family and multi-family dwellings and we use the average consumption per square meter, equal to 150 kWh per sqm for single-family dwellings and 120 kWh per sqm for multi-family dwellings, as our starting point for our projections.

We are aware that Italian buildings vary greatly both in terms of energy performance as well as for climatic zones. For instance, Italy has six climatic zones (A, B, C, D, E, F) and there is a consistent share of buildings that consumes more than 220 kWh per sqm. In order to have comparable results with those elaborated by ENEA, we elaborate our projections just taking into account the average consumption per square meter.

Of course, the raw efficiency of existing dwellings is not expected to change. In the BAU we just model the evolution of the different energy fuels used for heating. The change in the energy mix is based on historical trends and it slightly improves the final useful energy intensity as more efficient energy sources are adopted (for instance, geothermal and district heating). By 2030, energy consumption equals 120 kWh for single-family dwellings and 100 kWh per sqm for multi-family dwellings.

The new single-family and multi-family buildings were divided in two types: those that comply with the Energy Efficiency Regulation for Buildings and those that are Nearly Zero Energy Buildings (NZEB). For each housing type, the useful energy intensity for space heating was determined using provided by CRESME (2012). In particular, we model that new buildings have a performance of 50 kWh per sqm; moreover, we model that from 2021 onwards, only NZEB buildings are built, with an overall energy performance of 20 to 30 kWh per sqm.

We project a 1% yoy renovation rate and a 0.05% demolition rate of existing buildings, following historic trends (CRESME, 2012). Also new additions are projected according to historic trends corrected for slower GDP growth.

As for air-conditioning, we model an increase in its use. Currently, only 31% of households have an air conditioning system. According to RSE's projections, a 1% yoy increase is expected. Moreover, overall energy consumption per dwelling is expected to grow from 330 KWh per dwelling to 578 kWh per dwelling.

As for cooking, we project an increase in induction and with no further penetration as cooking appliances are present in all dwellings.

As for lighting, we project a 100% penetration of efficient technology due to increased standards and phase out of incandescent light bulbs.

As for water heating, we project a growth of more efficient technologies following historical trends.

Finally, for all other appliances we use the results of the MATISSE model elaborated by RSE to project electric consumption to 2030.

Below, we show the projected evolution of space heating consumption for existing single and multi-family, both for those who are renovated as well as for those who are not. Those which are not subject to renovation might improve their efficiency as well, as there can be a change in the space heating system.

Figure 1: Existing Single Family, Useful Energy Intensity for Space Heating (Kilowatt-Hour per Square Meter).

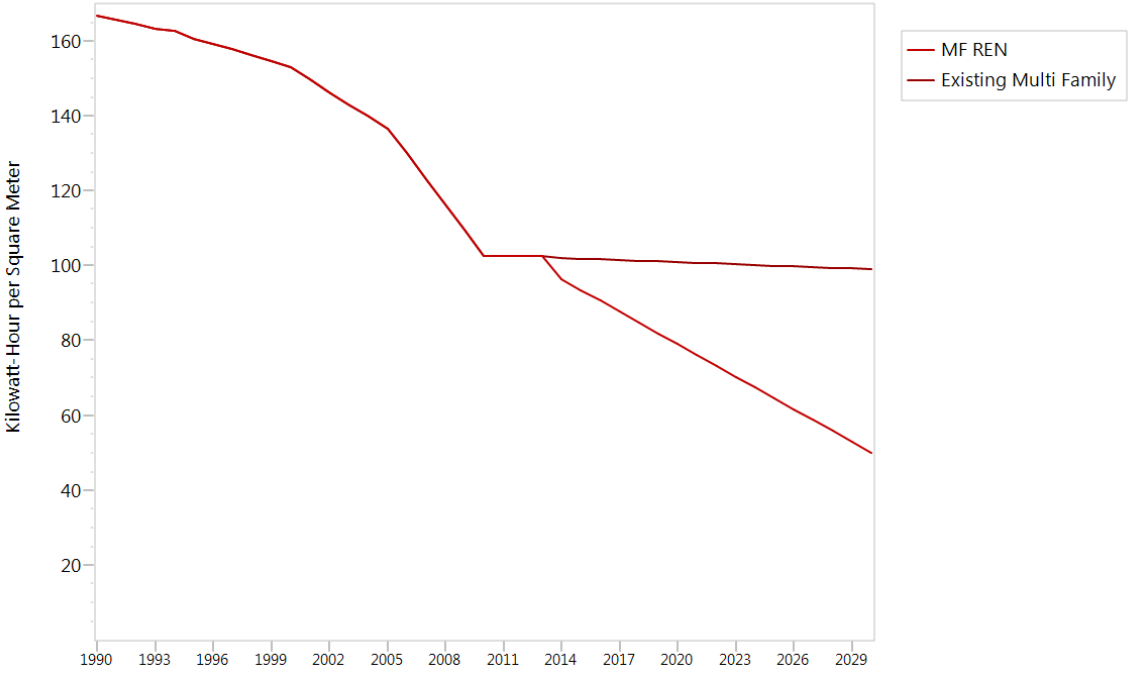

Figure 2: Existing Multi Family, Useful Energy Intensity for Space Heating (Kilowatt-Hour per Square Meter).

As for air-conditioning, we project a major increase in energy intensity, due to expected increase in adverse and hot summers as well as an increase in the penetration of this technology.

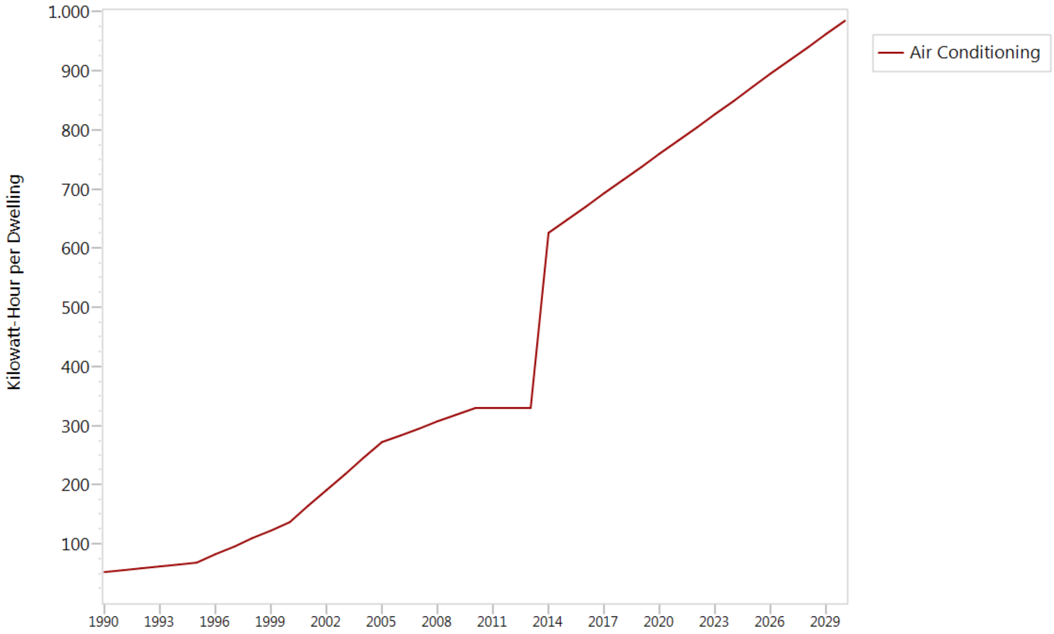

Figure 3: Air Conditioning: Useful Energy Intensity (Kilowatt-Hour per Dwelling).

Tertiary sector

According to the latest available data (OMI 2016), the tertiary buildings in Italy are 3,497,486. The latest available data on the buildings owned by the Public Administrations (MEF, 2014) reveals that in Italy we have more than 700,000 public buildings, of which more than 50,000 are schools.

Table 7: Type of tertiary buildings.

Category	Number of buildings	Percentage
Offices	644,311	18
Shops	2,550,998	73
Banks	20,117	1
Commercial buildings	223,681	6
Hotels	58,379	2
TOTAL	3,497,486	100

For our BAU, the existing buildings in the tertiary sector were divided into shops & Other Commercial Buildings, Offices, Hotels, Hospitals, Schools and all other public administration buildings. There are no available detailed data concerning different building types for each category, as in residential sector. Therefore, our projections are based on average final energy intensity, derived by the studies of ENEL FOUNDATION (2013) and ENEA (2009). As energy intensity data are provided in square meters, we have used the amount of square meters per single category as an input data, totaling to almost 800 million square meters.

In these last four years (OMI, 2016), stock additions have been limited: the compounded average growth rate has been 0.16% and it has come mainly from Hotels, Offices and Shops. In the BAU, we project stock additions only for these three categories. All other categories are projected to stay as they are (demolitions and additions are expected to equal). Following CRESME (2012), we project a renovation rate of 1%, similar to that of the residential sector.

We do not project any variation in energy intensity for existing buildings, while we project significant reduction in energy intensity for renovated buildings. Energy intensity targets are defined by ENEA (2009, 2011 and 2014) for all building categories.

Below, we show the evolution of the useful energy intensity in all sectors for existing buildings, which will not be subject to renovation. The reduction is generated by a change of the fuel for space heating. Historic data refer to the average consumption of the existing stock.

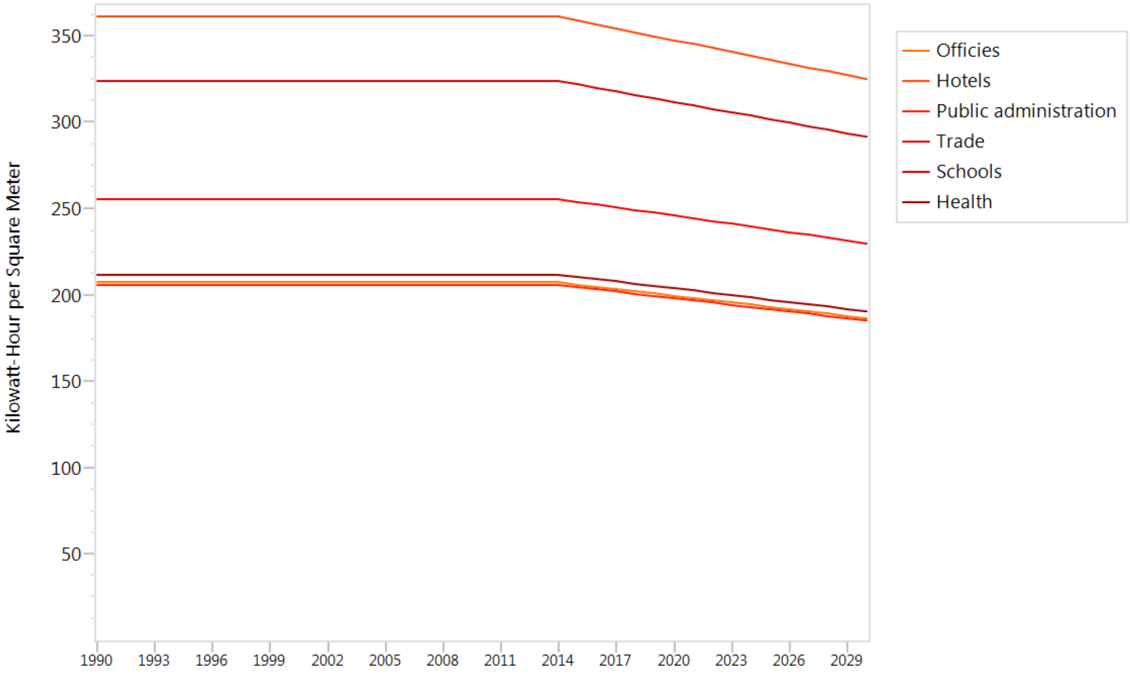

Figure 4: Existing, Useful Energy Intensity (Kilowatt-Hour per Square Meter).

Below, we show the evolution of the useful energy intensity in all sectors for renovated buildings. Historic data refer to the average consumption of the existing stock.

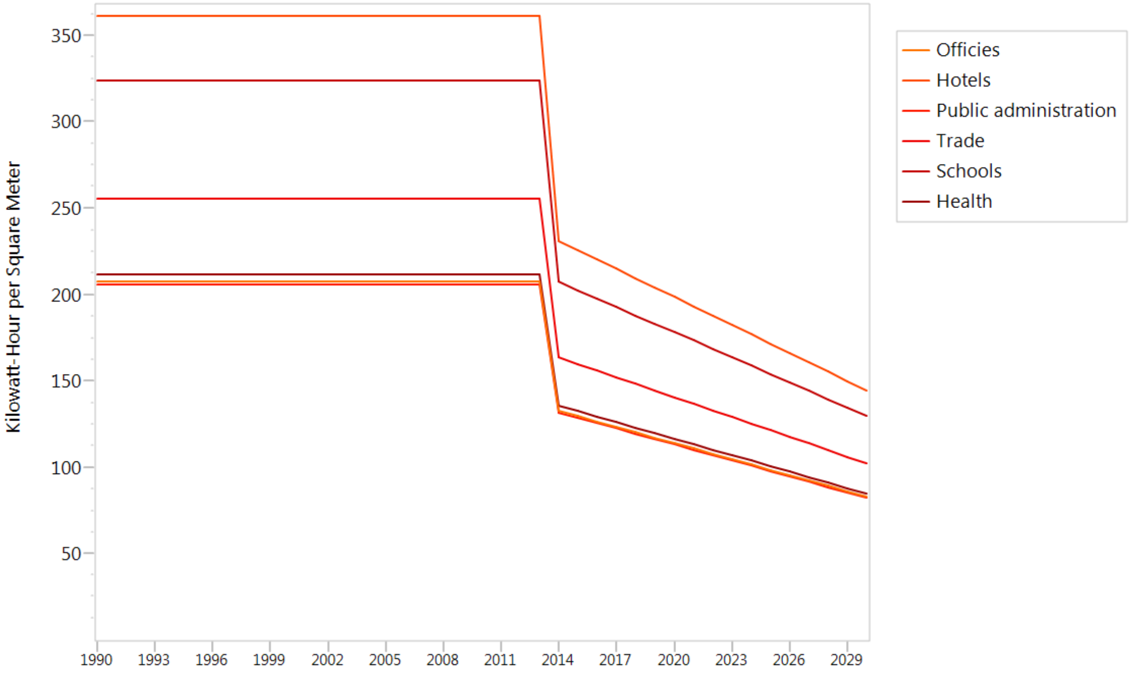

Figure 5: Renovated, Useful Energy Intensity (Kilowatt-Hour per Square Meter).

Results

Barriers

As explained above, the quantification of barriers proceeds in two steps: barrier weighting via the AHP method and total effect quantification by summing weights. In the Italian building sector, barriers with the highest singular weights resulting from AHP weighting are: 1) socio-economic status of building users (0.144), 2) lack of awareness on savings potential (0.091) and 3) lack of any type of financial support (0.086). If no policies address those barriers, savings can only be realised to some extent. Moreover, **our simulations show that some technologies will be affected more than others will. In Italy, barriers can reduce the saving potential by 56% in Building shell/heat system, by 26% for efficient heating and heat pumps technologies and by 21% in cooling technologies and other home appliances**.

Key results

The forward-looking scenario exercise for Italy is composed of a baseline scenario ("business as usual", BAU), presenting a likely scenario reflecting the existing (and certain-to-come) policies and technological developments. In addition, we defined a number of scenarios that reflect the implementation of additional policy measures and consequent effects on energy demand. All other scenarios are elaborated in order to incorporate barriers. At first, we test the effect of the barriers on the BAU. In a second step, we elaborate scenarios that overcome the effect of some of the barriers, by introducing additional policies.

The scenario analysis shows (see Figure 6 – **Errore. L'origine riferimento non è stata trovata.**), that if barriers are accounted for in calculations, EU energy and climate targets for Italy will probably be missed in the building sector. However, if policies are enacted that effectively overcome (most of) the existing barriers, then also the residential sector can almost achieve its targets.

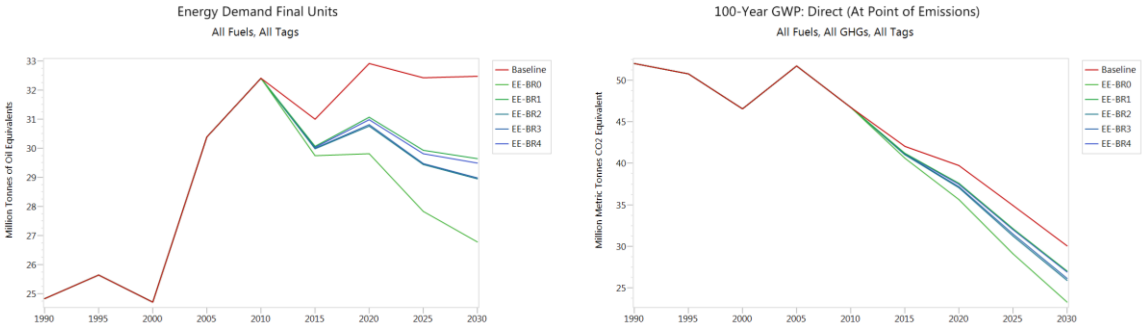

Figure 6: Residential building energy demand and GHG emissions by DST-scenarios.

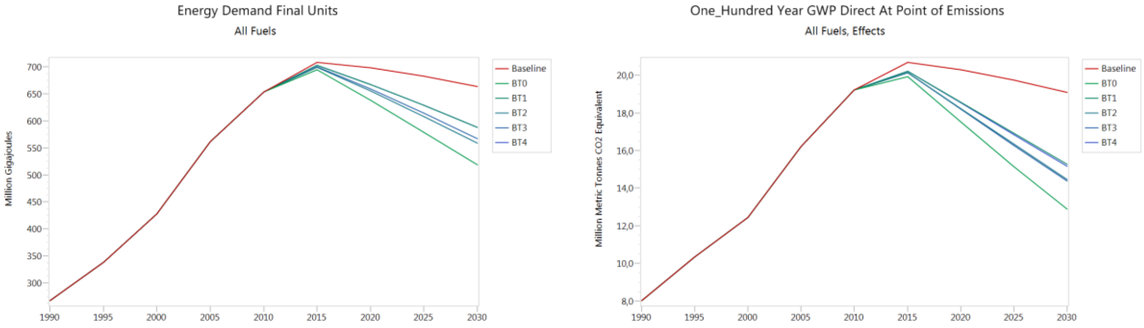

Figure 7: Tertiary building energy demand and GHG emissions by DST-scenarios.

Below we present the main tables summing up energy consumption and emission for the the building sector.

Table 8: Sum of both residential (BR) and tertiary (BT) scenarios for final energy consumption in building sector in Mtoe.

	Target for final energy consumption by 2020	*Final energy consumption in year 2020*	*%Change in 2020 compared to 2020 national target*	*Final energy consumption in year 2030*	*%Change in 2030 compared to HERON BAU scenario*
BAU	47.98	49.58	3.3%	48.33	
EE-B0		44.64	-7.0%	39.16	-18.97%
EE-B1		46.99	-2.1%	43.67	-9.64%
EE-B2 (1st combination)		46.42	-3.3%	42.28	-12.52%

EE-B3 (2st combination)		46.54	-3.0%	42.52	-12.02%
EE-B4 (3st combination)		46.91	-2.2%	43.54	-9.91%

Table 9: Sum of both residential (BR) and tertiary (BT) scenarios for GHG emissions in Mton.

	1990	2005	2020	2030
EU Policy target and national target if applicable		83.99	70.32	61.55
HERON BAU scenario			60.02	49.16
% change compared to target			-14.65%	-20.13%
HERON EE-B0 scenario			53.14	36.16
% change compared to target			-24.43%	-41.25%
HERON EE-B1 scenario			56.16	42.26
% change compared to target			-20.14%	-31.34%

HERON EE-B2scenario			55.29	40.39
% change compared to target			-21.37%	-34.38%
HERON EE-B3 scenario			55.39	40.52
% change compared to target			-21.23%	-34.17%
HERON EE-B4 scenario			56.02	42.06
% change compared to target			-20.34%	-31.67%

In the building sector, the adoption of cost-effective technologies, even without further supporting policies should be enough to meet EE targets**. As our analysis shows, though, barriers impede the penetration of these technologies. People perceive adoption costs, which “artificially” increase the cost of these EE technologies. Hence, there is the need to introduce specific policies aimed at reducing those “transaction costs”.**

In particular, barriers increase by more than 5% energy consumption in the residential sector and by more than 7% in the tertiary sector. Hence, barriers do not allow the residential sector to achieve its target by 2020. On the other hand, they still allow the tertiary sector to achieve its targets as it is performing much better than the forecasts that were used when targets were set.

All minimization scenarios are effective in smoothing the effect of the barriers. Not surprisingly, the scenario that focuses on minimizing the barriers for the “building shell improvement” technologies is the most effective in terms of EE results. BSI technologies are responsible for more than 50% of the expected savings and together with efficient heating technologies and heat pumps they are expected to contribute more than 90% to the overall targets.

Therefore, additional policies aimed at minimizing barriers should focus on BSI and efficient heating. In particular**, there is the need to introduce policies promoting “community energy” solutions for multifamily buildings. These policies need not be financial policies, but rather policies that allow people to invest collectively in deep renovation and in energy production. For instance, a good policy would be to allow multifamily building to sell electricity to all households within the building, using the electricity generated by a CHP technology.**

In terms of emissions, instead, irrespective of the barriers, Italy will meet its targets. This is given by the energy mix change that has happened in this last decade, which has dramatically reduced CO2 and NOx emissions.

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